Stroke Research and Treatment

Stroke: Physical Fitness, Exercise, and Fatigue

Guest Editors: Gillian Mead, Julie Bernhardt, and Gert Kwakkel

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Editorial

Stroke: Physical Fitness, Exercise, and Fatigue

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If we could put exercise into a drug, it would be one of the most effective medications to prevent vascular disease and treat patients with cardiovascular and cerebrovascular diseases including stroke. Exercise reduces the risk of diabetes and hypertension and improves lipid profiles. There is good evidence that exercise reduces the risk of a first-ever stroke [1]. There is now an increasing body of evidence that suggests that exercise after stroke has a number of benefits and may help address common post-stroke problems including fatigue [2].

This special issue has brought together a series of papers exploring the potential benefits of exercise after stroke, the barriers that exist to increased physical activity after stroke, and the mechanisms and time course of fatigue after stroke. The first paper by D. Deplanque and colleagues shows a dose-response relationship between higher levels of previous leisure time, physical activity, and lower initial stroke severity; this benefit might be mediated by neuroprotective as well as by vascular mechanisms. The low levels of activity seen in stroke survivors (A. Danielsson et al.), even after minor stroke (M. Hildebrand et al.), the decline in cardiorespiratory fitness ("Reduced cardiorespiratory fitness after stroke: biological consequences exercise-induced adaptations" by S. A. Billinger et al. and "Cardiopulmonary response to exercise testing in people with chronic stroke: a retrospective study" by S. A. Billinger et al.), the relationship between walking endurance and gait stability (M. Iosa et al.), and the potentially protective effects of exercise on bone loss (K. Borschmann) and falls risk (H. van Duijnhoven et al.) all underline the importance of physical fitness training as a key target in the multidisciplinary management of organized stroke care in the first weeks after stroke and beyond. Early commencement of physical activity is feasible after stroke [3] and appears to fast track recovery of walking [4]. Physical fitness training after stroke improves physical function including walking [5].

Observational studies of stroke patients continue to show that most patients are inactive during their stay in hospitals (T. West and J. Bernhardt) in both acute and rehabilitation wards, suggesting that the physical fitness of stroke patients is still a neglected part of the agenda in stroke management. We would urge therapists to consider how to build fitness training into their regime in addition to focusing on improving function after stroke. As therapists' time is often limited, we need to consider novel, more time-efficient methods to increase physical activity such as fitness classes, circuit class training, family mediated exercises, and telerehabilitation services [6]. For example, a recent Cochrane review of English and Hillier [7] has shown that task-oriented circuit class training is effective in terms of gait speed, walking distance, and balance control. A large randomised controlled trial is underway in which the cost effectiveness of circuit class training as a replacement for usual care is compared, acknowledging that lack of time and lack of staff are major barriers to the implementation of intensive practice after stroke [8].

If we are to optimize stroke survivors' participation in physical activity, it is important to understand the factors determining participation. M. A. Alzaharini et al., in their paper "Mood and balance are associated with free-living

physical activity of people after stroke residing in the community," reported that mood and balance are important predictors of physical activity. The existing literature suggests that self-efficacy, physical activity beliefs, and social support are important determinants of exercise behaviour after stroke (J. Morris et al.). G. Banks and colleagues, in their paper "Exercise differences are different after stroke," report that exercise preferences after stroke differ from those people without stroke, whilst Tiedemann and colleagues, in "Predictors of adherence to a structured exercise program and physical activity participation in community dwellers after stroke," have provided new insights into the factors predicting adherence to group exercises. Taken together, it would seem sensible to ensure that exercise beliefs and preferences are taken into account when advising stroke survivors to be more physically active. Stroke services are now beginning to explore how to establish community-based exercise environments for stroke survivors which will, one hopes, help maintain or improve fitness after usual stroke rehabilitation has been completed [2].

From the patient's perception, post-stroke fatigue often seems to be triggered at the time of stroke (perhaps by the brain lesion) and that exercise, rehabilitation, and good sleep may reduce feelings of fatigue (V. L. Barbour and G. E. Mead). These observations might help provide new targets for the development of interventions for post-stroke fatigue. We need new treatments for fatigue because it seems to persist in the long term (A. Lerdal et al.). The initial level of fatigue is the main determinant of increasing fatigue over time (H. M. van Eijsden et al.), and so targeting fatigue soon after stroke may be important to prevent it from persisting. Post-stroke fatigue is a well-recognized symptom that should be differentiated from often accompanying symptoms such as depression. There is one published case definition of clinically significant post-stroke fatigue [9], but no clear consensus about which of the plethora of outcome measures recommending different cutoffs for determining fatigue that we should be using. This is an area where further research is needed.

Unfortunately, we have no evidence-based interventions available to prevent and treat the post-stroke fatigue. The treatment of this multidimensional symptom will probably require a multidisciplinary approach that targets the physical as well as cognitive aspects of fatigue. However, the underlying mechanisms that cause fatigue as well as the impact of physical (in) activity and physical fitness on this time course are poorly understood and still in their infancy. The present special issue focused on "Stroke: Physical Fitness, Exercise, and Fatigue" is an important step forward in our journey aiming at preventing inactivity and reducing fatigue.

Gillian Mead
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Clinical Study

Development and Process Evaluation of a 5-Week Exercise Program to Prevent Falls in People after Stroke: The FALLS Program

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Falls are a common complication after stroke, with balance and gait deficits being the most important risk factors. Taking into account the specific needs and capacities of people with stroke, we developed the FALLS program (FALL prevention after Stroke), based on the "Nijmegen falls prevention program" (a proven-effective 5-week exercise program designed for community-dwelling elderly people). The program was tested in twelve community-dwelling persons with stroke, and a process evaluation was conducted with patients, trainers, health care professionals, and managers. The FALLS program was considered suitable and feasible by people with stroke in the study and relevant health care professionals, and recommendations for implementation in clinical practice have been suggested.

1. Introduction

Approximately 610,000 people in the United States and 41,000 in The Netherlands sustain a first-ever stroke each year [1, 2]. Although (partial) functional recovery is seen in a majority of those who survive their stroke, disabling cognitive, sensory, and motor deficits persist in many subjects. Due to these deficits, falls are a common complication after stroke. A recent paper showed that at one-year followup, 43–70% of the stroke survivors have fallen once, with a fall incidence rate of 1.4–5.0 falls each person-year [3]. Furthermore, it stated that community-dwelling stroke survivors report walking as the most important activity leading to falls and that balance and gait deficits are identified as the most important risk factors [3].

Although numerous papers have reported on the epidemiology of falling and fall risk factors after stroke, few studies have addressed the prevention of falls in people with stroke. A recent paper identified a total of 13 randomised controlled trials in which falls had been included as an outcome measure, but in the vast majority of these studies, falls only constituted a secondary outcome [4]. Hence, the interventions were not designed with the primary aim to prevent falls, and, in addition, most of the studies were not adequately powered to identify potential reductions in falls.

Given the central role of balance and gait deficits in the etiology of falls after stroke, exercise programs seem to be the most promising approach to prevent falls. It is known that task-specific exercise programs improve balance and gait abilities in people with stroke, and there is some preliminary evidence that they can reduce the number of falls as well [3]. Marigold et al. demonstrated that an agility exercise program improved quiet-stance stability, responses to balance perturbations, and walking under challenging circumstances [5]. The fall rate for the agility exercise group was 0.10 falls/month per person versus 0.26 falls/month per

person for the group receiving stretching and weight-shifting exercises (sham intervention), but this difference was not significant due to the relatively small group sizes. However, for a subgroup of participants (75% of the total group) with an increased fall risk, that is, those with a history of falls, the authors found a significantly lower proportion of fallers in the experimental group (53%) compared to the sham group (87%) at one-year followup. Another study of a small group of people with stroke ($n = 10$) also yielded promising results of exercise with respect to falls prevention [6].

In the general elderly population, there is overwhelming evidence for exercise programs to be the most effective single intervention to reduce falls. Specifically multimodal programs including strength, balance, endurance, and flexibility have shown to be effective [7–10]. One such exercise program is the "Nijmegen falls prevention program" (NFPP), which was found to reduce the number of falls by 46% and to improve balance confidence and walking skills [11]. This program consists of three elements: (1) negotiating obstacles based on obstacles mimicking hazards in daily life; (2) walking exercises simulating walking in crowded environments; (3) training of fall techniques, derived from martial arts. The program is designed to include the most challenging circumstances of daily life, with the highest fall risk. With the introduction of the practice of fall techniques, the program not only aimed at a reduction in the number of falls, but also at the prevention of fall-related injuries and at a decrease of fear of falling [12]. An adjusted version of the NFPP (designed for persons with osteoporosis) was demonstrated to reduce the number of falls by 39% in conjunction with improved balance confidence [13]. We expect that an adjusted version of the NFPP, that takes into account the specific needs and capacities of people with stroke, will also be effective in preventing falls in this population.

Thus, the first aim of the present study was to develop a stroke-specific version of the NFPP, named the "FALL prevention after Stroke" (FALLS) program. The program was tested in two groups of six community-dwelling persons with stroke. As a second aim, we conducted a process evaluation in patients, trainers, health care professionals, and managers to identify the suitability of the FALLS program for people with stroke and its feasibility in clinical practice.

2. Material and Methods

2.1. Intervention. The "FALLS program" is based on the NFPP, a proven-effective 5-week exercise program, designed for community-dwelling elderly people with a history of falling [11]. To adjust the NFPP to the specific needs and capacities of people with stroke, a project committee was formed. The committee consisted of three physiotherapists specialized in stroke rehabilitation and the two primary investigators (H. J. R. van Duijnhoven, resident in rehabilitation medicine; V. Weerdesteyn, movement scientist and physiotherapist). Two members of the committee (W. Hellebrand and V. Weerdesteyn) were also involved in the development of the original NFPP. The members studied the NFPP training protocol in detail and proposed a number of adjustments, additions, and deletions of exercises. These were discussed among the committee members during three sessions of two hours, after which consensus was reached on the final protocol. The committee met a fourth time after the first group had finished the training program to discuss suggested changes on the basis of the observations and experience of the trainers.

Figure 1: Obstacle course.

The size of the training groups was reduced from 10 to 6 persons, because people with stroke were expected to need more intensive guidance and supervision. The number of supervisors was set at 2-3 physiotherapists per group, depending on the specific exercises. The walking exercises were revised to match with the smaller group size. The duration of the sessions was extended from 1.5 to 2 hours, and the number of repetitions of exercises was reduced because of the slower walking and movement speed of people with stroke. In addition, the higher physical and mental fatigability of people with stroke was taken into account by introducing a resting break of approximately 15 minutes. Furthermore, the rate at which the exercises increase in complexity was reduced (and, as a consequence, the final level of complexity) because of the physical impairments and the reduced speed of learning after stroke. Finally, solutions were formulated for the difficulties participants might encounter in several exercises due to paresis of the upper extremity. No specific homework exercises were included in the program, but participants were encouraged to implement the skills and knowledge as acquired during the sessions in their daily life. It was evaluated at the beginning of each session whether the participants had been able to do so.

The final FALLS program consists of 10 sessions (two sessions per week) of 2 hours each. A detailed overview of its contents is presented in Table 1. The first session of the week is dedicated to an obstacle course that challenges balance, gait, and coordination (Figure 1). The obstacles mimic ADL activities with a high fall risk, like walking over doorsteps, stepping stones, or various kinds of ground surface. In addition, the obstacle course contains elements to practice reaching sideways while sitting or standing and standing up without using the hands. It emphasizes on dynamical balance training but also contains training of strength (e.g., m. quadriceps while standing up without using the hands). To further simulate the complexity of daily life, these balance and gait tasks are executed simultaneously with additional

Table 1: Final content of the FALLS program.

Session		Content	Min
(1)	*Obstacle course*	Uneven pavement, slopes, balance beam, walking under clothing line, various ground surfaces with doorsteps, narrow passage, stepping over a bench, stepping stones, transfer from stance to kneeling position, reaching, rotating, slalom with stepping over obstacles in lateral direction, walking backwards, and sitting down and standing up from a chair without arm use.	105
(2a)	*Fall techniques*	Trunk stability while sitting, falling sideways from a sitting position, and safely standing up from ground.	60
(2b)	*Walking exercises*	Walking in a row: changing walking speed and direction; throwing and catching a ball while walking: changing direction and avoiding collision with other participants; balance exercise: standing in a circle while pulling an elastic rope and walking in different directions.	45
(3)	*Obstacle course*	Motor dual task: walking in pairs holding a stick; visual deprivation: walking with dimmed light; cognitive dual task: count 1 specific sound in a piece of music while walking over the obstacle course.	105
(4a)	*Fall techniques*	Trunk stability, falling sideways and backwards from a sitting position, and rolling exercises to prepare for a forward fall.	60
(4b)	*Walking exercises*	Walking in a row or square: changing walking speed and direction and backward walking; walking in a crowd with a balloon balancing on the hand; walking in pairs with badminton rackets and balloons.	45
(5)	*Obstacle course*	Motor dual task: walking with a serving tray; cognitive dual task: listening to a story and counting words while walking over the obstacle course.	105
(6a)	*Fall techniques*	Falling sideways and backwards from a sitting position, falling sideways and forwards from kneeling position.	60
(6b)	*Walking exercises*	Shuttle walk exercise: walking at gradually increasing speeds (1.5–6 km/h); playing a balloon with a badminton racket and one leg trapped in a hoop. Ball tunnel: walking through hoops while other participants throw balls.	45
(7)	*Obstacle course*	Different arrangement of the obstacles and walking in two groups in opposite directions; motor dual tasks: walking with serving tray with cups, walking with umbrella and filled bag.	105
(8a)	*Fall techniques*	Falling forwards and sideways from a kneeling position, falling backwards from a standing position.	60
(8b)	*Walking exercises*	Turning hoops: working together in a group to keep hoops turning; hockey game.	45
(9)	*Obstacle course*	Motor dual task: walking with serving tray, walking with a hockey stick and ball; cognitive dual task: count one specific sound in a piece of music.	105
(10a)	*Fall techniques*	Falling forwards and sideways while standing beside a thick mattress and falling backwards from a standing position.	60
(10b)	*Evaluation*	Evaluation of the total program.	45

cognitive or motor tasks (20 and 25% of the time, resp.) and under visual constraints, for example, dimmed light (15% of the time). While negotiating the obstacles, participants not only practice their balance and coordination, they also learn to recognize and cope with potentially hazardous situations. The second session comprises walking exercises (45 minutes) and the practice of fall techniques (60 minutes). The walking exercises mimic walking in a crowded environment, where adjustment in walking speed and direction are required, and collisions with other people or objects may perturb one's balance. Because participants are physically active during the exercises, endurance is trained as well. The practice of fall techniques is based on martial arts techniques and includes falling in forward, backward, and lateral directions. The difficulty is gradually enhanced by increasing the height from which subjects fall (from sit to stance) [11]. These techniques have previously been demonstrated to be safe, even for persons with osteoporosis [14]. Furthermore, they are trainable in older adults and reduce the impact forces on the hip during sideways falls (as measured in a movement laboratory), which may reduce the risk of hip fractures when applied in real-life falls. The participants also perceived less fear of falling after intervention [12].

2.2. Participants. The final FALLS program was tested on twelve community-dwelling persons with stroke (divided over two consecutive groups of 6 participants). All participants had sustained a stroke more than 6 months ago, thereby eliminating spontaneous recovery processes to interact with training effects. They had all received (and completed) inpatient rehabilitation within the past two years and had a functional ambulation categories (FAC) score of 4

Table 2: Characteristics of the twelve participants. The means and standard deviations are given, as well as the frequencies and percentages (between brackets). Maximum scores are 100 for motricity index, 100% for Fugl Meyer lower extremity, 56 for berg balance score and 23 for trunk impairment scale.

Participant characteristics	Mean ± SD
Age	60.5 ± 3.1
Months after stroke	16.2 ± 1.9
Gender (%)	
Male	7 (58)
Female	5 (42)
Type of stroke (%)	
Haemorrhage	4 (33)
Infarction	8 (67)
Side of lesion (%)	
Right	5 (42)
Left	7 (58)
Motricity index leg	77.2 ± 16.1
Fugl Meyer lower extremity scores	74.3 ± 18.1
Berg balance score	50.5 ± 5.0
Trunk impairment score	17.8 ± 3.4

Table 3: Participant satisfaction regarding the FALLS program.

Component	Pleasant* Yes (%)	Instructive* Yes (%)	Time spent* Good (%)	Guidance* Good (%)
Obstacle Course	91	100	100	91
Fall Techniques	91	100	73	100
Walking Exercises	100	100	73	100

*Questions asked with answer possibilities: did you find the component pleasant? (yes/no); did you find the component informative? (yes/no); how do you judge the time spent on the component? (too little/good/too much); how do you judge the guidance of the trainers during this component? (too little/good/too much).

or more (the capacity to walk independently on even terrain). Exclusion criteria were other musculoskeletal conditions that affect balance or gait abilities, conditions in which physical activity is contraindicated, use of psychotropic drugs, and severe cognitive/behavioral problems (mini-mental state examination below 24).

The protocol was approved by the regional medical-ethical committee. All participants gave written informed consent.

2.3. Process Evaluation. The process evaluation was conducted at the level of the participants, the trainers (who developed the program and trained the subjects), other health care professionals, and the management. With regard to the participants, attendance rates were registered, and participant satisfaction was assessed by means of groupwise discussions and an anonymous questionnaire to be filled in at home after completion of the program.

The trainers (the physiotherapists who trained the participants) discussed in depth their observations and comments immediately after each session. They also established whether the session had been delivered according to protocol and whether the intended goals had been reached. Points for improvement were noted and applied to the following lessons.

Health care professionals' opinion on the suitability and feasibility in clinical practice of the program was assessed by interviewing physiotherapists, rehabilitation physicians, and team managers. Thirteen physiotherapists from the rehabilitation centre (not involved in the training) filled in a questionnaire, after having seen a presentation of the contents of the FALLS program. Subsequently, the answers to the questions were further discussed among the group members. Two rehabilitation physicians who have specialized in the treatment of people with stroke at the same rehabilitation centre were interviewed on these topics as well. A face-to-face structured interview was held with two team managers to identify organizational opportunities and barriers for implementation of the program in clinical practice.

2.4. Data Analysis. Descriptive statistics were used to analyse quantitative data from the questionnaires (answers to "yes/no" questions and to multiple-choice questions). The answers to the "open" questions were categorised and presented separately. The same procedure was followed for the qualitative data from the group discussions and the interviews.

3. Results

3.1. Participants . The characteristics of the participants are presented in Table 2. The attendance rate to the training sessions was 97.5%. Only 2 subjects missed one or two sessions, because of hospital visits or vocational obligations. There were no dropouts, and no adverse physical effects were reported.

Eleven participants returned the evaluation questionnaires. The results are presented in Table 3. In general, participants were satisfied with the frequency of the training sessions (91%), the duration of the sessions (100%), and the time of the day at which the sessions were planned (3 p.m. to 5 p.m., 100%). The majority (73%) was satisfied with the duration of the program. Two people considered the program too short, whereas one person thought the program was too long. With respect to the contents of the program, the three elements were generally judged pleasant and instructive. In addition, the guidance was considered to be good for all elements. The time spent per element was also judged positively although for the fall techniques and walking exercises, three people reported that the time spent on this element could be shorter (20%) or longer (10%). In the groupwise discussions, it was pointed out that the participants were interested in booster sessions (a short session a couple of months after the end of the intervention, repeating the most important elements, particularly of the fall techniques).

In general, the different elements of the obstacle course, walking exercises, and fall techniques were considered feasible by the participants, which demonstrates that the exercises matched their level of physical abilities. The balance beam and the stepping stones (see Table 1) were reported as the most difficult elements of the obstacle course, falling sideways towards the affected side for the fall techniques and increasing speed for the walking exercises. For the obstacle course, the slalom and slopes were considered relatively easy. All participants who walked with a cane were able to eventually complete the program without it.

As a result of the program, participants reported to have extended their range of physical abilities. The majority of the participants (73%) had been able to implement the training advice and acquired skills while walking under challenging circumstances in daily life. Seventy-three percent reported to feel less at risk of falling and to have lower fear of falling. Those persons who did not perceive these benefits were the ones without initial fear of falling and who did not consider themselves at high fall risk prior to the intervention. Furthermore, all participants would recommend the FALLS program to other persons with stroke.

3.2. Trainers. In general, the elements of the original FALLS program were considered to be feasible for the participants; however, some adaptations were made based on the trainers' evaluations. These were discussed and agreed upon during the meeting of the project committee after the first group of participants had been trained. On the obstacle course, observing other participants was instructive for healthy persons, but not for persons with stroke due to attentional deficits. As a compensation, a set of optional balance exercises was offered to participants who had to wait for a supervisor.

The most important changes in the walking exercises were based on the observed cognitive and attentional problems of the participants. Cognitive elements were added, and the number of exercises was limited to a maximum of 3 per session. To adapt the training to the variable abilities of the participants, each exercise consisted of a basic element of which the intensity or complexity was gradually increased. The fall training was feasible in its original design, as the participants were capable of executing the exercises according to the protocol. Therefore, no substantial adaptations had to be made.

3.3. Health Professionals. All 13 physiotherapists completed the questionnaires. They all considered the FALLS program to be a good addition to the existing treatment programs. The majority considered it feasible (85%) for implementation in routine clinical practice. They judged the content of the program well adjusted to the target group and did not expect organisational problems. A rehabilitation centre was identified as the most suitable setting for the program (93%), whereas 70% thought it would also fit in a primary care physiotherapy practice.

In general, the program was deemed most suitable for outpatients directly following discharge from inpatient rehabilitation, or in the chronic phase after stroke (85%). Forty-six percent considered the program feasible for inpatients as well. They agreed on independent walking ability (FAC 4 or 5) to be the necessary entry level for the program. In addition, balance problems and/or fear of falling were considered the main inclusion criteria, whereas participants should not suffer from severe cognitive and/or behavioral problems, which influence basic understanding and cooperation. All the therapists deemed themselves capable of delivering the training sessions, but prior to working as a trainer, they would like to receive education on the specific contents of the program.

The interviews with the rehabilitation physicians yielded similar results. They suggested that the program was suitable both for patients in the chronic phase of stroke and for patients who are recently discharged from inpatient rehabilitation. If the program would be implemented, it should be delivered by physiotherapists specialized in stroke treatment, if necessary, with the help of other disciplines. In addition, they also advised participants to be screened for cognitive and/or behavioral problems by a rehabilitation physician prior to entering the program, who should also determine whether additional support would be needed.

3.4. Management. The managers considered the FALLS program to be a good addition to the present rehabilitation program. They also indicated that it would fit within the reimbursement system for health care costs in The Netherlands, such that the costs for delivering the program would be sufficiently covered. Experience with comparable projects did not show large barriers for implementation, besides planning.

The program could probably be offered 3 to 4 times a year, depending on the number of persons eligible for participation. Trainers could be educated in the specific elements of the program, and interns could learn from more experienced trainers.

4. Discussion

In the present paper, we described the development and process evaluation of the FALLS program, a 5-week exercise falls prevention program designed for persons with stroke. The NFPP was adjusted to meet the special needs and capacities of people with stroke. The program was offered to two groups of six participants.

From the results of the present study, we can conclude that the FALLS program is safe and feasible for participants in the chronic phase of stroke. There were no adverse events, and the duration and frequency of the program were considered appropriate by the participants. There was an excellent attendance rate, which is important given the progressive nature of the program. These results are comparable to the original NFPP and to an adjusted version for persons with osteoporosis [11, 13]. Although data on the effectiveness of the program are not yet available, the experiences of the participants are promising. Most of them reported that their fear of falling was reduced after the program and that they felt to have improved balance maintenance while walking under

challenging circumstances. The original NFPP has already been proven to be effective in reducing the fall incidence after implementation in clinical practice [15].

Although the effectiveness of the FALLS program still needs to be established in a randomised controlled trial, the results of the questionnaires and interviews with the health care professionals and managers indicate that there appear to be no major hurdles for eventual implementation of the program in clinical practice. The program should preferably be offered to outpatients, in the chronic phase after stroke or shortly after discharge from inpatient rehabilitation. It is known that fall incidence rates increase strongly in the first 8 weeks after discharge [3]. It is suggested that this increase is due to the fact that people with stroke are not optimally prepared for the challenges they have to face in daily life. Nevertheless, patients who have not followed the program after discharge from the rehabilitation centre may still benefit from it in a later phase. These persons are likely to have experienced one or more falls and thus may feel a higher necessity to prevent falls. According to the health care professionals, the program should be embedded in specialized outpatient facilities of a rehabilitation centre. In that case, trainers have elaborated experience with treatment of persons with stroke, and there is a possibility of additional support from other disciplines (e.g., language and speech therapists or psychologists) for advice on guidance of participants with specific problems.

Furthermore, it was suggested that, to be included in the program, participants should be at increased fall risk, that is, have balance and/or gait problems, fear of falling, or a positive fall history. Participants should be independent walkers (FAC 4 or 5, with or without walking cane) and should not have severe cognitive, behavioral, or language problems, which could interfere with basic understanding and cooperation. Screening by a rehabilitation physician prior to the program is therefore necessary.

A limitation of the present study is that it was conducted on a small group ($N = 12$) of people with stroke. In addition, participants were mildly affected and had no or little cognitive problems. Therefore, the results can only be applied to this specific population. A second limitation is that the effectiveness of the FALLS program has not yet been established in a randomised controlled trial (with fall rate as the main outcome). Hence, the conclusions and recommendations regarding potential implementation of the program are somewhat premature.

Furthermore, although the management indicated that the costs of the program would be covered under the current reimbursement system in The Netherlands, the cost-effectiveness of the program should ultimately be demonstrated as well in order to support its implementation in the poststroke rehabilitation program. At this moment, it is hard to estimate the potential cost effectiveness due to the lack of information on the effectiveness of the program and on the average costs per fall in the population of people with stroke. The main costs for delivering the program would be the start-up costs (training of physiotherapists; ~2000 Euro material costs for the obstacle course and the walking exercises, assuming safety mats and regular physiotherapy equipment to be present) and personnel (~600 Euro per participant). If a reduction in fall rates could be achieved similar to the two prior studies on the Nijmegen falls prevention program [11, 13], an average of more than one fall per participant could likely be prevented based on the previously reported fall rates of 1.4–5.0 falls per year in people with stroke [3]. In the general elderly population, the average costs per fall amount 1,059 to 10,913 US Dollars [16]. Hence, if the FALLS program would be effective in reducing the number of falls, these numbers indicate that it has good potential to be cost effective as well.

In conclusion, with this process evaluation, we have demonstrated that the FALLS program is perceived, both by the users and relevant health care professionals, to be safe and suitable for the specific group of people with stroke as included in this study. Implementation of the program within a specialized rehabilitation centre is considered feasible by physical therapists, rehabilitation physicians, and team managers, but this should be preceded by a large randomized controlled trial to establish the effects of the program on fall rates. The perceived improvements in balance control and confidence are promising, and it is for future research to objectify these effects as well.

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Conflict of Interests

The authors declare that there is no conflict of interests.

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Research Article

Poststroke Fatigue: Who Is at Risk for an Increase in Fatigue?

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Background. Several studies have examined determinants related to post-stroke fatigue. However, it is unclear which determinants can predict an increase in poststroke fatigue over time. *Aim*. This prospective cohort study aimed to identify determinants which predict an increase in post-stroke fatigue. *Methods*. A total of 250 patients with stroke were examined at inpatient rehabilitation discharge (T0) and 24 weeks later (T1). Fatigue was measured using the Fatigue Severity Scale (FSS). An increase in post-stroke fatigue was defined as an increase in the FSS score beyond the 95% limits of the standard error of measurement of the FSS (i.e., 1.41 points) between T0 and T1. Candidate determinants included personal factors, stroke characteristics, physical, cognitive, and emotional functions, and activities and participation and were assessed at T0. Factors predicting an increase in fatigue were identified using forward multivariate logistic regression analysis. *Results*. The only independent predictor of an increase in post-stroke fatigue was FSS (OR 0.50; 0.38–0.64, $P < 0.001$). The model including FSS at baseline correctly predicted 7.9% of the patients who showed increased fatigue at T1. *Conclusion*. The prognostic model to predict an increase in fatigue after stroke has limited predictive value, but baseline fatigue is the most important independent predictor. Overall, fatigue levels remained stable over time.

1. Introduction

A common symptom after stroke is fatigue, with reported frequencies ranging from 38% to 77% [1], indicating that poststroke fatigue is a major problem after stroke. Forty percent of the patients considered fatigue to be one of the worst sequelae of stroke [2]. Patients feel unprepared for the fatigue phenomenon and struggle to adapt to it in daily life [3]. Fatigue has a debilitating influence on activities of daily living [3, 4] and is independently associated with health-related quality of life [4] and the resumption of paid work [5].

Several studies have examined determinants related to poststroke fatigue, but for many determinants there is inconclusive or insufficient evidence [1]. A recent prospective study demonstrated that baseline fatigue was the main predictor of the development of poststroke fatigue over time [6]. Conflicting evidence was found for personal factors such as gender [2, 7–12], age [2, 6–12], and marital status [7, 8]. A few studies found significant results for stroke characteristics, for example, previous stroke [7] and infratentorial infarctions [6, 11]. A strong relationship between depression and post-stroke fatigue was described, both in cross-sectional [2, 10, 11] and longitudinal analyses [6–9]. However, poststroke fatigue can also occur in the absence of depression, and depression was also found independent of fatigue in stroke survivors [2, 10]. A multivariate model including age, sex, locus of control, and depression explained 20% of the total variance of FSS scores 1 year after stroke [8]. This meant that the largest part of the variance in post-stroke fatigue, 80%, remained unexplained, suggesting that other determinants play a role in the occurrence of post-stroke fatigue. One hypothesis is that physical deconditioning, which is common after stroke [13], might be associated

with poststroke fatigue [14]. The influence of physical functioning has not been extensively investigated, and results have been inconsistent [15, 16].

Reported levels of poststroke fatigue are high and remain fairly stable over time within groups. At an individual level, however, significant changes do occur [6, 8]. It might in fact be more relevant for clinical practice to identify those patients with a variable course of fatigue and especially the patients who are at risk for an increase in poststroke fatigue. Therefore, the aim of the present prospective cohort study was to identify determinants predicting increasing fatigue in patients after stroke. Candidate determinants include personal factors, stroke characteristics, physical, cognitive, and emotional functions, and activities and participation.

2. Methods

2.1. Design and Procedure. Data used in this study were collected between July 2008 and January 2011 as part of a large randomized controlled trial called FIT-Stroke (trial number NTR1534). The primary objective of the FIT-Stroke trial was to evaluate the effects on gait and the cost-effectiveness of a structured, progressive task-oriented circuit class training (CCT) program, compared to usual physical therapy care during outpatient rehabilitation in a rehabilitation center [17].

Patients were included in the study (T0) at the time of discharge from inpatient rehabilitation, when outpatient rehabilitation started. The followup assessment (T1) took place 24 weeks after discharge.

All measures were assessed by an independent researcher.

2.2. Participants. Inclusion criteria to participate in the study were (1) verified stroke according to the WHO definition [18]; (2) age ≥18 years; (3) ability to walk a minimum of 10 m without physical assistance from a therapist (Functional Ambulation Categories ≥3) [19]; (4) having been discharged home from a rehabilitation center; (5) giving informed consent. Patients were excluded if they (1) had a score on the Mini-Mental State Examination of less than 24 points [20]; (2) were unable to communicate (i.e., <4 points on the Utrechts Communicatie Onderzoek test) [21]; (3) lived more than 30 km from the rehabilitation center.

The study was approved by the Medical Ethics Committee of the University Medical Center Utrecht and all the participating rehabilitation centers. All included patients gave written informed consent.

2.3. Measures

2.3.1. Primary Outcome: Poststroke Fatigue. The impact of fatigue was measured by the Fatigue Severity Scale (FSS) [22]. The FSS consists of 9 items, with scores for each item ranging from 1 to 7. The total FSS score is the mean of the 9 item scores [22]. Patients with a total score of ≥4 points are classified as "fatigued" [23]. A reliability study with two independent observers and 18 stroke patients found an Intraclass Correlation Coefficient (ICC) for the FSS of 0.82 [4]. Item analysis showed excellent internal consistency and reliability for stroke patients (Cronbach's $\alpha = 0.96$) [23]. In healthy subjects, the test-retest scores were stable over time [23]. The FSS scale was administered at T0 and T1. An increase in poststroke fatigue was defined as an increase in the FSS score beyond the 95% limits of the standard error of measurement (SEM) of the FSS, SEM being defined as $\mathrm{SEM} = \mathrm{SD} * \sqrt{1 - \mathrm{ICC}}$. The SD of the FSS was obtained from the current study. The ICC of the FSS used in our analysis was 0.82 [4].

2.3.2. Candidate Determinants. Determinants were classified using the International Classification of Functioning, disability and health (ICF). All candidate determinants were assessed at T0.

2.3.3. Personal Factors. Data on age, sex, marital status, physical activity, and comorbidity before stroke were obtained at T0. A person was classified as "physically active before stroke" if he or she participated in moderate-intensity activity for at least 30 minutes a day, on five days a week [24]. Comorbidity was assessed by the Cumulative Illness Rating Scale (CIRS), which is a valid and reliable instrument that addresses all relevant body systems without using specific diagnoses [25]. The CIRS consists of 13 items, and the total score ranges from 0 (i.e., no morbidity) to 52 (very severe comorbidities).

2.3.4. Stroke Characteristics. Data on type of stroke, lateralization, time since stroke onset, and previous stroke were obtained from medical records at T0. Type of stroke was classified as ischemic versus hemorrhagic stroke. Lateralization was divided into three categories namely right hemisphere, left hemisphere, and other (e.g., brainstem, cerebellum).

2.3.5. Physical Functions. Strength was assessed by the Motricity Index (MI), which was used to determine the strength of the upper paretic limb (MI upper limb) and the lower paretic limb (MI lower limb). Scores range from 0 (no visual movement) to 100 (normal strength). The test has proven to be highly reliable and valid [26].

Strength was also assessed by the "strength" domain of the Stroke Impact Scale, version 3.0 (SIS). The SIS is a self-reported, stroke-specific measure that includes 59 items and assesses 8 domains relating to activities and participation [27]. SIS has shown excellent clinimetric properties in terms of concurrent and construct validity, test-retest reliability and responsiveness [28, 29]. The SIS has been translated into Dutch, and the translated version also proved to be valid and responsive [30]. Subscale scores range from 0 to 100 percent [28].

Balance was tested by the Timed Balance Test (TBT). The TBT consists of 5 components scored on an ordinal scale and involves timed balance (i.e., 60 seconds) in five different positions of bilateral stance. One point is scored for each position maintained, so the score ranges from 0 to 5. The test has been shown to be reliable and concurrent valid [31, 32].

2.3.6. Cognitive Functions. Cognition was assessed by the MMSE, a widely used brief screening instrument to

determine orientation, memory, attention, calculation, language, and construction functions [20]. The score ranges from 0 to 30. A subject who scored less than 24 on the MMSE was considered to have cognitive impairments. Patients with an MMS < 24 were excluded from the study.

Memory function was assessed by the "memory" domain of the SIS, with subscale scores range from 0 to 100 [28].

Inattention was measured by the Letter Cancellation Task and was regarded as positive when patients had two or more omissions on one side compared to the other side [33].

2.3.7. Emotional Functions. The Hospital Anxiety and Depression Scale (HADS) was used to determine mood, emotional distress, anxiety, depression, and emotional disorder. It is a brief, valid, reliable, and widely used instrument, known to produce meaningful results as a psychological screening tool. The HADS consists of 14 items (7 anxiety, 7 depression), each with a 4-point rating scale (0–3) and is responsive to change [34, 35]. The depression and anxiety scales are analyzed as two separate domains, with scores for each scale ranging from 0 to 21.

Emotion was assessed by the corresponding domain on the SIS, with subscale scores range from 0 to 100 [28].

The Falls Efficacy Scale (FES) was used to measure fear of falling. The FES is based on the operational definition of this fear as "low perceived self-efficacy at avoiding falls during essential, nonhazardous activities of daily living" [36]. The score ranges from 0 to 130, with higher scores representing higher confidence and thus less anxiety.

2.3.8. Activities and Participation. Gait performance and endurance were assessed by the 6-Minute Walking Test (6 MWT), which has a good test-retest reliability (ICC = 0.973) [37–39].

The 5-Meter Timed Walking Test (5MTWT) was used to assess comfortable walking speed [40]. To reduce measurement error, we used the mean of three repeated walking speed measurements.

The Functional Ambulation Categories (FAC) instrument was used to assess walking ability. The scale includes six categories with scores ranging from 0 to 5, that is, from unable to walk to independently walking without physical assistance [19, 41], though only patients with FAC 3 or higher were included in the trial.

Mobility was assessed by the Rivermead Mobility Index (RMI). The RMI consists of 14 questions and one observation (maximum score 15), covering aspects ranging from turning in bed to running [42]. Questions are simple and are scored dichotomously. The measure is reliable, valid, and responsive [42–44].

Extended activities of daily living (ADL) performance was assessed by the Nottingham Extended ADL (NEADL). The NEADL scale [45] is based on a self-reported questionnaire on levels of activity actually performed. The NEADL consists of 22 items in 4 domains (mobility, kitchen, domestic, and leisure). It has proven to be reliable and valid as an outcome measure in trials and observational studies. Each item is rated by one of four responses (able, able with difficulty, able with help, unable) and scores range from 0 to 66.

Activity and participation domains of the SIS, that is, hand function, mobility, communication, ADL/IADL, and participation were also included in the analysis, with subscale scores ranging from 0 to 100 [28].

2.4. Statistics. Baseline characteristics were described using descriptive statistics (means and Standard Deviations (SDs); medians and ranges, odds ratio (95% confidence interval)).

First, bivariate logistic regression analyses were conducted with the candidate determinants measured at T0. Candidate determinants with a significance level of $P < 0.2$ were then selected for the forward multivariate logistic regression to identify independent predictors of an increase in fatigue at T1 (i.e., fatigue scores increasing beyond the 95% limits of the SEM). Multicollinearity was checked by means of Pearson correlation, with a correlation coefficient of $r > 0.7$ being classified as multicollinearity. If the correlation coefficient was >0.7, the variable with the lowest coefficient, relative to the outcome measure was omitted. Goodness of fit of the multivariate logistic model was tested by the Hosmer Lemeshow test. A significance level of 0.05 was used to include a determinant in the model. We used a generally accepted rule of thumb for the maximum number of factors in a regression analysis, viz. one determinant was added to the equation for every 10 patients [46]. The present cohort participated in an intervention trial on the cost-effectiveness of circuit class training after stroke [17]. Preliminary results show that there are no time and interaction effects of treatment allocation with fatigue. The complete cohort was therefore included in the present analysis. Data were analyzed using SPSS for Windows version 16.0.

3. Results

3.1. Baseline Characteristics. Two hundred and fifty patients were included in the study, and 243 patients were still eligible at T1. Two patients died, two were excluded due to recurrent stroke, and three patients withdrew from the study. FSS scores at T1 were missing for one patient, so 242 patients were included in this analysis.

The mean age of the group as a whole ($N = 242$) was 57.1 years (SD = 10.3 years); 64.9% of the patients were male. The average length of inpatient stay at the rehabilitation center was 72.1 days (SD 37.5). At the time of inclusion, the mean time since stroke onset was 97.0 days (SD 46.9).

3.2. Poststroke Fatigue. Fatigue was reported by 58.3% and 55.0% of the patients at T0 and T1, respectively. Mean FSS score was 4.1 (SD 1.7) at both measurements ($P = 0.83$). In 40.5% ($N = 98$) of the patients, fatigue (FSS ≥ 4) was present at both measurements, while about a quarter ($N = 66$) of the patients reported no fatigue at either measurement. Over 50% of the patients reported that fatigue was one of the three most disabling symptoms after stroke (score ≥5 on item 8 of the FSS).

Table 1: Descriptive statistics for changes in fatigue over time (N = 242).

Condition	N	Mean FSS score (SD) at T0	Mean FSS score (SD) at T1
Significant increase in perception of fatigue	38	2.7 (1.3)	5.4 (1.0)
No significant change in perception of fatigue	161	4.2 (1.6)	4.3 (1.6)
Significant decrease in perception of fatigue	43	5.2 (1.1)	2.7 (1.2)

FSS: Fatigue Severity Scale, SD: Standard Deviation.

The 95% SEM of the FSS was $(1.7 * \sqrt{(1-0.82)}) * 1.96 = 1.41$. A patient was classified as "having increased fatigue" when the score at T1 was 1.41 points higher than that at T0.

Using the 95% limits of the SEM, 38 patients (15.7%) showed an increased fatigue score, while FSS scores had decreased in 43 patients (17.8%), and the majority of the patients had remained stable in this respect (66.5%). Table 1 shows FSS scores for each group at both baseline and followup.

3.3. Regression Analysis. Logistic regression analysis was conducted, comparing the group showing an increase in fatigue with the reference group (i.e., those with stable or decreased FSS scores). Baseline characteristics of both groups are reported in Table 2. Bivariate analysis of the determinants measured at T0 showed six determinants with $P < 0.2$, viz. time since stroke, MI upper limb, 6MWT, MMSE, SIS memory, and FSS score at T0 (Table 2). Since there was no multicollinearity between these six determinants, all determinants were included in the multivariate logistic regression analysis. The only independent predictor of an increase in poststroke fatigue was the FSS score at T0 (OR 0.50 [0.38-0.64], Nagelkerke $R^2 = 0.243$). The multivariate model showed a good fit (Hosmer and Lemeshow test $P = 0.495$). The model including FSS at baseline correctly predicted 7.9% (3 of 38) of the patients whose fatigue had increased at T1 and 96.6% (197 of 204) of the reference group.

4. Discussion

In our study, the FSS score measured at T0 was the only independent predictor of an increase in fatigue over time. Nevertheless, a model including the FSS score at T0 still poorly predicted an increase in poststroke fatigue. Our findings also indicate that poststroke fatigue is experienced by the majority of stroke patients, with 58.3 and 55.0% of our patients reporting fatigue at T0 and T1, respectively. A large proportion (40.5%) of our patients were fatigued at both measurements, and 66.5% of the patients remained within the 95% limits of the SEM of the FSS, suggesting that the initial scores on the FSS are highly indicative for FSS scores at followup. This result further confirms that poststroke fatigue is a major problem after stroke, even in a relatively young and moderately affected population like ours, which remained fairly stable over time. However, the followup of the present study was restricted to 24 weeks. With that, it remains unclear if a longer followup would have resulted in the same conclusion.

A strong point of the current study was the large sample size of 250 participants and the use of a large variety of potential predictors at the different levels of the ICF. Some limitations need to be taken into account, however, when interpreting the results.

First, despite the large number of determinants included in the study, the multivariate regression model was a poor predictor of an increase in poststroke fatigue. This is in line with previously published studies [8, 12, 15, 16, 47]. In contrast to most other studies [2, 10, 11, 47, 48], our study examined the physical determinants by means of physical performance tests instead of using nonperformance measures like the Oxford Handicap Scale, modified Rankin Scale, SF-36, or Glasgow Outcome Scale. Our bivariate analysis suggested that the strength of the upper limb (MI) and the distance on the 6MWT were significantly related ($P < 0.2$) to an increase in fatigue over time. However, neither variable was included in the final multivariate model, suggesting that these physical determinants were not independent predictors of an increased fatigue score at T1.

The present study did not take determinants at the level of cognitive function and coping style sufficiently into account, which may have influenced the results. Previous studies found significant relations between poststroke fatigue and factors like cognition [48] and coping style [8, 48]. In our study, two of the three examined cognitive measures were included in the multivariate analysis, but they did not prove to be significantly related to an increase in poststroke fatigue. Although objective measures are generally preferred for cognition, we used a self-reported questionnaire and two global screening instruments, which may have influenced the results. Also, since we used the MMSE as an inclusion criterion, cognitive limitations in our sample were moderate.

Second, since there is no generally accepted definition of fatigue, there is no golden standard to measure poststroke fatigue either. Our study used the FSS to measure fatigue. Although this is a widely accepted and used scale to measure fatigue in stroke populations [1], this choice may have influenced the results.

Third, the use of an inception cohort at a fixed time after stroke onset is preferred in prognostic research, whereas our study took the baseline measurement at the time of discharge from inpatient rehabilitation, and there was a mean time interval between measurements of 96.9 days with a standard deviation of 46.9 days. Despite this, the frequency of poststroke fatigue found in our study is comparable to that reported in other studies using a similar timeframe [1, 8]. Also, time since stroke onset turned out not to be an independent predictor of an increase in poststroke fatigue.

To our knowledge, this is the first study which specifically attempted to identify patients whose poststroke fatigue increased over time. The significant odds ratio of 0.5 found in our study suggests that patients with higher baseline FSS

Table 2: Baseline characteristics and bivariate logistic regression analysis related to increased fatigue.

	Baseline characteristics		Bivariate logistic regression analysis	
	Deteriorated $N = 38$	Reference group* $N = 204$	OR (95% CI)	P value
Personal factors				
Age, mean ± SD	56.9 ± 10.4	57.1 ± 10.3	1.00 (0.97–1.03)	0.915
Male	63.2%	65.2%	1.10 (0.53–2.24)	0.809
Physically active before Stroke (yes)	81.6%	78.9%	1.88 (0.63–5.63)	0.261
CIRS, mean ± SD	6.1 ± 3.7	5.5 ± 2.6	1.07 (0.95–1.21)	0.251
Marital status; living with partner	78.9%	82.8%	0.78 (0.33–1.84)	0.565
Stroke characteristics				
Type of stroke; ischemic	84.2%	80.9%	1.26 (0.49–3.22)	0.629
Lateralization				
Right hemisphere (reference)			reference	reference
Left hemisphere	42.1%	48.0%	1.38 (0.65–2.94)	0.404
Other			1.05 (0.38–2.90)	0.925
Time since stroke (days)	108.8 ± 53.9	94.8 ± 94.8	1.06 (0.999–1.01)	0.094*
Previous stroke (yes)	10.5%	10.8%	0.812 (0.43–1.51)	0.513
Physical functions				
MI upper limb, mean ± SD	55.1 ± 29.3	61.3 ± 25.8	0.99 (0.98–1.00)	0.185*
MI lower limb, mean ± SD	67.4 ± 21.4	68.1 ± 20.1	1.00 (0.98–1.02)	0.843
SIS-strength, mean ± SD	53.6 ± 21.3	51.5 ± 19.9	1.01 (0.99–1.02)	0.546
TBT, median (range)	3.5 (1–5)	3 (0–5)	0.89 (0.65–1.23)	0.491
Cognitive functions				
MMSE, mean ± SD	28.5 ± 1.6	28.0 ± 1.7	1.21 (0.96–1.51)	0.104*
SIS-memory, mean ± SD	85.3 ± 13.9	81.4 ± 17.8	1.02 (0.99–1.04)	0.194*
Inattention (yes)	13.2%	21.6%	0.55 (0.20–1.50)	0.242
Psychological characteristics				
HADS-depression, mean ± SD	4.6 ± 3.6	4.8 ± 3.4	0.98 (0.88–1.09)	0.706
HADS-anxiety, mean ± SD	3.3 ± 2.8	3.8 ± 3.5	0.95 (0.85–1.06)	0.338
SIS-emotion, mean ± SD	80.6 ± 13.4	82.8 ± 13.7	1.00 (0.97–1.01)	0.353
FES, mean ± SD	97.1 ± 21.0	97.3 ± 19.2	1.00 (0.98–1.02)	0.955
FSS, mean ± SD	2.7 ± 1.3	4.4 ± 1.6	0.50 (0.38–0.64)	0.000*
Activities and participation				
6MWT, mean distance ± SD	279.1 ± 132.1	326.6 ± 126.0	1.00 (0.99-1.00)	0.037*
5MTWT, mean time ± SD	9.0 ± 6.1	8.1 ± 7.9	1.01 (0.97–1.05)	0.521
FAC, median (range)	5 (4-5)	5 (3–5)	0.78 (0.45–1.34)	0.361
RMI, mean ± SD	12.4 ± 1.5	12.5 ± 1.9	0.99 (0.82–1.20)	0.930
NEADL, mean ± SD	32.3 ± 10.5	34.0 ± 11.1	0.99 (0.96–1.02)	0.372
SIS-mobility, mean ± SD	79.0 ± 14.9	79.2 ± 14.2	1.00 (0.98–1.02)	0.940
SIS-hand function, mean ± SD	41.4 ± 38.7	45.5 ± 34.8	1.00 (0.99–1.01)	0.520
SIS-ADL/IADL, mean ± SD	67.1 ± 16.0	70.4 ± 15.2	0.99 (0.97–1.01)	0.238
SIS-communication, mean ± SD	83.4 ± 22.8	85.2 ± 18.2	1.00 (0.79–1.01)	0.579
SIS-participation, mean ± SD	63.4 ± 24.3	67.0 ± 20.3	0.99 (0.98–1.01)	0.329

*Reference group: those with stable or decreased FSS scores; CIRS: Cumulative Illness Rating Scale, MI: Motricity Index, SIS: Stroke Impact Scale, TBT: Timed Balance Test, MMSE: Mini-Mental State Examination, HADS: Hospital Anxiety Depression Scale, FES: Falls Efficacy Scale, FSS: Fatigue Severity Scale, 6MWT: 6-Minute Walking Test, 5MTWT: 5-Meter Timed Walking Test, FAC: Functional Ambulation Categories, RMI: Rivermead Mobility Index, NEADL: Nottingham extended activities of daily living, CI: Confidence Interval *P value <0.2, included in the multivariate logistic regression analysis.

scores are less likely to show increased fatigue (i.e., having a higher FSS score) in the long term. This is in contrast to the findings by Snaphaan et al. who reported that a higher fatigue score at baseline was related to a change from no fatigue at baseline to the presence of fatigue at followup (incident fatigue) [6]. Although the biological explanation for our finding remains unclear, the decreased likelihood to show an increase in FSS beyond the 95% limits of the SEM may be caused by a ceiling effect of the FSS and hence regression to the mean. Patients with high initial scores on a scale are more likely to show declining scores, whereas patients with very low scores at baseline are more likely to show an increase at a second assessment.

A significant relation between poststroke fatigue and depression has been shown in several studies [2, 7, 8, 10]. The study by Snaphaan et al. suggested that patients with fatigue at followup but not at baseline had higher baseline scores for depression compared to patients with no fatigue at either of these times [6]. The strong relation between fatigue and depression is consistent with the fact that fatigue is a symptom of depression. However, it has been shown that fatigue can occur without the presence of depression [8]. In our study, no significant relationship was found between depression and an increase in poststroke fatigue over time.

An ability to identify risk factors for an increase in poststroke fatigue will benefit efforts to design treatment modalities and counsel patients and their relatives. Currently, there is insufficient evidence to decide which treatment, whether pharmaceutical or by (multidisciplinary) rehabilitation, would be preferable [49]. Further research, for example, well-designed randomized controlled trials, will be necessary to show which interventions can be effective. Recently published preliminary results of a randomized controlled trial on the effect of combined graded physical activity training and cognitive treatment to treat poststroke fatigue show a significant decline in fatigue severity immediately after the treatment as well as 6 months after treatment [50]. Since coping style is an important factor in poststroke fatigue [8, 48], this is an important aspect to consider for inclusion in treatment. In addition to further exploration of effective treatment modalities, further research is needed to examine the determinants related to poststroke fatigue. The role of physical functioning should be further explored, since this has hardly been included in prognostic research so far. Poststroke fatigue is a multifactorial phenomenon which is probably not captured by one single outcome measurement. Therefore, future studies should consider including determinants of different domains and using various outcome measurements to determine the different dimensions of fatigue.

5. Conclusion

Baseline fatigue is the only independent predictor of an increase in poststroke fatigue, and predicting poststroke fatigue remains difficult. Most patients remain stable over time, meaning that the initial FSS scores are indicative of followup scores. A high percentage of our relatively young and moderately affected sample suffered from poststroke fatigue, indicating that this is a major problem in this group of stroke survivors.

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Research Article

The Impact of Mild Stroke on Participation in Physical Fitness Activities

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Objective. To compare participation in moderate to high intensity physical activities in persons before and after a mild stroke. *Methods*. We used data from the Cognitive Rehabilitation and Research Group to examine changes in moderate to high intensity physical activity participation in persons who had a mild stroke as defined by an NIH Stroke Scale score of less than 6 ($N = 127$). Using the Activity Card Sort, we compared the participants' high-demand leisure activity (leisure activities that are moderate to high intensity physical activities) participation at 6-months after stroke with their prestroke level. *Results*. We found a significant decrease in numbers of high-demand leisure activities in all participants and in each demographic group after mild stroke. *Conclusion*. These results suggest that persons after mild stroke are not retaining the high-demand leisure activities they were doing prior to their stroke. Health professionals must promote participation in high-demand leisure activities in patients with mild stroke as a tool to enhance health and fitness.

1. Introduction

Stroke incidence in the USA is estimated to be 795,000 per year with first-time attacks accounting for 610,000 and recurrent attacks accounting for 185,000 [1]. Cardiovascular comorbidities are common among stroke survivors with hypertension reported in 50–84% and heart disease in up to 75% of cases [2, 3]. As a result, recurrent stroke and cardiac disease are the leading causes of mortality in stroke survivors [3–5].

Physical inactivity is a modifiable risk factor that can affect cardiovascular disease and stroke severity, incidence, and functional recovery [2, 5–8]. Persons who were more physically active before stroke had less severe strokes and better functional outcomes than those who had been less active [5, 9, 10]. Participation in physical activity has been shown to improve performance of activities of daily living (ADL) and instrumental activities of daily living (IADL), improve fitness, and enhance perceived quality of life in stroke survivors [11, 12]. In spite of these benefits, stroke survivors have the highest percentage of inactivity when compared to persons with other chronic conditions [13].

Physical activity has been defined as any bodily movement produced by skeletal muscle that results in energy expenditure varying from low, moderate, or high intensity [6, 14]. Physical activity is positively correlated with physical fitness and is experienced in leisure time (including exercise as a subset of leisure), transportation, occupational, and household activities [6, 14].

The American Heart Association (AHA) has published specific physical activity guidelines for persons after stroke to address inactivity. They recommend 20–60 minutes of continuous or accumulated moderate to vigorous physical activity on three to seven days per week and strength, flexibility, and balance/coordination activities two to three days per week [12]. To meet these guidelines, it is essential that stroke survivors receive additional support to participate in physical activity. However, Tang and colleagues found that despite the common etiology between stroke and heart disease, physical activity and cardiac rehabilitation guidelines are

generally not prescribed for the stroke population [15]. Schmid et al. reported that in a sample of Veteran's Affairs (VA) occupational and physical therapists, less than half of those surveyed work with their patients to enhance health-promoting behaviors to prevent recurrent stroke in spite of published VA guidelines [16, 17].

Arguably stroke presents barriers that may prevent survivors from engaging in physical activity such as physical disability, depression, fatigue, lack of social reintegration, diminished motivation, and deconditioning [9]. However, the most prevalent form of stroke is mild stroke, defined by a National Institute of Health Stroke Scale (NIHSS) score less than 6 [2, 7]. Wolf et al. found that 49.4% of stroke survivors had a mild stroke in their sample of 7,740 persons who had experienced stroke [18]. This confirmed the findings of Tellier and Rochette in their review of literature that found that mild stroke is more prevalent than moderate and severe strokes [4]. Studies have tended to use differing definitions of mild stroke, but generally the criteria have included having a maximum score on a prognostic or stroke scale, few disabling after-effects such as an absence of or only slight motor impairments, no significant aphasia or unilateral spatial neglect, no impairment in ability to perform activities of daily living (ADLs), enough mobility to get in and out of bed, or the ability to perform a toilet transfer [2, 7]. Thus, we posit that persons who experience a mild stroke should be physically capable of following current poststroke guidelines and recommendations for participation in physical activities.

Since almost half of strokes are mild, it is important to examine the pre- and poststroke levels of moderate to high intensity physical activity participation in this population. This study has two objectives: (1) to determine if persons who had experienced a mild stroke retained their participation in prestroke moderate to high intensity leisure activities and (2) to determine if there are demographic differences in poststroke participation in moderate to high intensity leisure activities after mild stroke.

2. Methods

2.1. Subjects. This study is a secondary analysis of data collected for the Cognitive Rehabilitation Research Group (CRRG) at the Washington University School of Medicine in St. Louis. The CRRG recruits and registers patients from the Acute Neurology Stroke Service of Barnes-Jewish Hospital. The Washington University School of Medicine Human Research Protection Office (HRPO) reviewed and approved this study. Patients gave informed consent to be tested, to have their data placed in a registry, and to permit contact for future follow-up assessments. Data collected in the acute care setting included patients' demographic information, National Institute of Health Stroke Scale (NIHSS) score, and discharge dispensation information (i.e., if the patient was discharged to "no therapy," "home health," "outpatient," or "inpatient rehabilitation"). Between April 2003 and July 2007, the participants in the CRRG data registry were called and recruited 5–8 months (mean of 5.96 months) after stroke for a voluntary follow-up visit to administer the Activity Card Sort (ACS) and other functional and performance measures. As stated above, for the purposes of this study, only the participants who had experienced a mild stroke as evidenced by a NIHSS score of less than 6 (i.e., scores from 0 to 5) and who completed the ACS ($N = 127$) were included in this analysis.

2.2. Measures. The NIHSS is a measure that assesses neurologic impairment after stroke and is typically used as an indicator of stroke severity [19]. It is a 36-point scale that produces scores that range from 0 (no deficit indicated) to 42 (severe neurologic deficit). For this study, only participants with scores of less than 6 were included to indicate mild neurological deficits. A score of less than 6 on the NIHSS has also been found to strongly predict the likelihood of being discharged to home [20]. This population should theoretically have the physical capabilities to participate in physical activity. Several researchers have used the NIHSS score of less than 6 to differentiate between mild stroke to moderate and more severe strokes [18, 21, 22].

The Activity Card Sort (ACS) is a standardized instrument that assesses participation in 80 instrumental, social, and low-demand and high-demand leisure activities [23]. It uses a Q-sort methodology or rank order procedure to obtain a general history of adults' participation in the four categories (instrumental, social, low-demand leisure, and high-demand leisure activities.) The ACS has been shown to have test-retest reliability of 0.897 [23] and the Israeli version has been shown to have internal consistency [24]. Content and construct validity have also been reported [24, 25]. For the purpose of this study, only the high-demand leisure (HDL) category was examined because it includes 17 moderate to high intensity physical activities, for example, walking, running, swimming, bicycling, and gardening. For each of the activities, participants are asked to rate their level of participation using the following categories: "never done," "continue to do since the stroke," "given up since the stroke," "doing less often since the stroke," and "started to do this after the stroke." Standardized directions for scoring the ACS are as follows [23]. The total prestroke HDL activity score is a sum of activities that the participant rated as "continue to do since the stroke" plus "given up since the stroke" plus "doing less often since the stroke." The total poststroke HDL score is a sum of activities that the participant rated as "continue to do since the stroke" plus "started to do after the stroke" plus 1/2 the number of activities rated "doing less often since the stroke." A score to describe the percentage of HDL activities retained and/or gained after stroke was calculated by dividing the total poststroke HDL activities score by the total prestroke HDL activities score. Thus, a higher score indicates better retention of prestroke HDL activity participation or a gain in participation in new HDL activities since the stroke.

2.3. Data Processing and Analysis. Data was analyzed using SPSS 16.0 (SPSS Inc., 2007) with a significance level of .05. Descriptive statistics were used to describe patient demographic characteristics, level of rehabilitation services, HDL activities before and after stroke, and the percentage of HDL

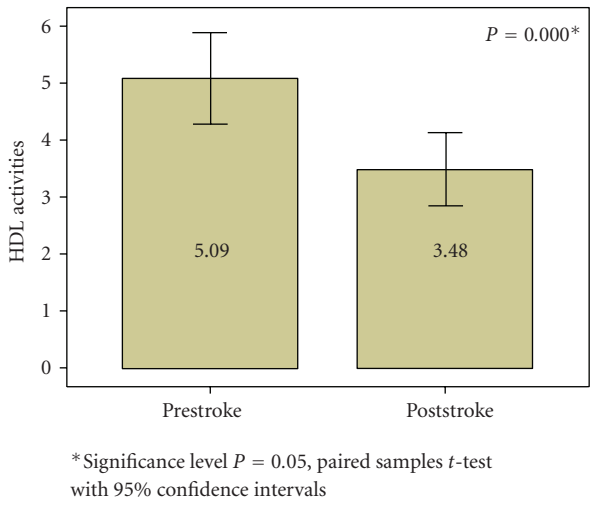

Figure 1: Mean number of HDL activities pre- and post-mild stroke for all participants ($N = 127$).

activities participants retained from pre-stroke to poststroke. We performed paired samples t-tests to determine if there was a significant difference when comparing the mean numbers of HDL activities before stroke with the mean numbers of HDL activities after stroke for all participants, each age group, gender, race, education level, and rehabilitation level. Independent samples t-tests compared mean numbers of HDL activities of the following pairs of groups: men and women, Caucasian and African American, and education of "high school or less" and "more than high-school." Rehabilitation services were combined into the following categories according to intensity level: no rehabilitation (discharged to home with no follow-up services), limited rehabilitation (outpatient rehabilitation, home health, or day treatment), or intensive rehabilitation (services in an inpatient rehabilitation hospital or a skilled nursing facility). A multiple regression analysis was conducted to evaluate how well age, education level, and rehabilitation group predicted poststroke HDL activity participation.

3. Results

Study participant demographic characteristics are presented in Table 1. The mild stroke sample ($N = 127$) had a mean age of 63 with a wide range between 31 and 90 years. Because the HDL activity participation may differ widely by age, the participants were divided into three age groups based on the distribution of the sample for further analysis: 54 and younger, 55–69, and 70 and older. Our sample had more participants with a "high school education or less" and more Caucasians than African Americans, but was fairly evenly split by gender. The most frequently reported level of rehabilitation service was limited rehabilitation.

As shown in Figure 1, there was a significant decline in participation in HDL activities for all participants. Overall, they reported losing an average of more than 1.5 of their prestroke activities 6–8 months after experiencing a mild stroke. We found that there was a significant decline without regard to age, gender, race, education, or poststroke rehabilitation level (see Table 1). When examining the percentage of activities retained, we found that in all groups the percentage of prestroke activities that participants retained ranged from 53% to 76%, that is, persons who have experienced a mild stroke are losing almost one-half to one-fourth of their prestroke HDL activities (see Table 1).

Men reported participating in significantly more HDL activities than women both before and after their stroke, but there was no significant difference in the percentage of activities that they retained (i.e., retaining approximately only 69 and 68%, resp.) The same can be stated for those who had an education level beyond high school. They reported significantly more HDL activities than those with an education level of high school or less, but we found that there was no significant difference in the percentage of HDL activities retained between these groups (only 70 and 67%, resp.) There were no significant differences in pre- or poststroke HDL activities reported by Caucasians or African Americans and no significant difference in percentage of HDL activities retained (only 72 and 64%, resp.) (See Table 2).

Table 3 shows the results of the multiple regression analysis evaluating how well age, education level, and rehabilitation group predicted poststroke HDL activity participation. The linear combination of these factors was significantly related to poststroke HDL activity participation ($R^2 = 0.15$, $P < 0.000$); however, age was the only significant predictor ($P < 0.001$).

4. Discussion

Participation in HDL activities declined significantly across all groups examined after mild stroke. Men and those who had an education level greater than a high school diploma reported significantly greater numbers of prestroke and poststroke HDL activities, but all groups reported an equivalent decline in HDL activity levels after mild stroke. We found no significant group differences in the decline from prestroke to poststroke when we compared men to women, Caucasians to African Americans, and between two levels of education. We also found that rehabilitation level received after stroke was not a significant predictor of HDL activity. As one would expect, we did find that age was a significant predictor of HDL activity participation after stroke [26].

Studies have reported that stroke survivors participate in less physical activity than others with chronic conditions [13]. However, although mild stroke makes up almost half of the occurrences of stroke, to our knowledge, there has been no description of the physical activity levels of participation before and after stroke and physical activity retention after stroke for this subpopulation. Since motor impairments are not characteristic of mild stroke as it is presently defined, we anticipated that there might not be significant poststroke declines from their prestroke HDL activity levels. In addition, we speculated that experiencing a mild stroke would be a "wake-up call" that might spur patients to seek opportunities to increase participation in prestroke HDL

Table 1: Demographics, mean pre- and post-HDL activities, and mean % HDL activities retained, $N = 127$.

	N (%)	Mean HDL act. prestroke	Mean HDL act. poststroke	P value	HDL act. % retained (post/pre)
NIHSS score: mean (SD), range	2.39 (1.54), 0–5				
Age, years: mean (SD), range	62.55 (13.51), 31–90				
54 years or younger	38 (30)	7.47	5.18	0.000*	69%
55 to 69 years	48 (38)	4.75	3.47	0.000*	73%
70 years or older	41 (32)	3.27	1.91	0.000*	58%
Gender					
Female	65 (51)	3.68	2.52	0.000*	68%
Male	62 (49)	6.56	4.48	0.000*	69%
Race					
Caucasian	74 (58)	5.18	3.78	0.000*	72%
African American	53 (42)	4.96	3.06	0.000*	64%
Education: mean no. of years (SD), range	12.87 (2.88), 6–22				
High school or less	68 (54)	3.96	2.68	0.000*	67%
More than high school	59 (46)	6.39	4.41	0.000*	70%
Rehabilitation services poststroke					
None	29 (23)	5.79	4.03	0.000*	70%
Limited	60 (47)	5.08	3.84	0.000*	76%
Intensive	33 (26)	4.30	2.27	0.000*	53%
Missing data	5 (4)				

* Differences between mean pre- and post-mild stroke HDL activity levels significant at $P < 0.004$ after Bonferroni correction.

Table 2: Comparison of mean pre- and post-mild stroke HDL activities and % retained by gender, race, and education, $N = 127$.

	n	Mean HDL act. prestroke	P value	Mean HDL act. poststroke	P value	Mean HDL activities % retained	P value
Gender							
Female	65	3.68	0.000*	2.52	0.002*	67.82	0.875
Male	62	6.56		4.48		68.83	
Race							
Caucasian	74	5.18	0.797	3.78	0.799	71.57	0.227
African-American	53	4.96		3.06		63.73	
Education							
High school or less	68	3.96	0.003*	2.68	0.003*	67.18	0.410
More than high school	59	6.39		4.41		69.54	

* Differences between mean HDL activity levels significant at $P < 0.005$ after Bonferroni correction.

Table 3: Regression results for poststroke HDL activity participation.

	Beta	Standard error
Constant	7.701	2.423
Age	−0.081*	0.024
Education	0.166	0.113
Rehabilitation Groups	−0.652	0.443

$R^2 = 0.153$; $^*P < 0.001$.

activities or participate in new ones, especially given that our stroke rehabilitation guidelines include patient education on the importance of increasing physical activity to maintain health and improve possible cardiovascular comorbidities. However, our findings indicate that persons after mild stroke decreased participation in a significant number of their prestroke HDL activities and did not initiate new HDL activities as a means to increase physical activity in an effort to meet poststroke guidelines [2, 7].

While HDL activity numbers dropped despite the need for increased participation, we acknowledge that there are several barriers associated with the lack of physical activity after stroke seemingly unrelated to motor impairment. These include depression, fatigue, social reintegration problems after hospitalization, decreased motivation, deconditioning,

other acute illness, and lack of familial support [12]. We contend that many of these barriers can be addressed by rehabilitation professionals and urge them to go beyond the typical focus on activities of daily living with their patients with mild stroke [27].

Our results support what other studies have found; women, persons with less education, and older adults report lower participation in moderate to high intensity physical activities than men, persons with higher education, and younger adults [28]. Although all groups should be targeted for intervention to retain and increase their moderate to high intensity physical activity, medical professionals in rehabilitation should be acutely aware of providing appropriate recommendations and interventions to these higher risk groups.

Most stroke survivors have long-standing lifestyle risk factors such as poor diet and obesity, smoking, and inactivity [7]. Intervention guidelines for poststroke rehabilitation have been published that include recommendations for therapists to address healthy lifestyle behaviors in their patients after stroke [7, 12, 17]. Because they are less likely to have residual physical disabilities that make it difficult to participate in physical activity, persons who have experienced a mild stroke are the ideal candidates for self-management programs, behavior change education, and physical activity interventions in rehabilitation or community settings. Our results show that the level of rehabilitation services received after stroke was not a significant predictor of patients' participation in HDL activities. Participants in all levels showed a significant decline in numbers of HDL activities. It is vital that we become familiar with the AHA and VA guidelines and devote time and effort to these modifiable lifestyle risk factors with all stroke survivors [7, 12, 17]. To accomplish this in rehabilitation settings, better understanding of the HDL activity preferences of persons who have experienced a mild stroke has been recommended to help increase their participation [29]. Additionally, to increase participation in this group, we would also recommend that all patients with mild stroke be given an assessment, such as the ACS, to identify prestroke HDL activities and other physical activities that may be meaningful for the individual. Therapists could use these activities to motivate participation in therapy, increase self-efficacy in performing them, and find community resources to address perceived barriers to participation in them [30].

There are several possible limitations with our study. All subjects volunteered to participate in the follow-up assessment six months after their stroke and may not be a representative sample of persons with mild stroke. The level of rehabilitation received on discharge from the acute care hospital may be dependent on the patient's comorbidities, not on impairment caused by the mild stroke, thus, the comorbid condition may be the deciding factor affecting the patient's ability to participate in an HDL activity. In addition, others have argued that the NIHSS assessment may not measure the deficits that affect a person with mild stroke who experiences problems with participation in everyday activities [18]. The ACS is a self-report measure and may not accurately reflect actual participation in HDL activities before and after stroke. In addition, the ACS measures the numbers of HDL activities, but does not measure the intensity, frequency, or duration of each activity. For example, a person after stroke may have given up gardening, but perform more walking and, thus, would be scored as having decreased his/her number of HDL activities.

5. Conclusions

Participation in HDL activities declines in all groups even after a mild stroke with few identified neurological impairments. It is critical for rehabilitation specialists to address this decline in all persons who have experienced a mild stroke. By meeting recommended guidelines, persons with mild stroke may ameliorate common cardiovascular comorbidities, improve performance in daily activities, improve fitness, and enhance quality of life. The next step to increase participation in HDL activities in persons with mild stroke will be to design and test behavior change and self-management programs that will successfully increase healthy lifestyle behaviors in this population.

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Clinical Study

Mood and Balance are Associated with Free-Living Physical Activity of People after Stroke Residing in the community

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Purpose. To determine which characteristics are most associated with free-living physical activity in community-dwelling ambulatory people after stroke. *Method*. Factors (age, gender, side of stroke, time since stroke, BMI, and spouse), sensory-motor impairments (weakness, contracture, spasticity, coordination, proprioception, and balance), and non-sensory-motor impairments (cognition, language, perception, mood, and confidence) were collected on 42 people with chronic stroke. Free-living physical activity was measured using an activity monitor and reported as time on feet and activity counts. *Results*. Univariate analysis showed that balance and mood were correlated with time on feet ($r = 0.42, 0.43, P < 0.01$) and also with activity counts ($r = 0.52, 0.54, P < 0.01$). Stepwise multiple regression showed that mood and balance accounted for 25% of the variance in time on feet and 40% of the variance in activity counts. *Conclusions*. Mood and balance are associated with free-living physical activity in ambulatory people after stroke residing in the community.

1. Introduction

The importance of physical activity to health is well established. After stroke, regular physical activity is critical for regulating blood glucose and promoting decreases in body weight, blood pressure, level of total blood cholesterol, serum triglycerides, and low-density lipoprotein cholesterol [1]. There is evidence from a meta-analysis of cohort studies that sufficient physical activity has a protective effect against stroke [2]. Therefore, it has been suggested that physical activity could decrease the incidence of recurrent strokes and coronary events [3]. However, many individuals with stroke are sedentary—both before and after the stroke—and their free-living physical activity is below the recommended level [4–6].

Walking performance has been found to be significantly associated with free-living physical activity in community-dwelling stroke survivors [7, 8]. However, this is perhaps not surprising given that physical activity is usually measured as steps per day. In other words, walking performance and physical activity are effectively two aspects of the same theoretical construct within the ICF classification [9], that is, activity limitations. One aspect is related to the individual's performance such as walking measured using a 10 m walk test or a 6 min walk test (i.e., what they *can* do). The other is related to quantity, such as the amount of physical activity carried out every day (i.e., what they *do* do). In other words, what stroke survivors can do predicts what they actually do.

However, less attention has been paid to the influence of impairments, that is, a loss or abnormality of body structure and function [9], on physical activity. After stroke, many individuals are left with impairments—both sensory-motor (such as muscle weakness, spasticity, contracture) and non-sensory-motor (such as aphasia, depression, and poor cognition). It is logical to assume that sensory-motor impairments will affect physical activity, through their influence on walking performance [10–13]. In general, the presence of non-sensory-motor impairments is associated

with poorer outcomes [14]. However, little is known about the impact of non-sensory-motor impairments on free-living physical activity. Non-sensory-motor impairments may indirectly impact on physical activity as much as sensory-motor impairments do.

Personal factors (such as age, BMI, psychological characteristics, and social support) may influence physical activity after stroke. Although physical activity has not been investigated directly, the presence of a spouse at home and good social support have been found to predict the ability to carry out activities of daily living in the long term [15, 16].

Given that some impairments and personal factors are amenable to modification in people after stroke, an understanding of which of these are associated with free-living physical activity may assist in planning appropriately targeted interventions. Therefore, the aim of this study was to determine which impairments and/or personal factors are most associated with free-living physical activity in community-dwelling people after stroke.

2. Methods

2.1. Design. A cross-sectional observational study was carried out with community-dwelling people after stroke. Ambulatory people with chronic stroke were recruited from the local community within a major city. Personal factors and impairments were collected on one day, and free-living physical activity was collected over two days in the community. Each participant was randomly allocated a day of the week and wore the activity monitor on this day across two consecutive weeks. The days for measurement of free-living physical activity were counterbalanced across the week so that there was the same amount of data collected for each day of the week. Data were collected from 30 min after getting out of bed (i.e., after dressing) until 30 min prior to going to bed (i.e., before undressing). Participants were instructed to carry out their routine activities. All measurements for each participant were completed within a 2-week period.

2.2. Participants. People with stroke were included if they were within 1 to 5 years of their first stroke, over 50 years old, and able to walk 10 m independently without an aid. They were excluded if they could not speak English or if they were unable to follow instructions. Ethical approval was obtained from the Human Research Ethics Committee at the local institution. Informed consent was obtained from all participants before data collection commenced.

2.3. Outcome Measures

2.3.1. Personal Factors. Age, gender, weight, height, side of hemiplegia, time since stroke, and presence of spouse were collected. Weight and height were used to calculate BMI in kg/m^2.

2.3.2. Impairments. Eleven impairments were measured and were divided into two categories: sensory-motor (including muscle weakness, contracture, spasticity, loss of coordination, proprioception, and balance) and non-sensory-motor (including cognitive, language, perceptual, mood abnormalities, and loss of confidence). Measures were chosen on the basis that they were easy and quick to perform in the clinic (e.g., they did not require extensive equipment), that they measured the impairment directly (i.e., they were not a subsection of a larger scale), and where possible, that they were valid and reliable for use in neurological conditions or with elderly patients. One person took all measures in order to eliminate inter rater variability and where relevant; the affected leg was measured.

Strength of the knee extensors was measured using hand-held dynamometry [17] since knee extensor strength has been shown to be associated with walking ability after stroke [18]. Participants lay supine with the hip and knee flexed to 90° and the lower leg resting on a stool, and the dynamometer was placed on the anterior surface of the lower leg. Participants were instructed to perform two maximum voluntary contractions with a minutes rest in between; the highest reading in N was used for analysis.

Contracture of the plantarflexors was measured using the method of Moseley and Adams [19] since the plantarflexors are a common site of contracture in people with stroke [20, 21]. Participants were seated with their feet on a sliding board, knees flexed to 90°, and a weight of 5 kilograms on the top of the knee. The examiner slid one foot at a time back until the heel lifted off the ground and took a photo in the sagittal plane thereby producing a measure of passive range of dorsiflexion with a standardized force. The angle between the vertical and the lower leg was measured by an examiner blinded to side of hemiplegia, and the difference between the intact and affected ankle in degrees was used in the analysis.

Spasticity of the plantarflexors was measured using the Tardieu scale [22–24] since the plantarflexors are a common site of spasticity and the Tardieu Scale is capable of differentiating spasticity from contracture [25]. Participants lay supine and were instructed to relax while the examiner dorsiflexed the ankle as fast as possible. The quality of the muscle reaction to stretch was rated on a scale from 0 to 4 with 0 being normal [26].

Coordination of the lower limb was measured using the Lower Extremity Motor Coordination Test (LEMOCOT) [27]. Participants were seated and, after practicing with their unaffected leg, moved the big toe of the affected leg from one target to another 30 cm away as fast as possible for 20 seconds (measured with a stopwatch). The accurate hits were counted and converted to taps/second to be used in the analysis.

Proprioception of the knee joint was measured using a matching task [28] since absent proprioception in the knee joint is related to frequent falls in people after stroke [29]. Participants were blindfolded and seated, knees flexed to 90°, with a vertical clear acrylic sheet ($60 \times 60 \times 1$ cm) inscribed with a protractor placed between their legs. After a practice, the examiner moved the affected knee randomly to 5 angles between 20- and 60 degree-flexion and instructed participants to move the intact leg to align their big toes. The mean error in degrees in matching the knee angle was averaged over the 5 trials to be used in the analysis.

Balance was measured using a modified version of the Single Leg Stance Test [30]. Participants stood unsupported on the affected leg in bare feet, arms folded across their chest, and eyes focusing on a stationary visual target located on a wall one meter from their standing position, for as long as possible (up to 30 s). If the feet moved, the foot touched the floor, the legs touched each other, or the arms moved, the examiner stopped the test and asked the participant to do the test again. The longest duration in seconds from three trials was used in the analysis.

In terms of non-sensory-motor impairments, cognition was measured using the Mini-Mental State Examination (MMSE) [31], since it is a commonly used test. The examiner asked the participant 11 questions generating a score between 0 and 30, where 30 is normal and <24 is considered cognitively impaired.

Language was measured using the Frenchay Aphasia Screening Test (FAST) [32] since a review study conducted by Salter and colleagues [33] indicated that it was the most widely used and thoroughly evaluated language test in stroke research. The shortened version of the test was used (0 to 20) with 10 points allotted for comprehension and 10 points for expression.

Perception was measured as neglect using the Line Bisection Test adapted from Olk and Harvey [34], since it is a simple test and can be completed within a short period [35]. Participants sat on a chair and were instructed to bisect a 10 cm horizontal line as centrally as possible. The examiner then measured the distance between the bisection and the actual midpoint of the line, and the error in mm was used in the analysis.

Mood was measured using the 6-item self-report Short Depression-Happiness Scale (SDHS) [36] since it is a short test which is not particularly susceptible to memory impairments. Three items record positive thoughts and feelings while three items record negative thoughts and feelings over the past 7 days ranging from never (0), rarely (1), sometimes (2), and often (3). Items concerning negative thoughts and feelings are reverse scored so that the range of scores is 0 to 18, where poor mood or depression is defined as a score <10 [37].

Confidence was measured using the 10-item self-report General Perceived Self-efficacy Scale [37] since it measures confidence across life generally, rather than in specific tasks such as falling [38], self-care [39], or walking, climbing stairs, and lifting objects [40]. Participants rated their confidence in each item from not at all confident (1) to very confident (4), so that the range of scores was 10 to 40, where 10 is the lowest confidence.

2.3.3. Free-Living Physical Activity. Free-living physical activity was collected using an activity monitor-Intelligent Device for Energy Expenditure and Activity (IDEEA). This device is light (58 g), and the recorder is clipped to the belt or waist of the pants. It monitors body motion through five sensors attached to the front of the chest, to the front of both thighs, and underneath both feet using medical tape. Postures (lying, reclining, sitting, standing, and leaning), transitions (lie to sit, sit to lie, recline to sit, sit to recline, recline to stand, stand to recline, sit to stand, and stand to sit), and gait (walking, running, up and down stairs, and jumping on both legs) are measured. An investigator visited participants' homes and calibrated the device. The recording of physical activity was then begun, with the investigator returning to turn the device off and check the data at the end of the day. Free-living physical activity was reported as duration (time on feet and time not on feet) and frequency of activity (activity counts) carried out per person per day [41]. "Time on feet" was measured in minutes and comprised the time spent walking, going up and down stairs, standing, and in sit to stand transitions. "Time not on feet" comprised time spent sitting, reclining, and lying down. "Activity counts" comprised the number of steps walked, stairs ascended and descended, and number of sit to stand transitions.

The IDEEA has been found to be >98% accurate for duration, frequency, type, and intensity of a variety of physical activities in normal adults [42] and reliable and valid for measuring walking in people after stroke [43]. We also compared the IDEEA with direct observation in three people after stroke with varying walking abilities. There are two algorithms available for use, with one being more sensitive to pathological movement. When using this algorithm, we found that the accuracy of duration of physical activity was 99% and of frequency of physical activity was 94%. Given that there was some variability of physical activity over the two days of measurement ($ICC_{3,1}$ 0.68 to 0.80), data were averaged over these days to present the breadth of activity.

2.4. Data Analysis. We collected data on 42 participants so that if up to 8 variables were entered into the regression analysis, there would be at least 5 cases per independent variable [44]. In addition, 42 participants meant that each day of the week is represented by data from 6 participants.

Shapiro-Wilk normality test was used to determine if the free-living physical activity data was normally distributed. It showed that the variable "activity counts" was positively skewed. When a log transformation was performed which normalized the activity counts data, there was no difference in the regression results. That is, the deviation from normal was not so large as to affect the outcome of the analysis. Therefore, the original data was used in order to facilitate interpretation.

Univariate analysis was undertaken using Pearson's correlation coefficient to examine the association between characteristics and free-living physical activity. Characteristics with correlations of $P < 0.05$ were entered into multivariate analysis. Stepwise multiple regression analysis was used to examine which characteristics were independently associated with free-living physical activity ($P < 0.05$) or explained an additional 5% of the variance.

3. Results

3.1. Participants. Forty-two stroke survivors aged 70 years (SD 10) with a BMI on the upper limit of normal participated in this study (Table 1). Over two-thirds of the participants were male; approximately half were right hemiplegics and

Table 1: Characteristics of participants.

Characteristic	Participants ($n = 42$)
Personal factors	
Age (yr), mean (SD)	70 (10)
Gender, *n* male (%)	29 (69)
Weight (kg), mean (SD)	73 (12)
Height (m), mean (SD)	1.7 (0.1)
Side of hemiplegia, *n* right (%)	23 (55)
Time since stroke (yr), mean (SD)	2.8 (1.4)
BMI (kg/m^2), mean (SD)	26.4 (4.3)
Living with spouse, *n* yes (%)	37 (88)
Impairments	
Sensory-motor impairments, mean (SD, range)	
Strength (*N*)	116 (52, 53–303)
Contracture (°)	4.8 (4.8, 0–19)
Spasticity (0 to 4)	1.2 (1.0, 0–3)
Coordination (taps/s)	0.6 (0.4, 0–1.6)
Proprioception (°)	4.2 (2.6, 0–12.6)
Balance (s)	5 (7, 0–30)
Non-sensory-motor impairments, mean (SD, range)	
Mood (0 to 18)	11 (4, 3–18)
Confidence (10 to 40)	29 (5, 17–39)
Perception (mm)	2.2 (1.6, 0–5)
Cognition (0 to 30)	25 (3, 17–30)
Language (0 to 20)	17 (4, 2–20)
Free-living physical activity over waking day, mean (SD, range)	
Time on feet (min)	230 (115, 29–506)
Activity counts (#)	5656 (4091, 543–18804)

the majority lived with their spouse. On average, participants had strong knee extensors, mild contracture of the plantarflexors, some spasticity, poor coordination, and normal proprioception in the affected leg. Their ability to balance was poor with 6 (14%) participants not being able to stand on their affected leg.

The mood score of 18 participants (43%) was below 10 which fulfills the criteria for depression. Most of the participants were confident and most also bisected the horizontal line within 5 mm of the middle, suggesting good perception. On average, the cognitive score was within normal limits; however, the scores of 11 (27%) participants were <24 suggesting the presence of cognitive impairment in some participants. Moreover, the Frenchay Aphasia Screening showed that 8 (19%) participants had language impairment.

The mean duration of free-living activity monitored was 10.8 hr/day (SD 1.3). On average, participants spent 230 min (SD 115) on their feet which was 35% of the monitored time. On average, they registered 5656 activity counts (SD 4091).

Table 2: Univariate analysis of the correlation between characteristics and free-living physical activity using Pearson's correlation coefficient r (P).

Characteristic	Free-living physical activity	
	Time on feet	Activity counts
Personal factors		
Age	−0.18 (0.26)	−0.26 (0.09)
Gender	0.10 (0.52)	0.17 (0.28)
Side of hemiplegia	0.12 (0.45)	0.00 (0.99)
Time since stroke	0.00 (0.99)	−0.03 (0.85)
BMI	−0.29 (0.06)	−0.12 (0.45)
Living with spouse	0.00 (0.98)	0.12 (0.44)
Impairments		
Sensory-motor impairments		
Strength	0.18 (0.25)	0.03 (0.85)
Contracture	−0.28 (0.07)	−0.27 (0.09)
Spasticity	−0.15 (0.33)	−0.21 (0.18)
Dexterity	0.10 (0.52)	0.15 (0.33)
Proprioception	0.07 (0.68)	−0.02 (0.89)
Balance	0.42 (<0.01)	0.54 (<0.001)
Non-sensory-motor impairments		
Mood	0.43 (<0.01)	0.52 (<0.001)
Confidence	−0.03 (0.84)	0.09 (0.57)
Perception	−0.13 (0.42)	−0.26 (0.10)
Cognition	0.18 (0.25)	0.03 (0.85)
Language	0.11 (0.50)	−0.04 (0.80)

3.2. Prediction of Free-Living Physical Activity. Univariate analysis showed that balance and mood were significantly correlated with time on feet ($r = 0.42, 0.43$, $P < 0.01$) and balance and mood were also significantly correlated with activity counts ($r = 0.52, 0.54$, $P < 0.01$). No other impairment or personal factor were correlated with either time on feet or activity counts (Table 2).

When the characteristics that were correlated with time on feet ($P < 0.05$, i.e., balance and mood) were entered into multiple regression, mood was independently associated with time on feet, with a regression coefficient of 8.2 (95% CI 0.2 to 16.2). Balance was not significantly associated with time on feet; however, it accounted for an additional 7% of the variance in time on feet. Balance and mood together accounted for 25% of the variance in time on feet.

Similarly, when the characteristics that were correlated with activity counts ($P < 0.05$, i.e., balance and mood) were entered into multiple regression, balance and mood were both independently associated with activity counts, with regression coefficients of 227 (95% CI 74 to 380) and 337 (95% CI 88 to 586), respectively. Balance and mood together accounted for 40% of the variance in activity counts.

4. Discussion

The aim of this study was to determine which characteristics were most associated with free-living physical activity in community-dwelling people after stroke who could walk

independently. Balance and mood were associated with free-living physical activity in community-dwelling stroke survivors, regardless of whether physical activity was measured as time being active or frequency of activity.

There was only one sensory-motor impairment—balance—that was associated with free-living physical activity such that the poorer the balance, the lower the amount of physical activity. Even though our sample could all walk 10 m unaided, standing on one leg was less than one quarter of normal performance in our participants [45]. Falls are common after stroke, and balance has been found to be an important risk factor for falls in stroke survivors [46]. Furthermore, balance has been found to be one of the independent predictors of satisfaction with community reintegration [47].

There was also only one non-sensory-motor impairment—mood—that was associated with free-living physical activity such that the greater the depression, the lower the amount of physical activity. 42% of our population met the criteria of depression, which is similar to findings from two community-based studies of poststroke depression [48, 49] and higher than two other studies [50, 51]. Moreover, there is evidence that the prevalence of depression increases over time after stroke [52, 53]. Previous research has shown that depression is also related to stroke recovery [54–56]. For example, Kotila et al. [57] found that depression is associated with poor recovery at one year after stroke in four different districts in Finland. In addition, two studies have found that people with depression at least one year after stroke are significantly more impaired in activities of daily living than those without depression [52, 58]. Similarly, others have found that participation restrictions are significantly correlated with depression [59].

The finding that balance and mood are associated with physical activity does not mean that depression and poor balance cause low levels of physical activity—the relationship is more likely to be cyclical. For example, if stroke survivors have poor balance, their physical activity is likely to be curtailed, which in turn may lead to a worsening in balance from lack of practice, thereby setting up a vicious cycle of deterioration in balance and physical activity. Similarly, depression can also curtail physical activity, which in turn may lead to further depression [60, 61].

In our study, spouse support was not correlated with free-living physical activity, which differs from Jorgensen and colleagues' [14] findings. One possible explanation may be that, in our study population, 88% lived with their spouses, which did not allow a thorough exploration of this variable. We also found a trend towards age and BMI negatively correlating with physical activity ($P = 0.09$ for age and 0.06 for BMI), in line with findings reported by Hagstromer and colleagues [62].

There are several implications from the findings of this study for clinicians involved in rehabilitation after stroke. Our findings suggest that intervention aimed at improving balance and enhancing mood may be useful in promoting long-term physical activity. Although the evidence for the benefit of exercise in managing depression is not clear-cut in the nonstroke population [63], there is some evidence that it may be effective in stroke [64–68]. In addition, there appears to be a small benefit for strategies such as education and advice targeting emotional recovery and adjustment to the impact of stroke [69]. Establishing supportive programs for community-dwelling stroke survivors is likely to decrease the rate of depression. There is evidence that community-dwelling stroke survivors who live in places with supportive programs (that encourage them to actively participate in social activities and provide any help they need for adapting to life) had better mood scores than those who live in the districts without such supportive programs [57]. More recently, Pakkala et al. [70] found that stroke survivors who were involved in a free-living physical activity counseling programs demonstrated lower depressive symptoms than controls.

The strengths of this study were that an activity monitor was used to measure free-living physical activity by which the limitations of self-report methods such as recall bias was avoided [8]. The limitations of this study include the relatively small sample size. However, by performing a univariate analysis to eliminate nonsignificant variables, there was sufficient power to conduct a stepwise regression analysis. Furthermore, the participants were recruited from the community, so that, while we measured the level of their disability, we have no information about the specific site and size of their lesion.

5. Conclusion

We have found that balance and mood were associated with free-living physical activity in community-dwelling people after stroke who can walk independently. These findings provide guidance to professionals working in rehabilitation in appropriately targeting intervention. Further research is required to examine prospectively whether early intervention to improve mood and balance will increase free-living physical activity of this population.

Conflict of Interests

The authors certify that no party having a direct interest in the results of the research supporting this paper has or will confer a benefit on them or on any organization with which we are associated.

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Research Article

Predictors of Adherence to a Structured Exercise Program and Physical Activity Participation in Community Dwellers after Stroke

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Aim. To investigate predictors of adherence to group-based exercise and physical activity participation among stroke survivors. *Methods*. 76 stroke survivors participated (mean age 66.7 years). Adherence was the percentage of classes attended over one year. Physical activity was the average pedometer steps/day measured over seven days at the end of the trial. Possible predictors included baseline measures of demographics, health, quality of life, falls, fear of falling, cognition, and physical functioning. *Results*. Mean class attendance was 60% (SD 29%). Only one variable (slow choice stepping reaction time) was an independent predictor of higher class attendance, explaining 5% of the variance. Participants completed an average of 4,365 steps/day (SD 3350). Those with better physical functioning (choice stepping reaction time, postural sway, maximal balance range, 10-m walk, or 6-min walk) or better quality of life (SF-12 score) took more steps. A model including SF-12, maximal balance range, and 6-min walk accounted for 33% of the variance in average steps/day. *Conclusions*. The results suggest that better physical functioning and health status are predictors of average steps taken per day in stroke survivors and that predicting adherence to group exercise in this group is difficult.

1. Introduction

Stroke is a leading cause of death and disability throughout the world [1] with 15 million people worldwide having a stroke each year [2]. The major socioeconomic burden of stroke results from the associated chronic disability rather than death [3]. For example, in Australia, there are around 350,000 stroke survivors, of whom 90% live at home and 282,000 (80%) live with permanent disability [4]. People are now more likely to survive after suffering a stroke, increasing the burden of disability over the last decade. This burden will continue to increase dramatically over the next two decades as the population ages [5].

Falls are a significant contributor to stroke-related disability [6]. Over 70% of stroke survivors fall within six months of discharge from hospital [7], and nearly 50% of community-dwelling female stroke survivors continue to fall each year [8]. Gait and balance problems have been found to be important factors underlying this increased falls risk in this group [8, 9].

Effective strategies to prevent falls and minimise stroke-related disability are essential to provide quality-of-life benefits and minimise spiralling health costs. There is now good evidence that well-designed exercise programs can enhance function after stroke [10–12] and can prevent falls in the general community of older people [13]. However, as is evident in the general population [14] and stroke survivors [15], ongoing adherence to exercise programs remains a major barrier to their effectiveness. An improved

understanding of barriers to exercise adherence may assist in designing and administering optimal exercise programs.

A recent systematic review of facilitators and barriers to participation in falls prevention in older people included 24 trials [16]. The authors identified several factors associated with increased exercise participation, including high exercise self-efficacy, past exercise history, good general health, and functional independence. The specific program characteristics associated with improved adherence were frequent, moderate duration activity, program accessibility and convenience, emphasis on social aspects, strong leadership, and individually tailored exercise.

Similarly, in a recent study involving older retirement village residents [17], we identified poor balance, impaired cognition, and multiple medication usage to be significant independent predictors of poor exercise class attendance. This result indicates that the people with the poorest physical functioning were the most likely to find it difficult to adhere to the exercise program.

Walking speed and endurance among community dwelling stroke survivors are markedly lower than age-matched controls [11, 12] and are associated with reduced quality of life and social isolation. This demonstrates the importance of physical activity promotion to stroke survivors to maximise their health outcomes. Documenting factors that predict adequate physical activity participation may also prove helpful in designing the content and delivery of exercise programs.

To address the above issues, we documented exercise class adherence and physical activity participation in a large sample of stroke survivors. The first study aim was to identify factors that were associated with adherence to a 12-month supervised group-based lower-limb exercise program designed to enhance mobility and prevent falls. The second aim was to identify factors that are associated with the average number of steps taken per day at the end of the trial period. A range of health, medical, and physical status variables measured at baseline were assessed as possible predictors of adherence.

2. Methods

2.1. Study Design. This study comprises a secondary analysis of data from participants randomised to the lower limb intervention group of a prospective, multicentre, randomised trial [18]. The study protocol was approved by Sydney South West Area Health Service Ethics Committee (Clearance no: X06-0039) and The University of Sydney Human Research Ethics Committee (HREC no. 07/2006/9031), and written informed consent was obtained from all participants.

2.2. Participants. Participants were stroke club members who had suffered at least one stroke, were able to walk 10 m independently with or without a mobility aid, gained medical clearance for exercise, were willing to join the New South Wales Stroke Recovery Association if not already a member, were willing to commit to a weekly exercise class and home program for 12 months, and were able to give informed consent. Participants were excluded if they had a cognitive impairment defined by a Folstein Mini-Mental State Examination (MMSE) [19] score of less than 20, had insufficient communication/English skills to participate in assessment and intervention, or had a medical condition precluding exercise such as unstable cardiovascular disease or suffered from other uncontrolled chronic conditions [20] that would interfere with training and/or testing protocols. Age, side of stroke, time since stroke, and comorbidities were recorded.

2.3. Exercise Program. Study participants took part in weekly exercise classes and were given a home exercise program to be completed at least 3 times per week. Classes were conducted over 40 weeks at the Stroke Club and were provided to participants free of charge. The intensity of the exercises included in the program was progressed as performance improved to ensure the intervention remained challenging. Experienced physiotherapists specifically trained in the trial protocol delivered the exercise classes and also designed individual home programs, which were reviewed and modified monthly. Exercise sessions took between 45 and 60 minutes. The exercise intervention was designed to prevent falls, enhance mobility, and increase physical activity (the Weight-bearing Exercise for Better Balance (WEBB) program available from the authors on request). Participants were also encouraged by exercise leaders to increase the amount of walking undertaken if considered safe to do so by the leader. Further information about the intervention program can be found in the trial protocol [18].

2.4. Adherence Measures. Two measures of adherence were used to determine the amount of physical activity participation and the factors associated with greater adherence in this group. Exercise class attendance for the duration of the study was recorded by exercise leaders and then expressed as a percentage of the number of classes offered. Physical activity participation was measured by recording the number of steps taken each day for seven consecutive days using a Digimax pedometer and then calculating the average number of steps per day. This measure was recorded at the end of the 12-month intervention when all classes were complete, during which time participants had been encouraged by exercise leaders to walk if safe to do so.

2.5. Predictor Variables. Data for possible predictors of exercise class attendance and averaged steps per day were collected via an interview, and a physical assessment was conducted at baseline by a physiotherapist. Potential predictor variables were grouped in the following domains: demographic, health and health-related quality of life, falls and fear of falling, cognition, muscle strength, standing balance, and mobility.

Demographic data (*age, gender*) were collected during the baseline questionnaire. Health was measured by asking about the presence of or history of a number of *health*

conditions and symptoms (visual problems, hearing problems, Parkinson's disease, peripheral vascular disease, diabetes, heart conditions, hypertension, asthma, incontinence, epilepsy, osteoporosis, arthritis, hip fracture, vertigo, and pain). Health-related quality of life was measured using the *SF12 Version* 2 [21]. Possible predictor variables from the health and health-related quality-of-life domain used in the analyses were the *total number of health conditions or symptoms, incontinence, poor vision* (as measured in the physical assessment on the Melbourne Edge test of visual contrast sensitivity), the *SF12 Version* 2 *physical composite,* and *SF12 Version* 2 *mental composite* scores (0–100) [22]. Falls were assessed with a yes/no question about whether the person had experienced *recurrent falls. Fear of falling* was measured with a single question; "Are you afraid of falling?" which required a "yes" or "no" response. Cognition was measured using the *Montreal Cognitive Assessment* [23]. The Montreal Cognitive Assessment assesses different cognitive domains: attention and concentration; executive function; memory; language; visuoconstructional skills; conceptual thinking; calculations; orientation. The Montreal Cognitive Assessment is scored from 0 to 30 points.

The domains of muscle strength, standing balance, and mobility were assessed by trained physiotherapists using performance-based tests. Muscle strength was evaluated by measuring *knee extensor strength* in both legs in a seated position. Strength (kg) was recorded as the best score from three attempts for each leg. Two aspects of mobility, walking speed, and capacity were assessed. Walking speed (m/s) was measured using the 10-*m walk test*. Participants were timed as they walked at their comfortable and fastest speed over the middle 10 m of a level 14 m walking track. Walking capacity was measured by quantifying the distance walked (m) during a *6-min walk test* [24]. Standing balance was assessed using three tests involving different movements in standing. The *maximal balance range* [25] test measures the maximal forward- and backward-leaning capacity of the participant. Subjects were asked to lean forward as far as possible from the ankles without moving the feet, then back as far as possible. Maximal anterior-posterior distance moved was measured in millimetres with a sway meter that measured displacements of the body at the level of the pelvis. For the maximal balance range test the sway meter extended in the anterior plane. Participants had three attempts at the test, with the best trial used in the analysis. *Postural sway* [26] was also assessed using a sway meter, positioned around the waist and extending posteriorly. Testing was performed with participants standing with eyes open on the floor and on a foam rubber mat (40 cm by 40 cm by 7.5 cm thick) [26]. *Choice stepping reaction time* was measured as the time(s) to complete a standardized stepping routine, where participants were required to step from either leg onto targets on the floor in response to a verbal cue directing the foot placement [27]. This is a modified version of an electronically timed test previously found to be a good composite measure of the risk of falling [27].

2.6. Statistical Analyses. Analyses were conducted using the SPSS and Stata software packages. Linear regression was used to determine the univariate associations between potential predictor variables and (a) exercise class attendance and (b) average pedometer steps per day. Predictor variables for which the individual P values were less than 0.2 were then included as candidate predictor variables for multivariate linear regression models. To ensure there were at least 15 cases for each predictor [28], one potential predictor variable from each domain with a maximum of 4-5 variables was included in each of the multivariate linear regression models. Where there was more than one variable from each domain that was associated with the outcome in univariate analyses, the variable with the lowest P value was entered. Statistical assumptions underlying linear regression models were met in the final models for adherence and steps taken. Specifically, the residuals were normally distributed, and there was no indication that the residuals were heteroscedastic and no indication of a nonlinear relationship between predictor and outcome variables. There was also no indication of multicollinearity as the variables were not highly correlated ($r < 0.5$), and the variance inflation factor values for each variable were less than 10.

3. Results

One hundred and fifty-one participants were recruited to the RCT investigating the effects of exercise on falls and mobility. These people were recruited from 11 stroke clubs between November 2006 and January 2009. Seventy-six participants (38 male and 38 female) were allocated to the lower limb exercise group, and these people are included in the analyses described here. The mean age of the participants was 66.7 years (SD 14.3), and average time since stroke was 6.7 years (SD 6.7; range 0.1–24.8). The baseline characteristics of the sample are shown in Table 1.

3.1. Exercise Class Adherence. An average of 31 (SD 8) exercise classes were available to participants over the 12-month study period. Average attendance rates were 60% (SD 29%). Eight physiotherapists, on average 28 (SD 13) years since graduating, provided the intervention at the 11 stroke clubs.

Univariate linear regression analyses identified just one variable to be significantly ($P < 0.05$) associated with better exercise class attendance; slower choice stepping reaction time ($P = 0.03$, coefficient 0.2, 95% CI 0.02 to 0.4). Those with more comorbidities ($P = 0.08$), a self-reported fear of falling ($P = 0.21$), or a history of recurrent falls ($P = 0.20$) were also more likely to attend more classes, but these relationships did not reach statistical significance. The variables included in the analysis but not found to be predictors of class attendance included age, gender, vision, incontinence, SF-12 mental composite scores, cognition, knee extensor muscle strength, maximal balance range, postural sway, 6-min walk test distance, and 10-m walking speed. The results of the univariate analyses are included in Table 2.

The three variables with individual P values from the univariate analyses that were less than 0.2 and which

Table 1: Characteristics of participants on entry to study.

Characteristic	Lower limb exercise group (n = 76)
Demographics	
Age (*yr*), mean (SD; range)	66.7 (14.3; 31–91)
Time since stroke at enrolment *(yr)*, mean (SD; range)	6.7 (6.7; 0.1–24.8)
Mini-Mental State Examination score (0–30), mean (SD; range)	27 (3; 20–30)
Gender, *n* males (%)	38 (50)
Side of hemiplegia, *n* right (%)	34 (45)
Recurrent falls, *n* (%)	19 (25)
Fear of falling, *n* (%)	34 (45)
Health conditions/symptoms	
Visual impairment, *n* (%)	61 (80)
Hearing impairment, *n* (%)	26 (34)
Parkinson's Disease, *n* (%)	1 (1)
PVD/Leg ulcers, *n* (%)	4 (5)
Diabetes, *n* (%)	16 (21)
Heart condition, *n* (%)	26 (34)
Hypertension, *n* (%)	44 (58)
Asthma/COPD, *n* (%)	16 (21)
Incontinence, *n* (%)	20 (26)
Epilepsy, *n* (%)	14 (18)
Osteoporosis, *n* (%)	16 (21)
Arthritis, *n* (%)	34 (45)
Hip fracture, *n* (%)	5 (7)
Vertigo/dizziness, *n* (%)	29 (38)
Pain, *n* (%)	47 (62)

represented different predictor domains were entered into a multivariate regression model (number of medical conditions and symptoms, history of recurrent falls, and choice stepping reaction time). This model explained 8% of the variability in exercise class attendance. As shown in Table 3, none of the individual variables were statistically significant in the multivariate model (although $P = 0.055$ for choice stepping reaction time) indicating some shared explanatory ability. The adjusted r^2 of a model including choice stepping reaction time only was 5%, indicating a small amount of additional predictive ability of the other variables and a high proportion of unexplained variability.

3.2. Physical Activity Participation. Averaged steps per day data were available for 64 participants. Overall, the mean number of steps recorded was 4,365 steps per day (SD 3,350), and the range was 55 to 12 733 steps. This mean represents 44% of the 10,000 steps recommended by physical activity guidelines to improve health and wellbeing. In the univariate analyses, several variables were significantly associated ($P < 0.05$) with averaged steps per day. These included a better SF12v2 physical composite score and each of the balance and mobility measures (better postural sway while standing on the foam mat, better maximal balance range, better choice stepping reaction time, better 6-min walk test distance, and better 10-m walk test time). There was no association between steps recorded and age, gender, vision, incontinence, total number of health conditions or symptoms, SF12v2 mental composite score, fear of falling, recurrent falls, cognition, or leg muscle strength. The results of the univariate analyses are included in Table 2.

Three of these significant variables representing one variable from each of the domains of health/health-related quality of life (SF12v2 physical composite score), standing balance (maximal balance range), and mobility (6-min walk test) were entered into a multivariate regression model to determine independent predictors of averaged steps per day. The univariate P values for maximal balance range and postural sway were both less than 0.001. The maximal balance range measure explained slightly more variability in averaged steps per day (adjusted r^2 15.9% versus 15.7%), so this measure was chosen for the multivariate model. Similarly, the P values for 6-min walk test and 10-metre walk distance were both less than 0.001, but the 6-min walk test explained more of the variability (adjusted r^2 34% versus 27%). The 3-variable model explained 33% of the variability, and, as shown in Table 3, better 6-min walk test performance remained strongly associated with averaged steps per day ($P < 0.001$) in the multivariate model. Thus, for predicting averaged steps per day, we found no benefit from assessing these other variables in addition to the 6-min walk test. There was also no indication of multicollinearity as the variables were not highly correlated ($r < 0.5$) and the variance inflation factor values for each variable were less than 10.

4. Discussion

Our community dwelling sample of older people had been living with stroke on average for more than five years. They walked at three quarters the speed [29] and covered half the distance in six minutes compared to that of healthy older people [30] and took approximately 44% of the recommended 10,000 steps/day [31].

Exercise class attendance rates for the group ranged from 0 to 100% with a mean of 60% (SD 29%). Contrary to expectation, we found that exercise class attendance was better among those with poorer physical functioning. This indicates that it is possible to design and deliver exercise classes that are acceptable to stroke survivors with impaired physical abilities. Choice stepping reaction time was the baseline measure of physical performance that best predicted attendance over the 12-month follow-up period. None of the other physical performance variables measured at baseline were associated with class attendance. There was some additional explanatory power of measures of comorbidity and recurrent falls that also indicated that those who were more impaired attended more exercise classes.

At baseline, we assessed demographic, health, health related quality of life, cognition, and physical performance using a variety of measures. Despite this, the variables we

Table 2: Descriptive data for predictor variables and results of the univariate linear regression analysis for predicting exercise class attendance and physical activity participation.

Predictor variable	Mean score (SD)/*N* (%)	Results for prediction of exercise class attendance ($n = 76$) Coefficient (95% CI)	*P*	Results for prediction of physical activity participation ($n = 64$) Coefficient (95% CI)	*P*
Demographic					
Age, years	66.7 (14.3)	−0.1 (−0.6 to 0.3)	0.61	−27 (−93 to 39)	0.42
Gender, male *n* (%)	38 (50)	−0.4 (−13.6 to 12.8)	0.95	−522 (−2205 to 1160)	0.53
Health/quality of life					
Conditions/symptoms, total number	5.7 (2.1)	2.8 (−0.4 to 5.9)	0.08	−92 (−504 to 318)	0.65
Incontinence, *n* (%)	20 (26)	4.0 (−10.9 to 18.9)	0.60	−953 (−2877 to 910)	0.30
Vision; Melbourne Edge Test (score/24)	19.4 (3.0)	0.6 (−1.7 to 2.8)	0.61	106 (−173 to 385)	0.45
SF12v2 physical composite (score/100)	36.7 (10.2)	−0.4 (−1.0 to 0.3)	0.23	94 (10 to 177)	**0.03**
SF12v2 mental composite (score/100)	49.9 (11.4)	0.2 (−0.4 to 0.7)	0.60	−28 (−103 to 48)	0.47
Falls/fear of falling					
Recurrent falls, *n* (%)	19 (25)	9.8 (−5.2 to 24.9)	0.20	−53 (−2045 to 1938)	0.96
Fear of falling, *n* (%)	34 (45)	8.3 (−4.8 to 21.4)	0.21	−261 (−1962 to 1438)	0.76
Cognition					
Montreal Cognitive Assessment (score/30)	22.0 (5.6)	−0.4 (−1.6 to 0.7)	0.48	−24 (−174 to 126)	0.75
Muscle strength					
Knee extension strength (kg)	22.4 (9.7)	−0.2 (−0.9 to 0.4)	0.48	7 (−79 to 93)	0.88
Standing balance					
Postural sway (mm)	584.9 (302.8)	0.01 (−0.02 to 0.03)	0.62	−5 (−7 to −2)	**0.001**
Maximal balance range (mm)	113.8 (56.8)	−0.06 (−0.2 to 0.06)	0.30	23 (10 to 36)	**0.001**
Choice stepping reaction time (sec)	63.5 (30.8)	0.2 (0.02 to 0.4)	**0.03**	−31 (−57 to −5)	**0.02**
Mobility					
10-m walk speed (m/sec)	0.9 (0.5)	−5.0 (−19.5 to 9.4)	0.49	3889 (2317 to 5459)	**<0.001**
6-min walk test (m)	233.4 (124.0)	−0.01 (−0.06 to 0.05)	0.82	16 (10 to 22)	**<0.001**

Table 3: Results of the multivariate linear regression analysis for predicting exercise class attendance and physical activity participation.

Predictor variable	Coefficient (95% CI)	P	Adjusted R^2 (%)
	Results for prediction of exercise class attendance		
Conditions/symptoms (total number)	1.99 (−1.02 to 5.00)	0.191	8
Fear of falling (yes/no)	7.50 (−4.93 to 19.93)	0.233	
Choice stepping reaction time (sec)	0.20 (−0.004 to 0.40)	**0.055**	
	Results for prediction of physical activity participation		
SF12v2 physical composite (score/100)	11.60 (−65.62 to 88.80)	0.765	33
Maximal balance range (mm)	7.77 (−6.05 to 21.6)	0.265	
6-min walk test (m)	13.60 (6.58 to 20.61)	**0.000**	

measured were not able to explain the majority of the variability (92%) in class attendance rates over the 12-month follow-up period. Either the measurement tools we used were not able to accurately measure these factors in this population, or these factors are not important in the prediction of exercise adherence in stroke survivors. Factors such as depression, family support, and social isolation were not measured in our study but have been previously found to be associated with uptake and adherence with exercise programs in stroke survivors [15]. There was no cost to take part in the study, and none of the participants were in paid employment; therefore, these factors were not barriers to participation.

Our study involved the establishment of exercise classes within stroke clubs where stroke survivors were already meeting regularly. Our results may not generalise to the broader population of community-dwelling stroke survivors as our participants may have been different from stroke survivors who do not choose to meet regularly with their peers. Furthermore, most of the study participants relied on community transport or transport assistance from a relative or friend to travel to the exercise classes, so it is likely that some missed classes were due to the occasional unavailability of transport.

Physical activity participation, as measured by the average number of steps taken per day after a 12-month intervention period, was predicted by baseline performance in several tests of balance and mobility and health-related quality of life (SF-12 physical composite scale). The 6-min walk test was the strongest predictor of physical activity participation, but the measure of mobility (the 10-m walk test) was also a very strong predictor and may be easier to measure. While pedometers are commonly used as a motivational tool in patient behaviour change programs, they do undercount steps for those people with gait impairment [32]. This undercounting is likely to strengthen the association between walking speed and physical activity (step counts). Although several balance and mobility variables were associated with averaged steps per day in the univariate analyses, they did not remain significantly associated with averaged steps per day in the multivariate model which included the 6-min walk test. These variables were moderately correlated ($r = 0.43$–0.89) which indicates they are likely to be measuring similar factors. Additionally, exercise class attendance in itself was not a predictor of independent physical activity participation ($P = 0.535$).

It therefore appears that physical activity among stroke survivors was influenced by mobility but not the other study variables included here as possible predictors. This result suggests that advice and guidance to participate in regular physical activity should be targeted at all stroke survivors, regardless of individual comorbidities and functional status. In addition, people with impaired mobility may need more specific advice and different strategies to increase their physical activity levels as their steps per day may be limited by mobility. Cycling and arm cranking have been previously suggested as ways to increase physical activity in people with impaired mobility [33, 34]. Of course, exercise prescription should consider individual impairments (e.g., arm cranking may be difficult for those with affected upper limbs), may need modified equipment, and should follow preexercise screening protocols [20] to ensure safety.

Averaged steps per day data were missing for 12 people due to difficulty using the equipment for one participant and loss to 12-month follow-up for 11 others. It is possible that this resulted in an overestimation of physical activity participation as more than half of those people lost to follow-up cited health problems as the reason for nonattendance at the 12-month reassessment. Furthermore, formal accuracy testing of the pedometers with all participants was not carried out prior to their use, which may have led to inaccuracies in the measures obtained.

The predictor variables we measured at baseline explained a greater proportion of the variability in averaged steps per day (33%) compared with exercise class attendance (8%). Although this finding should be replicated in other populations of stroke survivors, it suggests that physical activity can be more easily predicted than exercise class attendance.

5. Conclusions

The uptake and sustained compliance with recommendations around the importance of ongoing, regular physical activity for prevention of disease and maintenance of health is as important in stroke survivors as in the general population. The results of this study confirm that participation in specific structured exercise programs and general physical activity is difficult for many long-term stroke survivors. We found exercise class attendance was variable and difficult to predict but better among those with poorer mobility at

baseline. Conversely, we found a higher average number of steps taken per day among those with better mobility. We hope that these results assist in the design of physical activity programs for stroke survivors.

Conflict of Interests

Professor S. R. Lord developed the The Physiological Profile Assessment (FallScreen) which is commercially available through Neuroscience Research Australia.

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Review Article

Exercise Protects Bone after Stroke, or Does It? A Narrative Review of the Evidence

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Physical inactivity contributes to accelerated bone loss after stroke, leading to heightened fracture risk, increased mortality, and reduced independence. This paper sought to summarise the evidence for the use of physical activity to protect bone in healthy adults and adults with stroke, and to identify international recommendations regarding any means of bone protection after stroke, in order to guide rehabilitation practice and future research. A search was undertaken, which identified 12 systematic reviews of controlled trials which investigated the effect of physical activity on bone outcomes in adults. Nine reviews included healthy adults and three included adults with stroke. Twenty-five current international stroke management guidelines were identified. High-impact loading exercise appears to have a site-specific effect on the microarchitecture of healthy postmenopausal women, and physical activity has a small effect on enhancing or maintaining bone mineral density in chronic stroke patients. It is not known whether this translates to reduce fracture risk. Most guidelines included recommendations for early mobilisation after stroke and falls prevention. Two recommendations were identified which advocated exercise for the prevention bone loss after stroke, but supporting evidence was limited. Research is required to determine whether targeted physical activity can protect bone from early after stroke, and whether this can reduce fracture risk.

1. Introduction

Stroke-related impairments and inactivity contribute to the accelerated development of osteoporosis [1–3]. Combined with a high rate of falls [4–6], stroke survivors are particularly vulnerable to fall-related injuries, especially fractures. The risk of fracture after stroke is 1.5- to fourfold compared to age-matched controls [7], and fractures after stroke reduce the ability to regain independent walking and increase mortality [8].

Bone maintains its strength through the modulation of its remodelling activity (bone turnover), adapting its structural and material properties in response to its loading environment [9]. Loads on bone are generated by ground reaction forces and muscle activity. Immobility from hemiplegia or extended bed rest decreases loads and thus contributes to increased removal of bone [10]. Conversely, during adulthood, mechanical loading of bone can contribute to maintenance of bone strength by maintaining bone mass, and vigorous high-impact loading may have a small capacity to increase bone mass [10].

Physical activity levels are often very low among acute stroke patients [11, 12], who may spend over half of the day (8 am to 5 pm) resting in bed [12]. Prolonged bed rest, however, leads to rapid loss of bone [13]. Urinary markers of bone resorption (C-telopeptide and N-telopeptide), which can be used to predict hip fracture in older women [14], were elevated by 17.8% and 28.7%, respectively, after one day of bed-rest in healthy men aged 25.5 years (SD 2.9) [13]. In addition, reductions in bone mineral density (BMD) at the tibia of up to 3% have been observed in a similar group of young men after five weeks of bed rest [15]. In comparison, the normal rate of bone loss in healthy men and women aged over 60 years is approximately 1% per year [16–18].

The period of immobility after stroke appears to strongly influence the amount of bone which is lost. People who remained nonambulant for one year after stroke lost up to 13% of femoral neck BMD of the paretic limb [19]. In

contrast, people who relearned to walk within two months, and people who walked from the first week after stroke showed losses of 8% and 3%, respectively [19]. Other stroke-induced impairments also appear to contribute to the amount of bone loss: severity of impairment [20, 21], disuse of paretic limbs [22], reduction in weight bearing [20], reduced muscle mass [23], muscle weakness [24], and reduced cardio-respiratory fitness [23].

Evidence supports the role of targeted physical activity for maintaining or improving BMD in healthy women and men aged over 60 years, in whom bone loss is occurring [25, 33]. High-impact loading exercise has a modest, positive, and site-specific effect in healthy postmenopausal women, primarily enhancing cortical, rather than trabecular, bone mass and geometry [29]. National guidelines recommend physical activity for the prevention of osteoporosis in the healthy adult population [36]. Moreover, physical activity is recommended to improve mobility and function [37], muscle strength [38, 39], and fitness [40] after stroke, and early and frequent mobilisation is recommended for the prevention of complications in acute stroke patients [41]. In addition, some evidence suggests that physical activity may maintain or improve bone density in chronic stroke [42]. However, despite the prevalence and detrimental effects of bone loss after stroke, and the potential for physical activity to modulate bone structure and density, recently updated Australian clinical guidelines for stroke management [41] did not mention bone loss. Evidence from healthy adults contributes to our understanding of bone loss after stroke; however, separate evaluations are warranted, since the generalisability of results from healthy adults to adults with stroke may be limited due to stroke-related impairments and neurovascular changes. The aims of this paper were to summarise the evidence for the use of physical activity to protect bone in both healthy adults and adults with stroke. A secondary aim was to summarise international recommendations regarding any means of bone protection after stroke.

2. Method

A search was undertaken in order to retrieve all systematic reviews, of controlled trials that investigated physical activity interventions and contained bone-related outcomes in healthy adult or adult stroke populations. The following electronic databases were searched from 2001 on 31 May 2011: Ageline, Allied and Complimentary Medicine (AMED), Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, Medline, Physiotherapy Evidence Database (PEDro), PsycINFO, SPORTDiscus, and Web of Knowledge. Keywords used to identify reviews included "bone, bone loss, fracture, or osteoporosis" combined with "physical activity, exercise or loading." International stroke management guidelines were identified in these databases using terms "stroke" and "management, guideline, or consensus statement." Additionally, stroke association websites and colleagues with content knowledge were consulted to identify systematic reviews and clinical guidelines. Non-English language guidelines were identified in the described search and were included in subsequent drafts of the manuscript once colleagues were available to translate.

The identified systematic reviews were summarised for included trials, conclusions, and recommendations for future research, and this information is contained on Table 1. The identified stroke management guidelines were searched for key terms of "bone, fracture, or osteoporosis," and recommendations were reviewed for content regarding bone protection, physical activity, exercise, and falls prevention. Summaries of these recommendations and their levels of evidence are recorded on Table 2. Appendices A and B contain descriptions of classifications of levels of evidence and grades of recommendations.

3. Results

3.1. Physical Activity for the Prevention of Bone Loss in Healthy Adult Populations. Nine systematic reviews of controlled trials which investigated the use of exercise as an intervention against bone loss in healthy adults were identified. One review investigated adults with low bone mineral density [30], one investigated premenopausal women [68], five studied postmenopausal women [25, 26, 28, 29, 31], and two [32, 33] included adults of all age groups. Interventions were based on various forms of physical activity which were hypothesised to reduce bone loss through weight bearing and muscular action on bone. Outcomes were two dimensional measurement of bone mass of spine, hip, wrist, or total body, using dual-energy X-ray absorptiometry (DXA), or three-dimensional bone mass and bone architecture, measured with peripheral quantitative computerised tomography (pQCT).

There were mixed results regarding the effect of impact (weight bearing) and nonimpact (resistance training, aerobics) exercises on BMD of pre- and postmenopausal women's lumbar spine [25, 26, 28, 31, 68], femoral neck [26, 31], whole hip [25, 28, 68], and wrist [25]. Bone mineral density was reported to be improved by weight-bearing aerobic exercise with or without muscle strengthening exercise, when the duration of the intervention was at least a year [30]. Exercise appeared to positively influence site-specific bone mass and geometry in postmenopausal women, with the most prominent changes being in response to high-impact loading exercise. Exercise was reported to be able to reduce falls, fall-related fractures, and several risk factors for falls in individuals with low BMD [30]. Most authors commented on the heterogeneity of interventions and research quality. Recommendations were made for the design of future studies including high-quality methodology, larger sample sizes, periods of intervention greater than one year, targeted exercise programs, and consistent methods and sites of outcome measurement. It was reported that research was needed to determine whether improvements in bone mass and geometry were capable of preventing fractures.

Table 1: Summary of systematic reviews of exercise interventions for the prevention of adult bone loss.

Reference	Objectives and number of included studies	Conclusions and recommendations
Bonaiuti et al. [25]	To examine the effectiveness of exercise in preventing bone loss and fractures in postmenopausal women 18 RCTs; $n = 1423$	(i) Aerobics, weight bearing, and resistance exercises are effective in increasing BMD of the spine in postmenopausal women. Aerobic exercise is effective in increasing BMD of the wrist. Walking is effective on the hip. (ii) The quality of the reporting of the trials in the meta-analysis was low, in particular, in allocation concealment and blinding.
Martyn-St James and Carroll [26]	To evaluate effects of progressive, high-intensity resistance training on postmenopausal BMD. 15 RCTs; $n = 585$	(i) Significant increase in BMD of the lumbar spine following high-intensity resistance training. (ii) Methodological quality of studies was low, and a reporting bias towards studies with positive BMD outcomes was evident
Myint et al. [27]	Critical review of recent studies on strategies to prevent bone loss and fractures after stroke. 1 RCT of exercise in chronic stroke patients, $n = 63$	(i) Emerging evidence that exercise can improve bone health in chronic stroke. Further work is necessary to evaluate early physiotherapy and exercise interventions in acute stroke patients (ii) Prevention of falls is important in preventing hip fractures. Studies of falls prevention for stroke populations are needed.
Marsden et al. [1]	158 papers focusing on risk factors or interventions to prevent bone loss or fractures after stroke. 1 RCT of exercise intervention, $n = 63$	(i) Early mobilisation may reduce bone loss & avoid fracture, but evidence is needed. Large, prospective studies are needed to clarify optimum treatments to reduce poststroke bone loss, and test the effects on clinical outcomes.
Martyn-St James and Carroll [28]	To assess the effects of prescribed walking programmes on BMD at the hip and spine in postmenopausal women. 5 RCTs, 3 non-RCTs, $n = 621$	(i) Regular walking has no significant effect on preservation of BMD at lumbar spine in postmenopausal women. Inconsistent results observed on BMD of femoral neck. (ii) Diverse methodological and reporting discrepancies in published trials. Other forms of exercise that provide greater targeted skeletal loading may be required to preserve BMD in this population.
Hamilton et al. [29]	To determine the effects of exercise on bone mass and geometry in postmenopausal women 4 RCTs, 1 non-RCTs, 3 cross-sectional & 4 longitudinal studies, $n = 905$	(i) Exercise appears to positively influence bone mass and geometry in postmenopausal women, with the most prominent changes in response to high-impact loading exercise. Exercise effects appear to be modest, site-specific, and preferentially influence cortical rather than trabecular components of bone. (ii) Research is needed to determine the types and amounts of exercise required to optimise improvements in bone mass and geometry in postmenopausal women & determine whether these improvements are capable of preventing fractures.
De Kam et al. [30]	To investigate efficacy of exercise interventions in individuals with low BMD in reducing (1) falls & fractures (2) risk factors for falls & fractures 28 RCTs, $n = 1592$	(i) Exercise can reduce falls, fall-related fractures, and several risk factors for falls in individuals with low BMD. Bone strength was improved by weight-bearing aerobic exercise with or without muscle strengthening when interventions were at least a year long. (ii) Exercise for patients with low BMD or osteoporosis should include weightbearing, balance, and strength training to reduce falls & fracture risk

Table 1: Continued.

Reference	Objectives and number of included studies	Conclusions and recommendations
Martyn-St James and Carroll [31]	To assess the effects of impact exercise on postmenopausal bone loss at the hip and spine 10 RCTs & 5 nonrandomised controlled trials, $n = 1358$	(i) Mixed loading exercise programmes combining jogging with other low-impact loading activity (walking and stair climbing) and programmes mixing impact activity with high-magnitude resistance training appear effective in reducing postmenopausal bone loss at the hip and spine. (ii) High-impact only and odd-impact only protocols were ineffective in increasing BMD at any site in this population. (iii) Diverse methodological and reporting discrepancies are evident in published trials.
Guadalupe-Grau et al. [32]	To review relevant studies in adults and animals, highlighting variables like mode of exercise, intensity, duration, endocrine and metabolic factors, and sex differences in the osteogenic response to training.Young men: 4 cross-sectional studies, $n = 442$; 4 longitudinal, $n = 161$ Middle-aged men: 2 longitudinal, $n = 158$ Older men: 3 longitudinal, $n = 194$ Young women: 4 cross-sectional studies, $n = 381$, 9 longitudinal, $n = 4$ Premenopausal women: 4 longitudinal, $n = 293$ Older women: 8 longitudinal, $n = 221$	(i) Participation in high impact sports, especially before puberty, is important for maximising bone mass and achieving a greater peak bone mass in men and women. Continuing sport practice is associated with fewer fragility fractures in older men and women (ii) A mix of high impact and weight-lifting exercises may be the best method for enhancing bone mass and preventing OP. Unloaded exercise (swimming and cycling) has no impact on bone mass. Walking & running has limited positive effect. (iii) For those with OP, WB exercise in general, and resistance exercise in particular, along with balance, mobility and posture exercise should be recommended to reduce the likelihood of falling. (iv) Older men respond better to osteogenic training than women, but RCTs on the effect of exercise on bone mass in older people are lacking.
Nikander et al. [33]	To evaluate the effects of long-term supervised exercise on estimates of lower-extremity bone strength from childhood to older age. 5 RCTs of children/adolescents, $n = 1160$ 1 RCT of premenopausal women, $n = 80$ 4 RCTs of postmenopausal women, $n = 369$	(i) Exercise can enhance bone strength at loaded sites in children but not in adults. In premenopausal women with high exercise compliance, improvements of 0.5% to 2.5% have been reported. (ii) There is a need for further well-designed, long-term (>2 year) RCTs with adequate sample sizes to quantify the effects of exercise on whole bone strength and its structural determinants throughout life.
Martyn-St James and Carroll [34]	To assess the effects of impact exercise on BMD at the hip and spine in premenopausal women. 6 RCTs, 3 non-RCTs, $n = 735$	(i) Combining odd- or high-impact activity with high magnitude resistance training appears effective in augmenting BMD in premenopausal women at the hip and spine. High-impact-only protocols are effective only on hip BMD in this group. (ii) Diverse methodological and reporting discrepancies are evident.
Borschmann et al. [35]	To investigate the skeletal effects of physical activity in adults affected by stroke. 1 RCT, 1 non-randomized CT, 1 quasirandomized CT ($n = 95$)	(i) Small effect size of physical activity in maintaining of improving bone density and bone structure on paretic side for chronic stroke patients. (ii) Quality studies are required to investigate the effect of targeted physical activity from early after stroke.

BMD: bone mineral density, OP: osteoporosis, RCT: randomised controlled trial, SCI: spinal cord injury, WB: weight bearing.

Table 2: Summary of current guidelines regarding bone protection, mobilisation and rehabilitation, and falls prevention after stroke.

Reference	Keyword* or bone protection included (level of evidence)	Mobilisation and rehabilitation (level of evidence)	Falls prevention (level of evidence)
American Heart Association *Physical activity recommendations for stroke survivors*. [43]	Decreased activity after stroke leads to secondary complications including osteoporosis.	Rehab goals include preventing complications of prolonged inactivity. Initiate regimens to regain prestroke level of activity as soon as possible.	Not included
American Heart Association ...*Rehabilitation care for stroke survivors* [44]	Not included	It is reasonable to provide a comprehensive interdisciplinary assessment of mobility.	Consider all people with stroke as having increased falls risk. Work with patient & carers, to minimise falls.
Beijing Neurological Club [45] (English summary only available)	Not included	Rehab should occur as early as possible: 48 hours after stabilisation of vital signs and symptoms in ischemic strokes. Delay rehab until 10–14 days after haemorrhage.	Not included
Belgian Stroke Council [46, 47]	Not included	Mobilise on stroke unit as soon as possible to prevent complications including aspiration pneumonia, DVT, decubitus ulcers.	Not included
Canadian Stroke Network and the Heart and Stroke Foundation of Canada [48]	Not included	Early consultation with rehab professionals can reduce risk of complications from stroke-related immobility such as joint contracture, falls, aspiration pneumonia, & DVT.	Multifactorial community interventions including individualised exercise programs may prevent or reduce falls number & severity. (Level A)
Chinese Stroke Management Guidelines [49] (English summary only available)	Not included	Recommend stroke unit (I, A).	Not included.
Croatian Stroke Society [50]	Not included	Recommend early mobilisation unless intracerebral hypertension is present, to help prevent complications including aspiration pneumonia, DVT, & ulcers (IV).	Not included
European Stroke Organization [51]	Exercise, calcium supplements, & bisphosphonates improve bone strength & decrease post stroke fracture rates. Bisphosphonates for women with previous fractures (II, B).	Early mobilisation is recommended to prevent complications such as aspiration pneumonia, DVT, and pressure ulcers (IV, GCP).	Assessment of falls risk is recommended for every stroke patient (IV, GCP).Vitamin D/calcium for patients at risk of falls (II, B).
Italian SPREAD Collaboration [52]	Not included	Early mobilisation for acute stroke patients, unless clinically contraindicated (C).	Evaluate falls risk on admission and periodically during hospitalisation (C).

Table 2: Continued.

Reference	Keyword* or bone protection included (level of evidence)	Mobilisation and rehabilitation (level of evidence)	Falls prevention (level of evidence)
Japan Stroke Guidelines Committee [53]	Not included	Aggressive rehab can reduce incidence of pneumonia & other complications (B). Stroke unit for acute patients, except sub-arachnoid haemorrhage, lacunar infarction, deep coma, or patients with poor premorbid ADL (A).	Not included
National Collaborating Centre for Chronic Conditions (UK) [54]	Not included	People with acute stroke should be mobilised as soon as possible (when their clinical condition permits) on a specialist stroke unit.	Not included
National Stroke Foundation (Australia) [41]	Not included	Patients should be mobilised as early and as frequently as possible (B). Rehab should provide as much practice as possible within the first 6 months after stroke (A), minimum of one hour active practice per day at least five days a week (GCP).	Falls risk assessment should be undertaken using a valid tool on admission to hospital. Management plans should be initiated for people at risk of falls (GCP). Provide multi factorial community interventions, including individually prescribed exercises for people at falls risk (B).
Norwegian Stroke Guidelines [55]	"Fracture" mentioned twice.	Comprehensive stroke unit for all patients. Multidisciplinary team to contribute to patients' mobilisation out of bed, as early and frequently as possible (B).	Give patients with falls risk multi factorial intervention targeting individual and contextual risk factors, including individually prescribed exercise (C).
Nova Scotia Health [56]	Prevention & management of medical complications including osteoporosis is required in stroke rehabilitation.	All patients with stroke should begin rehab early, once medically stable (1). Patients should be mobilised as early and as frequently as possible (III-3). As much therapy as patients are willing & able to tolerate (A).	All patients should be assessed for fall risk (III-2). Patients at risk of falls should have a management plan formulated and documented in collaboration with the patient and caregiver(s) (III).
Ottawa Panel [57]	Not included	147 recommendations for 13 rehab treatments including gait & exercise.	Balance training is essential in preventing falls
Royal Dutch Society for Physical Therapy [58]	Not included	Starting rehabilitation as soon as possible (within 72 hours of stroke), preferably in a stroke unit, may accelerate & enhance recovery. If possible, mobilise immediately to reduce DVT risk.	It is plausible that the positive effects on postural symmetry & speed of symmetric standing up & sitting down reduce falls while standing up and sitting down.
Scottish Intercollegiate Guidelines Network (SIGN) [59]	Not included	Where safe, every opportunity to increase the intensity of therapy for improving gait should be pursued (B).	Not included
Scottish National Advisory Committee for Stroke [60]	Risks from exercise include cardiac events, falls and fractures.	Community programs: should be mostly aerobic walking, also functional strength & balance exercises. Frequency: 3x per weekDuration: 1 hour per sessionIntensity: moderate if possible	Individuals' history of falls, balance, osteoporosis & psychoactive medications need to be considered in tailoring of exercise interventions..

Table 2: Continued.

Reference	Keyword* or bone protection included (level of evidence)	Mobilisation and rehabilitation (level of evidence)	Falls prevention (level of evidence)
Singapore Ministry of Health [61]	Not included	Early mobilisation for all stroke patients to reduce DVT & pulmonary embolism (D, 2+)	Long-term anticoagulation is contraindicated in elderly patients at high risk of falls.
South African Stroke Society [62]	Not included	Early mobilisation is recommended to prevent complications: aspiration pneumonia, DVT, & pressure ulcers (IV, GCP).	Recommend assessment of falls risk for every stroke patient (IV, GCP). Patient safety & prevention of falls and injury are of paramount importance.
Stroke Foundation of New Zealand [63]	Not included	Early mobilisation for all acute stroke patients to prevent DVT and PE (IV).Rehab should provide as much practice as possible within 6 months of stroke (A), a minimum of 1 hour active rehab per day (IV).	Falls risk assessment should occur on hospital admission, and a management plan initiated (IV).Multifactorial community intervention, including tailored exercises for people at falls risk (B)
Stroke Society of the Philippines [64]	Not included	Major rehab goals for stroke patients are to (1) prevent complications of prolonged inactivity, (2) decrease recurrent stroke and cardiovascular events and (3) increase aerobic fitness.	Stroke survivors are often deconditioned & predisposed to sedentary lifestyle that limits performance of ADLs, increases falls risk, and may contribute to increased risk for recurrent stroke & cardio-vascular disease.
Swedish Stroke Guidelines [65]	Training of balance, safe transfers, and education are important measures to prevent falls and related fractures.	Stroke units are strongly recommended, and mobilisation from early after stroke is of highest importance. Patients should not have unnecessary heart monitoring if it interferes with early mobilisation.	Some evidence supports assessment and prevention of falls for stroke patients, including balance training, patient/ carer information, home hazard reduction, and discontinuation of psychotropic drugs.
UK National Guidelines [66]	Not included	Mobilise people with stroke as soon as their clinical condition permits, on a specialist stroke unit.	Any patient with significant balance impairment should be given intensive progressive balance training.
Veteran's Affairs/Department of Defence (U.S.) [67]	Early mobilisation & paretic limb movement reduces fracture risk (II-1, A). Consider medications to reduce bone loss (II-1, B), including vitamin D (I, B). Consider assessing bone density for patients with osteoporosis who have been mobilised (sic) for 4 weeks.	All patients should be mobilised, as soon as possible, for prevention of DVT.	Not included

*Keyword: bone, fracture or osteoporosis, ADL: activity of daily living, DVT: deep vein thrombosis, GCP: Good clinical practice, PE: pulmonary embolism. Class A–D and levels I–V; see appendices for classifications of levels of evidence.

3.2. Physical Activity for the Prevention of Bone Loss in Adults with Stroke. Three systematic reviews of controlled trials which investigated the use of physical activity as an intervention against poststroke bone loss were identified [1, 27, 35], and these reviews described three controlled trials. One trial [42, 69] investigated people who were approximately 5 years after stroke. This study found beneficial effects on tibial bone architecture, and maintenance of paretic hip BMD, as a result of a 19-week exercise intervention. Marsden et al. [1] reported that although the study was level "A" evidence due to its being a randomised trial, the sample size was small ($n = 63$) and was biased toward a younger male population. Marsden et al. [1] concluded "*...early mobilization may reduce bone loss and avoid fracture, but evidence is needed...,*" *which reflects the conclusion of Myint et al. [27] "Further work is necessary to evaluate early physiotherapy and exercise interventions in acute stroke patients....*" Two further trials which included chronic stroke patients were identified by Borschmann et al. [35]. One was a low-quality trial [70] which found no effect on upper limb BMD with an intervention of ball squeezing for a duration of one-to-three years. The other trial [71] observed a small positive on enhancing tibial bone cortical thickness with six months of twice weekly body-weight supported treadmill training. Borschmann et al. concluded that although the number of studies was limited, results demonstrated a small effect of physical activity in maintaining or improving bone density and bone structure on the paretic side in chronic stroke patients. Quality studies are required to investigate the effect of targeted physical activity interventions to minimize bone loss after stroke.

3.3. International Recommendations Regarding Bone Protection after Stroke. Twenty-five international stroke management guidelines were identified [41, 43–60, 62, 64–67, 72]. Seven guidelines [43, 51, 55, 56, 60, 65, 67] contained one or more keywords "bone, fracture, or osteoporosis." Almost all guidelines included recommendations for physical activity after stroke, and most contained recommendations for falls prevention. Two guidelines [51, 67] contained comments regarding the use of physical activity for bone protection after stroke, one [67] which contained a chapter regarding poststroke osteoporosis.

The European Stroke Organisation's stroke management guideline [51] contained the statement "*Exercise, calcium supplements, and bisphosphonates improve bone strength and decrease fracture rates in stroke patients...*" However, the supporting reference [73] did not provide evidence for the use of exercise to improve bone strength or decrease fracture rates. The US Veteran's Affairs guideline [48] contained a chapter on osteoporosis after stroke, including the recommendation "*Early mobilization and movement of the paretic limbs will reduce the risk of bone fracture after stroke....*" Three supporting references were supplied for this recommendation. Two references were the literature reviews previously described [1, 27], and the third reference was a narrative review by Beaupre and Lew [74] which included 18 longitudinal or cross-sectional studies which investigated bone density changes after stroke. Beaupre et al [74] reported that "*...it is beginning to be recognized that improvements in performing the activities of daily living...will also benefit the patient by helping to preserve bone mass and thereby reducing the risk of hip fracture...,*" in reference to a drug trial by Ikai et al. [75]. In the control group of this trial, people who had higher activity of daily living (ADL) function were observed to experience less bone loss over three months, compared to people who had lower ADL. Although the trial did not use an intervention based on ADL training, Ikai et al. concluded "*ADL is related to the progression of osteoporosis for women with hemiplegia and that increasing the level of ADL (will) lead to decrease the progression of osteoporosis ....*"

4. Discussion

Despite well-documented bone loss, increased fracture risk, and poor outcomes after fracture in people with stroke [19, 77], only seven of the 25 international stroke management guidelines identified in this search contained a keyword "bone, fracture, or osteoporosis." Many of the guidelines provided information on falls prevention, which is likely to reduce fracture rate, and the use of pharmacological bone protection was advocated. Targetted exercise appears to enhance site-specific bone architecture in healthy postmenopausal women, and there is limited evidence to support the use of physical activity to enhance bone mineralisation and architecture in chronic stroke patients. If physical activity from early after stroke can prevent bone loss, then current recommendations for early mobilisation may provide skeletal benefits. However, the safety of early mobilisation is still being investigated. Recommendations should take this into consideration, given their potential to change practice.

Although more research is required, it appears that physical activity has the capacity to maintain or improve bone-related outcomes in both the healthy and stroke adult populations. Healthy adults have an approximate annual bone loss of 1%. Healthy adult participants without reported activity limitations, who were included in the trials reported in this paper, were observed to have enhanced BMD when the intervention duration was at least a year. Moreover, exercise appears to positively influence site-specific bone geometry in postmenopausal women, with the most prominent changes in response to high-impact loading exercise. In contrast, in the trials which included people with chronic stroke who were able to walk at least 10 m, and who had potentially lost 15% of BMD in the first year after stroke, small effect sizes were observed in hip BMD, with just 23 weeks of physical activity intervention. It is possible that in people with higher rates of bone loss (stroke patients compared to healthy adults), a shorter duration of intervention is required to observe the effects of interventions. However, it is not clear whether these skeletal improvements (bone mineralisation and bone geometry) reduce fracture risk.

Coupled with bone fragility, falls are an important component of fracture risk for people with stroke [27]. De Kam et al. (2009) reported that exercise for people with low BMD or osteoporosis should include weight-bearing,

Table 3: Principles of exercise to maximise bone adaptation.

Exercise principle	More effective	Less effective
Weight bearing	(i) High impact (jogging, jumping) (ii) Bursts of activity (iii) Rapid movement	(i) Low impact (walking) (ii) Sustained activity (iii) Slow movement (iv) Non-weight-bearing aerobic (swimming or cycling) does not enhance bone density
Resistance training	(i) Heavy weight (ii) Rapid lifting (power training)	(i) Light weight (ii) Slow lift (traditional resistance training)
Muscle groups	(i) Target muscle connected to bones at risk of osteoporotic fracture (hip, wrist, spine)	(i) Non-specific-muscle groups
Length of training	(i) Short bouts interspersed with rest breaks	(i) Continuous movement
Direction of force	(i) Novel force patterns (change in direction or height of jumps)	(i) Repetitive force patterns (jogging in one direction, consistent height jumps)

Adapted from http://www.osteoporosis.org.au/images/stories/documents/internal/oa_exercise_gphp.pdf.

Table 4: Levels of evidence for intervention studies.

Level of evidence	Type of evidence
1++	High-quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias.
1+	Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias.
1−	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias.*
2++	High-quality systematic reviews of case-control or cohort studies. High-quality case-control or cohort studies with a very low risk of confounding, bias orchance and a high probability that the relationship is causal.
2+	Well-conducted case-control or cohort studies with a low risk of confounding, bias orChance, and a moderate probability that the relationship is causal.
2−	Case control or cohort studies with a high risk of confounding, bias or chance, and asignificant risk that the relationship is not causal.*
3	Nonanalytic studies (e.g., case reports and case series).
4	Expert opinion, formal consensus.

* Studies with a level of evidence "–" are not used as a basis for making a recommendation.
RCT, randomised controlled trial.
National Institute for Health and Clinical Excellence, *The guidelines manual 2007*, ed. NICE. 2007, London [76].

balance, and strength training to reduce falls and fracture risk. Most stroke management guidelines identified in this review recommended falls risk assessment and individualised management for all stroke patients. Level A evidence was presented in the guidelines to recommend mobility training for people with stroke who have difficulty walking [41] and individually tailored exercise programs for community-based falls prevention [44, 48]. Multifactorial falls prevention programs were recommended within the hospital environment, but supporting evidence for this was low [41, 59].

Until further research into poststroke bone loss is undertaken to guide the ongoing development of recommendations for protection of bone, it would be prudent to incorporate principles of bone adaptation into individually tailored stroke rehabilitation programs. Individual tailoring of programs for people with stroke should consider falls risk, mobility, potential low bone mass, ability to follow commands, and other stroke impairments. High impact exercises may not be practical or safe for people with stroke impairments and possible osteoporosis, but any weight-bearing activity provides greater loading on bone than bed rest. Guidelines for healthy adults [36] report that although there is a lack of evidence regarding the optimal prescription of exercise to prevent fracture, evidence-based principles of exercise to maximise bone adaptation have been developed (Table 3).

The body of literature regarding the use of exercise to modulate bone loss in adults demonstrates the large international interest in this important area of research. However, there are many gaps in the literature regarding the skeletal effect of physical activity, particularly in the stroke population. Only three intervention trials [42, 69, 71] which investigated the skeletal effects of physical activity in people with stroke were reported in any of the 25 international stroke guidelines and 12 systematic reviews identified in this review. There is an urgent need to develop the international research agenda regarding bone loss after stroke, in order to reduce fracture risk and its devastating outcomes after stroke.

Table 5: Gradings of recommendations.

Grade	Description
Level A	Body of evidence can be trusted to guide practice
Level B	Body of evidence can be trusted to guide practice in most situations
Level C	Body of evidence provides some support for recommendations(s), but care should be taken in its application
Level D	Body of evidence is weak, and recommendation must be applied with caution
Good clinical practice (GCP) points	Recommended best practice based on clinical experience and expert opinion

National Health and Medical Research Council, *NHMRC additional levels of evidence and grades for recommendations for developers of guidelines*. 2008–2010 [78].

5. Conclusion

Weight-bearing exercise and avoidance of bed rest have the potential to prevent bone loss after stroke. Bone loss appears to be rapid after stroke, but evidence regarding the timing and magnitude of bone loss is required, in order to determine the most beneficial timing of interventions. High-quality studies of over two year's duration, with adequate sample sizes and consistent outcome measurement, are required to determine whether targeted skeletal loading exercise, mobilisation, and avoidance of bed rest, from early after stroke are able to reduce bone loss and fracture risk. This information will support the ongoing development of international stroke management guidelines to guide rehabilitation practice and improve outcomes for people with stroke.

Appendices

A.

For more details, see Table 4.

B.

For more details, see Table 5.

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Research Article

The Course of Fatigue during the First 18 Months after First-Ever Stroke: A Longitudinal Study

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Background. Little is known about the course of poststroke fatigue. *Objectives*. To describe the course of poststroke fatigue in relation to the patient's level of physical functioning, depressive symptoms, and self-reported history of prestroke fatigue. *Methods*. A longitudinal study using structured face-to-face interviews, questionnaires, and patients' medical records. Data were collected from 95 patients in Norway with first-ever stroke. Fatigue was measured with the Fatigue Severity Scale 7 item version and assessed for change between the acute phase, six, 12, and 18 months after stroke using 2-way ANOVA repeated-measures analyses. *Results*. The patients' level of fatigue did not change over time. However, those who reported prestroke fatigue showed a relatively high level of fatigue over time in the poststroke period, while patients with no history of pre-stroke fatigue showed a stable course of relatively low fatigue over time. *Conclusion*. Studies on poststroke fatigue should control for the patient's pre-stroke fatigue level.

1. Introduction

Fatigue is one of the most common complaints after stroke [1, 2]. Despite this, little is known about the development of poststroke fatigue, its development over time and how this development is related to other clinical factors. A few longitudinal studies have been conducted, but to our knowledge, no longitudinal studies have considered that patients with poststroke fatigue may have experienced fatigue for a long time before stroke. In fact, epidemiological studies report that approximately 20–25% of the general population experience current fatigue [3, 4]. A relationship between prestroke fatigue and poststroke fatigue has previously been reported in a cross-sectional study [5] 15 months after stroke (mean time after stroke) and in a study of stroke patients in the acute phase [6]. Thus, prestroke fatigue may confound the clinical covariates associated with poststroke fatigue reported in previous studies.

Fatigue can be defined as a sense of exhaustion, lack of perceived energy, or tiredness [7, 8] distinct from sadness or weakness [7]. Because of the subjective character of fatigue and the fact that no objective signs of the condition have been identified, self-report is seen as the most valid way to assess fatigue [9]. Although fatigue is understood as multidimensional with mental, physical, and motivational aspects [8], the Fatigue Severity Scale (FSS) is a one-dimensional self-report measure frequently used to assess fatigue in stroke populations [9].

In a previous published review of poststroke studies [9], poststroke fatigue was more common among women [10–12] and in those reporting a history of fatigue prior to their stroke [5]. Furthermore, poststroke fatigue was related to higher levels of depression [5, 13–19], sleep disturbance [5, 17], and dependency [5, 17, 18]. Some researchers have also observed a significant relationship between a patient's

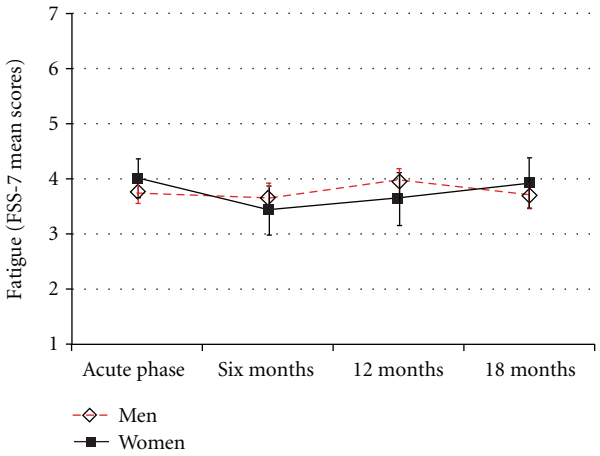
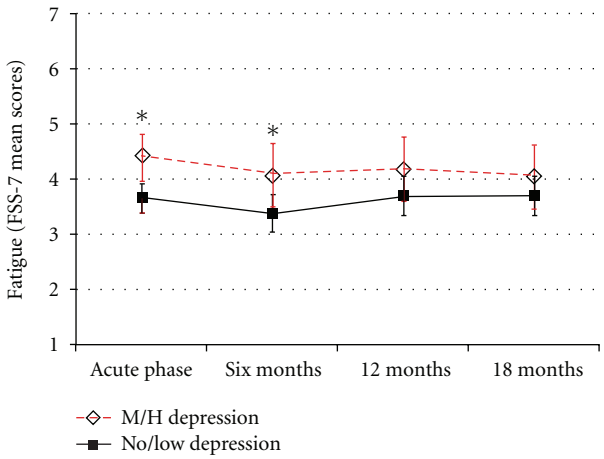
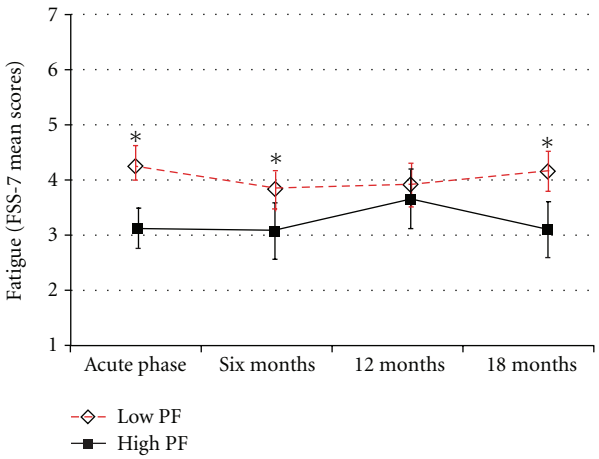


Figure 1: Time course for fatigue among men ($n = 56$) and women ($n = 39$). Adjusted for level of physical functioning, depressive symptoms, and prestroke fatigue. Bars are lower and upper 95% CI.



* Significant differences ($P < 0.05$) in the FSS-7scores between the groups at this time point shown in multivariate linear regression analyses.
*Note: M/H depression = BDI score > 13.

Figure 2: Time course for fatigue by patients with low depression scores ($n = 68$) versus those with medium-high depression scores ($n = 26$). Adjusted for level of physical functioning and prestroke fatigue. Bars are lower and upper 95% CI.



* Significant differences ($P < 0.05$) in the FSS-7scores between the groups at this time point shown in multivariate linear regression analyses.

Figure 3: Time course for fatigue by patients with low physical functioning (PF) ($n = 61$) versus those with high PF ($n = 33$). Adjusted for level of depression and prestroke fatigue. Bars are lower and upper 95% CI.

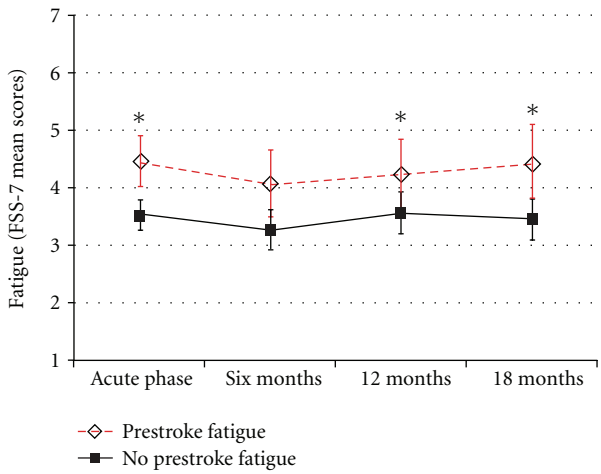
fatigue and neurological impairment [5, 18] while others have not [16, 17].

In a cross-sectional sample of stroke patients in the acute phase [6], we previously reported a higher proportion of cases of severe fatigue among women than among men, and that poststroke fatigue was related to current depressive symptoms, lower physical functioning in patients, and self-report history of prestroke fatigue. This paper reports on the findings from an 18 month follow-up of the participants of the cross-sectional study.

Based on previous findings, the aims of this study were to (1) describe the course of fatigue from the acute phase through six, 12, and 18 months in patients with first-ever stroke and (2) explore the time course related to the patient's level of physical functioning, depressive symptoms, and retrospective self-report of prestroke fatigue.

2. Methods

2.1. Participants and Procedures. Participants were recruited to a longitudinal poststroke fatigue study between March 2007 and September 2008 at a hospital in the southeastern region of Norway, and between September 2007 and June 2008 at a university hospital in Oslo. Upon admission to the hospital, patients with a clinical diagnosis of first-ever stroke were recruited for the study. Data were collected from medical records and in standardized interviews by three trained interviewers using validated questionnaires. When the patients were recruited to the study, they were informed that one of their significant others could be present during the interviews, but this occurred in very few cases. To ease the study participant burden in the acute phase, the interviews were conducted at two different times within 48 hours. Data on health-related quality of life (HRQoL) and fatigue were collected during the first interview, while data on sleep quality and depression were obtained during the second interview. At six, 12, and 18 months, data were collected by means of the same questionnaires used in the acute phase. Interviews in the acute phase were usually performed in the hospital, either in the patients room if they were alone or in a secluded room onsite. At the follow-up times, most participants were visited in their homes by one of the interviewers. For those who were working or travelling abroad at the time of the follow-up data collection, the questionnaires were sent by mail and returned in a sealed envelope. Inclusion criteria for the study were that the patients had a first-ever clinical presentation of stroke



* Significant differences ($P < 0.05$) in the FSS-7 scores between the groups at this time point shown in multivariate linear regression analyses.

Figure 4: Time course for fatigue by patients with no prestroke fatigue ($n = 69$) and those with prestroke fatigue ($n = 26$). Adjusted for level of physical functioning and depressive symptoms. Bars are lower and upper 95% CI.

defined according to the ICD-10 (I 60, 61, 62, 63, and 64) [20] were 18 years or older and had adequate cognitive functioning to allow participation. Patients who were fully conscious or were somnolent but could be awakened to full consciousness (equivalent to a score of 4 or 6 on item number 1 in the Scandinavian Stroke Scale [SSS]) [21] and oriented for time, place, and person (equivalent to a score of 4 on item number 6 in the SSS) were eligible. At one hospital, those who did not meet the criteria for cognitive functioning were further assessed with the MiniMental State Examination (MMSE). Those with an MMSE score ≤10 and those with an MMSE score between 11 and 23, but who were found cognitively incompetent by a physician or a nurse, were excluded. At the second hospital, patients who did not meet the SSS criteria were clinically assessed by the stroke team. Patients who were found to be cognitively impaired were excluded from participation.

In addition, patients who were assessed by the recruiting nurses to be unable to communicate (participate in a meaningful conversation with an interviewer or point to the response alternatives on questionnaires) were excluded. Of the 193 patients with a diagnosis of first-ever stroke, 14 were excluded because of poor cognitive functioning, 26 were excluded because of stroke-related difficulty in communicating, and one was excluded because of an inability to understand Norwegian. Of the 152 patients eligible to participate, 125 patients consented (82%) and 6 died or were transferred to hospitals in other regions before collection of the first set of data, resulting in the final sample of 119 patients. Data from 4 of the 119 patients were collected later than 15 days after admission and were excluded from analysis for acute phase findings. The study sample from the acute phase is described in detail in a previous report [6]. During the follow-up visits, 8 participants were excluded due to death, 3 had other serious illnesses, and 4 did not wish to participate in further data collection. Five more participants were excluded for other reasons: three did not respond when they were contacted by the research team at the follow-up times and two were on holiday at the six-month follow-up. Thus, 95 participants had valid responses on the FSS and responded to all the items in the questionnaires at all four time points; these 95 were included in this analysis.

2.2. Measurements

2.2.1. Fatigue. The 9-item FSS is the most commonly used instrument to measure fatigue in stroke patients [9, 13, 22, 23]. It has shown high validity and reliability [24–26]. A recent published review of fatigue measures in people with chronic illness reported that the FSS had the best psychometric properties [27]. Participants are asked to respond to the statements about their fatigue on a 7-point Likert scale ranging from disagree to fully agree [24]. Higher scores indicate higher levels of fatigue. Findings from recent studies in patients with multiple sclerosis [28, 29] or stroke [30] and people living with HIV/AIDS [31] have shown that items number 1 and number 2 of the FSS did not show acceptable goodness-of-fit and should not be included in the FSS mean score. Given this finding, only the last seven of the original nine (FSS-7) items were included in computing the mean score, but scores still range from 1 to 7. Conceptually, the items in FSS-7 refer to fatigue interference with daily function [30]. Internal consistency of the FSS-7 baseline scores in the present study was adequate (Cronbach's alpha coefficient = 0.86). Mean FSS-7 scores at baseline did not differ by interviewer or by hospital site.

2.2.2. Sociodemographic Variables. Data on age (years), sex, and cohabitation (married/living with a partner) were collected from patients' medical records, while data on the level of formal education (less than 11 years versus 11 years or more) were collected from the questionnaire. Those in paid work or self-employed were categorized as working, while all others (full-time home-makers and those on disability or old-age pensioners) were categorized as not working.

Social class was defined as I (high), II (middle), or III (low) based on the grouping of professions in the international Erikson Goldthorpe Portocare social class schema [31, 32] using the Occupation Classification 2000 [32]. *Social class I* thus comprised high-level professionals, while *Social class II* consisted of midlevel professionals and administrators, and *Social class III* contained employees performing routine manual labour.

2.2.3. Stroke Type and Location. At admission to the hospital, computerized tomography (CT) scans were taken of all patients. Stroke type was categorized based on the radiologist's description as one of the following four groups: (a) ischaemic infarct, (b) haemorrhage, (c) chronic cerebral ischaemia, and (d) negative findings. If an additional CT scan was performed, the most recent description was used for categorizing the stroke. Stroke location was grouped as left,

right, or bilateral. If the CT scan showed signs of lesions from previous undiagnosed strokes, these lesions were included in the classification of stroke.

2.2.4. Stroke-Related Variables

(1) Physical Function and Activities of Daily Living. The level of physical functioning was self-rated using 10 physical functioning items from the *Short Form-36 Acute version (SF-36A)* [33]. The SF-36A is a questionnaire that measures physical and mental issues (one-week recall). Higher scores correspond to better-perceived quality of life. The SF-36 has demonstrated reliability and validity [33, 34] and has been suggested as the preferred instrument to measure disability in stroke patients [35]. Cronbach's alpha for scores in the acute phase of the present study was 0.93. The mean score for physical functioning from the normal population (M = 81.2) [33] was used to categorize patients as either low or high physical functioning.

Functional ability was assessed with the *activities of daily living personal activities (ADL-P)* Barthel Index (BI) [36]. Ten items were scored. The total score can range from 0 (ADL-P dependent) to 20 (ADL-P independent) [37]. The Norwegian version of the BI has demonstrated validity and reliability in stroke patients [38]. Cronbach's alpha for the BI for the scores in the acute phase was 0.92.

(2) Depressive Symptoms. Depressive symptom severity was measured by using the Beck Depression Inventory Version II (BDI-II) [39]. The instrument consists of 21 groups of four statements by severity of the symptom (0–3), where the patient is required to select one in each group. The best possible score is 0. Cronbach's alpha for the BDI-II in the acute phase was 0.85. The BDI-II has been found to be an acceptable screening instrument for depression in stroke patients [40]. A cut-off value of 13 was used to categorize participants in this study as not depressed (BDI $\leq$ 13) or depressed (classified as mild, moderate, or severe) [40].

(3) Other Clinical Characteristics. The patient's weight and height were measured in the hospital. Body mass index was calculated as weight in kilograms divided by the square of the height in meters. The patients' use of sleep medication during the last three days in hospital, their past or present illnesses and medical diagnoses, and the date of hospital admission were collected from their medical records.

(4) Prestroke Fatigue. Prestroke fatigue was measured retrospectively by two items: "did you experience fatigue before you had your stroke" (yes/no), and if yes, "how long did you experience fatigue" (less than a week, less than three months, 3–6 months, and more than six months). Patients who reported fatigue lasting longer than three months before the stroke were defined as having prestroke fatigue.

2.3. Statistical Analysis. Differences between groups were assessed by chi-square (χ^2) for categorical variables or by t-test for continuous variables. One-way and two-way repeated-measures analysis of variance (ANOVA) was used to assess the course of fatigue for the whole sample, for the two groups with low or high physical functioning, for groups with and without depression (BDI-II scores >13 versus those with BDI-II scores $\leq$13) and groups with and without prestroke fatigue lasting more than three months. In the two-way ANOVA analyses, the statistical model controlled for level of physical functioning (continuous variable), for depressive symptoms (continuous variable), and for prestroke fatigue (yes/no). For each time point, the fatigue scores were analysed for possible differences between the groups by a linear regression controlling for similar covariates as in the two-way ANOVA analyses. A Rasch measure of the FSS-7 [30] was used when FSS-7 scores were treated as a continuous variable; the mean scores are presented in the text and figures for ease of interpretation. The level of significance was set at $P < 0.05$ and all tests were two tailed. The data were analysed using SPSS for Windows Version 17.0 (SPSS Inc., Ill, USA).

2.4. Ethics. The study was approved by the Regional Medical Research Ethics Committee of Health East of Norway, the Norwegian Data Inspectorate, and the hospital units for approval of security of personal data. Informed written consent was obtained from all patients.

3. Results

Among the 95 patients in the sample, 56 (59%) were men and 39 (41%) were women. The mean age for the whole cohort was 67.8 years (standard deviation [SD] = 13.3) and did not differ significantly between men (66.0 years [SD = 12.8]) and women (70.4 years [13.0], t = 1.64, P = 0.10). Compared with the women, the men were more likely to have higher education, be in a paired relationship, and belong to a higher social class (see Table 1). Clinical characteristics at baseline are shown in Table 2 for the 95 participants who completed all four time points.

A previous report from the baseline data on the entire sample [6] showed that, except for a higher proportion of circulatory diseases and higher proportion of cases with severe fatigue among women, there were no differences in clinical profiles between men and women. The level of physical functioning at baseline ranged from 0 to 100, and 34.7% (n = 33) had high physical functioning. The depression scores ranged from 0 to 22 and 26 participants (27.4%) were depressed. Twenty-six of the patients (27.4%) retrospectively reported that they had prestroke fatigue lasting more than three months.

3.1. The Course of Fatigue. The mean FSS-7 scores by sex for the different time points are shown in Figure 1. The within-subject analysis showed that the patient's level of fatigue did not vary over time (Wilks' lambda = 0.99, F [3, 87] = 0.38, P = 0.77), and the slope did not differ by sex (F [1, 89] = 0.01, P = 0.96, partial η^2 = 0.04) after adjusting for level of physical functioning and prestroke fatigue. No sex difference in fatigue scores was found when separate analyses

Table 1: Sociodemographic characteristics of the sample at baseline.

Sociodemographic variables	Total sample $N = 95$	Men $n = 56$	Women $n = 39$	Statistics	P
Age, years, mean (SD)	67.8 (13.0)	66.0 (12.79)	70.41 (13.0)	$t = 1.64$	0.10
	N (%)	n (%)	n (%)	χ^2	
Level of formal education				4.78	0.04
<11 years	69 (72.6)	36 (86.4)	33 (84.6)		
≥11 years	26 (27.4)	20 (35.7)	6 (15.4)		
In paired relationship (yes)	65 (68.4)	43 (76.8)	22 (56.4)	4.42	0.05
Work status				1.88	0.23
Working	24 (25.3)	17 (30.4)	7 (17.9)		
Not working	71 (74.7)	39 (69.6)	32 (62.1)		
Social class ($n = 91$)				17.42	0.97
High (class I)	17 (18.7)	13 (24.1)	4 (10.8)		<0.001
Middle (class II)	13 (14.3)	1 (1.9)	12 (32.4)		
Low (class III)	61 (67.0)	40 (74.1)	21 (56.8)		

Table 2: Clinical characteristics at baseline of the study sample ($N = 95$).

Clinical variables	Mean (SD)
SF-36—Physical function (1–100)	61.8 (31.5)
ADL-P (Barthel Index) (1–20) ($n = 87$)	17.9 (3.9)
Depression (BDI-II sum score) ($n = 94$)	9.4 (7.4)
Body mass index ($n = 85$)	26.5 (5.2)
Stroke characteristics	n (%)
Stroke type	
Infarct	74 (77.9)
Haemorrhage	7 (7.4)
Unknown	14 (14.7)
Location ($n = 72$)	
Right	32 (33.7)
Left	26 (27.4)
Bilateral	14 (14.7)
Comorbidity (past or present)	
Prestroke fatigue	26 (27.4)
Endocrine	21 (22.1)
Circulatory	55 (57.9)
Respiratory	12 (12.6)
Digestive	9 (9.5)
Muscular	18 (18.9)
Other disease	38 (40.0)

of fatigue scores for each time point was assessed in separate multivariate linear regression analyses.

The course of fatigue among patients with low versus high scores on depressive symptoms is shown in Figure 2. There was no within-subject change over time (Wilks' lambda = 0.98, $F\ [3, 88] = 0.58$, $P = 0.63$). However, the pa-tients without depression showed less fatigue than those with symptoms of depression ($F\ [1, 88] = 3.81$, $P = 0.05$, partial $\eta^2 = 0.04$) after adjusting for level of physical functioning and prestroke fatigue.

When fatigue was assessed in groups with and without depression by multivariate linear regression analysis, patients without depression reported less fatigue only at the six-month time point ($\beta = 0.19$, $P = 0.05$) compared with the acute phase ($\beta = 0.16$, $P = 0.08$). Results showed a similar trend at 12 months ($\beta = 0.15$, $P = 0.15$), but at 18 months there was no difference between the groups ($\beta = 0.05$, $P = 0.65$).

When the course of fatigue was compared between patients with low and high levels of physical functioning, there was no within-subject change in fatigue over time (Wilks' lambda = 0.94, $F\ [3, 88] = 1.91$, $P = 0.13$), as shown in Figure 3. However, there was a significant between-group difference ($F\ [1, 88] = 10.46$, $P = 0.002$, partial $\eta^2 = 0.10$) after controlling for depressive symptoms and prestroke fatigue. The scores differed significantly in the acute phase ($\beta = 0.39$, $P < 0.001$), at six-month ($\beta = 0.21$, $P = 0.04$) and 18-month ($\beta = 0.22$, $P = 0.04$) follow-up, but not at 12 month follow-up ($\beta = 0.11$, $P = 0.30$).

Mean scores for the course of fatigue among patients with and without prestroke fatigue are shown in Figure 4. Again, fatigue did not show any overall within-subject change over time (Wilks' lambda = 0.92, $F\ [3, 88] = 0.62$, $P = 0.60$). However, the main effect for the between-group comparison was significant, $F\ (1,90) = 10.54$, $P = 0.002$, partial $\eta^2 = 0.105$. The fatigue scores differed in the acute phase ($\beta = 0.27$, $P = 0.01$), and at six months ($\beta = 0.20$, $P = 0.05$) and at 18 months ($\beta = 0.29$, $P = 0.008$), but was not significant at 12 months ($\beta = 0.16$, $P = 0.11$).

4. Discussion

To our knowledge, this is among the first studies describing the course of fatigue in patients with first-ever stroke. Longitudinal studies on poststroke fatigue have mainly reported the prevalence of poststroke fatigue at different time points [13, 41], and findings from previous studies are contradictory. While an increase in prevalence of fatigue during

the 18 months after a stroke has been reported [13], other studies find a lower prevalence [41]. A recently published longitudinal study [42] showed that the proportion of patients with fatigue in the acute poststroke phase (35%, $n = 38$) was similar to the proportion of patients with fatigue 1.5 years later (33%, $n = 36$).

The important new finding from our study is that patients report different trajectories of fatigue depending on their experience of prestroke fatigue and their level of physical functioning in the acute phase. These two clinical factors independently predicted the long-term course of fatigue in our sample.

The relationship between prestroke fatigue and poststroke fatigue has previously been reported in cross-sectional studies [5, 6]. However, a new finding from our study is that patients who reported prestroke fatigue showed a relatively high level of fatigue over time in the poststroke period, while patients with no history of prestroke fatigue showed a stable course of relatively low fatigue over time. When studying poststroke fatigue, it is important to take into consideration that the prevalence of fatigue in the general population is relatively high, and that fatigue measured in the early period after a stroke may not necessarily be caused by the stroke. Studies of the general population have found prevalence rates of current severe fatigue ranging from 14% to 38% [3, 43, 44]. A prevalence of 23% severe fatigue for the general population in Norway was reported using the same instrument (FSS reported) [4].

When the course of fatigue among patients with or without depression was assessed in our study, the differences in fatigue levels observed at the acute phase and at six-month follow-up were not evident 12 months after stroke. Another study [17] showed that depressive symptoms had a tendency to predict fatigue at one year after stroke. However, in that study, depressive symptoms were only borderline significant as a predictor ($P = 0.07$). Direct comparison between these studies is complicated because one of the studies included patients with recurrent stroke [42], while the other study had patients from a rehabilitation clinic [13] where the patients might have more impairment. Although several studies have shown that depression is related to high levels of fatigue [10, 13–15, 23], this association does not seem to be evident from a longitudinal perspective. Difference in fatigue levels in the acute phase between patients with no/low depression versus those with mild/high depression seems to disappear during the period between the acute phase and 18-month follow-up, although the difference in fatigue between patients with and without depression remains at six months after stroke. This would support Kirkevold's proposal [45] that the recovery from stroke occurs in three phases: stabilization, adjusting for the long-term effects of the stroke, and getting on with life. It is possible that both fatigue and depression are common responses to the experiences of the acute phase of stroke, with a positive relationship between them, while poststroke experience in the later stages may have an independent effect on fatigue and depression with no observable relationship.

In the acute phase, we found a higher proportion of women than men with severe fatigue [6], but no significant differences between sexes in mean fatigue. This study showed that mean fatigue did not differ over time in relation to sex. Similar findings are reported in most other studies of poststroke fatigue [5, 15–18, 46]. However, other studies [11, 12] have shown that vitality is inversely associated with fatigue. Because female stroke patients reported lower vitality than men, it is possible that the observed effect of sex on fatigue may need to be examined further in terms of vitality. Further study of the relationship between fatigue and vitality is needed in order to interpret the sex differences in fatigue and vitality and to clarify the concepts of fatigue and vitality.

Our findings indicate that poststroke fatigue has different trajectories over time, depending on the patient's level of physical functioning, level of depressive symptoms, and particularly his/her history of chronic fatigue prior to the stroke. In studies exploring the aetiology and possible antecedents of poststroke fatigue, these factors need to be considered. For example, the aetiology of chronic fatigue might be different from fatigue that develops after stroke, and would require a different intervention approach. Fatigue needs to be studied more intensely in homogeneous groups during poststroke recovery.

Strengths of this study include the low attrition over 18 months and perhaps because of the large number of participants who were interviewed, there were no missing responses on any of the questionnaire items. One limitation with the study is that prestroke fatigue was measured retrospectively. Furthermore, the sample was recruited from only two hospitals in Norway. Although only patients with first-ever clinical presentation of stroke were included in the sample, and none of the participants had a history of clinical stroke, the CT findings showed that nine had signs of previous stroke. People who are interviewed face to face may have a tendency to give more socially acceptable responses than those who respond by means of a questionnaire [47]. A possible consequence of this may be under-reporting of depressive symptoms among those who were interviewed. However, at baseline, fatigue scores did not differ by interviewer.

A systematic review of empirical studies of poststroke fatigue [9] concluded that the fatigue experience should be conceptualized and studied as a multidimensional phenomenon including fatigue intensity, quality, timing, fluctuation, and long-term trajectory. In this study, fatigue was measured using the FSS-7 [30], an abbreviated version of the FSS scale [24]. As mentioned by Dittner et al. [48] and others, FSS is predominantly a measure of fatigue interference with daytime function. Thus, other dimensions of fatigue, such as severity or frequency, may have a different trajectory than the fatigue described in this study.

5. Conclusion

Because patients with and without prestroke fatigue experience a different but stable trajectory of poststroke fatigue, future studies need to control for prestroke fatigue experience to develop knowledge about the aetiology of poststroke

fatigue. Intervention studies should either control for prestroke fatigue experience or consider excluding patients with prestroke fatigue when studying the effect of interventions for poststroke fatigue. A more critical approach would be to partition out, both conceptually and in measurement, the components of fatigue that are generic and the components that are stroke related. It is possible that the presence of prestroke fatigue exacerbates the fatigue response after experiencing a stroke.

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Review Article

Physical Activity in Hospitalised Stroke Patients

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The aim of this paper was to examine the amount and type of physical activity engaged in by people hospitalised after stroke. *Method*. We systematically reviewed the literature for observational studies describing the physical activity of stroke patients. *Results*. Behavioural mapping, video recording and therapist report are used to monitor activity levels in hospitalised stroke patients in the 24 included studies. Most of the patient day is spent inactive (median 48.1%, IQR 39.6%–69.3%), alone (median 53.7%, IQR 44.2%–60.6%) and in their bedroom (median 56.5%, IQR 45.2%–72.5%). Approximately one hour per day is spent in physiotherapy (median 63.2 minutes, IQR 36.0–79.5) and occupational therapy (median 57.0 minutes, IQR 25.1–58.5). Even in formal therapy sessions limited time is spent in moderate to high level physical activity. Low levels of physical activity appear more common in patients within 14 days post-stroke and those admitted to conventional care. *Conclusions*. Physical activity levels are low in hospitalised stroke patients. Improving the description and classification of post stroke physical activity would enhance our ability to pool data across observational studies. The importance of increasing activity levels and the effectiveness of interventions to increase physical activity after stroke need to be tested further.

1. Introduction

The most beneficial time to commence rehabilitation and physical activity after stroke has not yet been established; however improved outcome is associated with earlier initiation of rehabilitation [1]. Favourable outcomes have been reported in stroke units where patients are helped to get out of bed within the first 48 hours of admission and continue this frequently until discharge [2, 3], and early start to activity is recommended in many guidelines [4–6]. However, the practice remains controversial [7, 8] and early commencement of physical activity is the subject of clinical trials [9–11]. Increased activity in the first six months after stroke has been found to improve functional outcome [12], but once again the optimal dose of physical activity necessary to aid recovery after stroke is unclear.

Physical activity is defined here as any bodily action produced by the skeletal muscles requiring more energy expenditure than at rest and therefore can include low level tasks such as actively maintaining sitting posture in a chair. However the effect of increasing therapy is enhanced if it involves the practice of higher level, functional activities such as standing and walking [1, 13].

Given the growing interest in promoting physical activity after stroke apparent within the literature and in clinical guidelines [4–6], it is important to understand what activity patients already undertake following their stroke, both throughout the day and during therapy time. The purpose of this paper was to examine common methods of monitoring activity in hospitalised stroke patients and summarise the amount and type of physical activity undertaken by stroke patients managed in a range of hospital settings. We were also interested in where patients were most active and who was with them during activity.

2. Methods

2.1. Literature Search. A search of the EMBASE, Medline, PubMed, AMED, and CINAHL databases was carried out up until the end of October 2010 to ascertain observational studies investigating the amount and type of physical activity in hospitalised stroke patients. The search was restricted

to observational studies as this is a common method of activity monitoring used in clinical practice. Although we were interested in publications investigating physical activity early after stroke (within 14 days), any study conducted in a hospital-based setting, at any time point in the care continuum, could be included. Combinations of the following search terms were used to locate potentially relevant studies: stroke, physical activity, mobilisation, rehabilitation, inpatient, hospital, early, acute, observation, observational study. Further literature was sourced from scans of the reference lists of selected publications. Potential studies were determined from review of the title and abstract.

2.2. Selection of Literature. Studies selected for inclusion in the review were prospective observational studies which employed methods such as behavioural mapping, therapist report, or video recording to determine the amount and type of physical activity undertaken by the stroke patients. Patients could be admitted to any inpatient service that managed stroke patients, including general medical wards, aged care units, neurology wards, mixed rehabilitation wards, and stroke units (acute, comprehensive, or rehabilitation).

Publications were included in the review if they described the physical activity undertaken either throughout the entire day or, alternatively, during formal therapy time alone. Publications in which only the amount of total therapy time and not the type of activity undertaken was reported were excluded.

2.3. Data Extraction and Analysis. The type of activity reported from each study was categorised as either general patient activity or therapy-specific activity. For studies that reported general patient activity we extracted data regarding patient activity undertaken throughout the day. For studies that investigated therapy-specific activity only we extracted data on the patient's activity during formal therapy sessions only. As the focus of this paper was on physical activity, only records from physiotherapy and occupational therapy sessions were obtained for the therapy-specific data, since these disciplines are known to concentrate more on physical function.

Data extracted from the included publications regarding the type of activity undertaken by stroke patients was grouped under four categories reflecting the physical demands of the activity.

(i) *Nil physical activity*: sleeping and other nontherapeutic activities while resting in bed including passive recreation such as reading, watching TV, talking, and eating.

(ii) *Low physical activity*: including sitting supported out of bed and self-care.

(iii) *Moderate physical activity*: including sitting unsupported and transferring without hoist equipment.

(iv) *High physical activity*: including activities involving standing and walking.

The amount of time spent in different types of activities was extracted and calculated as a proportion of total observation time for each individual study. For the general patient activity studies the locations in which these activities took place and the people present when they occurred was also extracted and expressed as a proportion of observation time. In the therapy-specific activity studies we determined the minutes of therapy per session and minutes of therapy per day. Wherever possible we extracted information about the study settings, patient characteristics, and study methods and procedures. To summarise data across studies we calculated medians and 25th and 75th percentiles (IQR).

We further categorised studies into hospital setting (general rehabilitation, stroke units, or conventional care) and time of observation (<14 days). General rehabilitation units were defined as units which provided only rehabilitation (not acute care) for both stroke and nonstroke diagnoses. This included mixed rehabilitation wards that accepted both neurological and nonneurological conditions.

Stroke unit care was defined as a geographically discrete unit which only admitted stroke patients. This included stroke rehabilitation wards for patients transferred from acute care usually at least one to two weeks poststroke, acute stroke wards which provided only acute care for patients usually within one to two weeks poststroke, and comprehensive stroke wards which combined both acute care and rehabilitation.

Conventional care units included any acute service which admitted both stroke and nonstroke diagnoses. This included general medical wards which could admit a range of medical conditions, elderly care units which specifically admitted elderly patients with various medical conditions, or general neurology wards which admitted patients with a range of neurological diagnoses.

Again, data were summarised across studies and medians and 25th and 75th percentiles (IQR) are reported. Statistical comparison between settings was not suitable as insufficient data were available to adequately adjust for important factors that may influence activity such as stroke severity.

3. Results

Forty-one potentially relevant studies were identified from a review of the title and abstract. Seventeen of these studies were excluded, eight of which did not provide sufficient information about the type of activity [14–21], five reported data already reported in another included publication [1, 22–25], two reported the frequency of different types of activities but not the total amount of time [26, 27], one study was a retrospective study [28], and one study included both stroke and other neurological diagnoses in the same data set [29].

Of the 24 included publications patient activity was observed throughout the day in 15 studies [30–44], and patient activity was observed in therapy sessions only in 10 studies [32, 45–53], with one publication examining patient activity during both the whole day and in therapy time alone [32]. All included studies reported the proportion of time spent in activities of interest across the whole

Table 1: General patient activity studies.

Study	Patients	Organisation of care categories	Behavioural mapping procedure for individual patients
Bear-Lehman et al. [30][a]	Rehabilitation inpatients	SU	8 am–4 pm, every 30 mins, for 1 weekday and 1 weekend day
Bernhardt et al. [31]	Acute (<14 d) inpatients	SU (<14 d)	8 am–5 pm, every 10 mins, for 2 consecutive weekdays
Bernhardt et al. [32][b]	Acute (<14 d) inpatients	SU (<14 d)	8 am–5 pm, every 10 mins, for 1 weekday
De Weerdt et al. [33][c]	Rehabilitation inpatients	SU	8.30 am–5.10 pm, every 10 mins, for 1 weekday
De Weerdt et al. [34]	Rehabilitation inpatients	SU	8.30 am–5.10 pm, every 10 mins, for 2 weekdays in 1st observation period, 1 weekday in 2nd period
De Wit et al. [35][d]	Rehabilitation inpatients	SU	7 am–12 pm or 12 pm–5 pm or 5 pm–10 pm, every 10 mins, for 1 weekday
Esmonde et al. [36]	Rehabilitation inpatients	SU	9 am–5 pm, average every 10.8 mins, for 4–9 weekdays
Keith [37]	Rehabilitation inpatients	SU	8.15 am–16.15 am every 30 mins, for 5 consecutive weekdays
Keith and Cowell [38]	Rehabilitation inpatients	SU, GRU	8.30 am–4.30 pm, every 8 mins, for 2 weekdays
Lincoln et al. [39]	Rehabilitation inpatients	SU	8.30 am–4.30 pm, average every 30 mins, for 3 consecutive days
Lincoln et al. [40]	Rehabilitation Inpatients	SU, CCU	6 am–2 pm or 8.30 am–4.30pm or 2 pm–10 pm, ~ every 10 mins, for 3 days
Mackey et al. [41][e]	Rehabilitation inpatients	GRU	7 am–7 pm, every 10 mins, for 3-4 weekdays and both weekend days
Pound et al. [42]	Inpatients	SU, CCU	7.30 am–3.30 pm or 9.30 am–5.30 pm or 2.30 pm–10.30 pm, ~ every 20 mins, for 1 weekday
Tinson [43][e]	Inpatients	CCU	9 am–1 pm or 1 pm–5 pm, every 30 mins, for 4 weekdays, plus 9 am–5 pm, every 30 mins, for 1 weekend day
Wellwood et al. [44]	Acute (<14 d) inpatients	SU, CCU (<14 d)	8 am–5 pm, every 10 mins, for 1 weekday

[a]Data for stroke patients only, excludes weekend data; [b]data for Trondheim patients only; [c]data for Switzerland patients only; [d]excludes 5 pm–10 pm data; [e]excludes weekend data; GRU: general rehabilitation unit (includes mixed rehabilitation units); SU: stroke unit (includes acute stroke units, comprehensive stroke units and stroke rehabilitation units); CCU: conventional care unit (includes general medical wards, elderly care units and general neurology wards); <14 d—all patients observed within 14 days of stroke.

study population. Few studies reported standard error or deviations preventing meta-analysis of these studies.

3.1. General Patient Activity

3.1.1. Activity Monitoring Method. All 15 of the included studies which examined patient activity throughout the day used a behavioural mapping method (structured observation) to determine patient activity (Table 1). Ten of the studies reported good interrater reliability with the behavioural mapping method [30, 31, 33–36, 38, 42, 44]. The remaining studies did not report reliability, and no studies tested the validity of behavioural mapping.

The behavioural mapping procedures varied across studies (Table 1). Days of observation ranged from 1 to 9 days (median 2 days). The time across which mapping was carried out on observation days ranged from 4 to 12 hours each day (median 8 hours) and the frequency of observations ranged from every 8 to 60 mins (median 10 minutes). Most studies focused on a normal working day, with observations taking place on weekdays, commencing between 8 am and 9 am and finishing between 4 pm and 5.30 pm. However four studies included weekday mapping outside the normal working day hours [35, 40–42]. Three studies also included mapping on weekends [30, 41, 43] but for the purpose of the current

paper weekend data were excluded where possible in order to allow a more accurate comparison of data across studies.

3.1.2. Participants Monitored. All study participants were hospitalised and in most studies only stroke patients were examined. One study compared hospitalised stroke patients with other neurological and nonneurological diagnoses [30]; however only the data for the stroke patients were included in the current paper.

The reported average or median age of the patients varied significantly across the studies, ranging from 52 to 80 years. Most of the studies had broad inclusion criteria, suggesting representative patient samples. Comparison of patient severity across the studies was difficult as a large range of measures were used to describe the impairment or disability of the monitored group. These included the National Institute of Health Stroke Scale (NIHSS), the Barthel Index, and the Functional Independence Measure (FIM). Most studies appeared to include patients from across the spectrum of stroke severity. In two studies patients needed to have a specified minimum impairment level to be included, thereby excluding very mild patients [35, 43]. In two studies very severe patients with low function, decreased consciousness, or ongoing acute medical issues were excluded [40, 43].

The majority of studies investigated patients who were in the "rehabilitation phase" of their admission. The concept of a "rehabilitation phase" was not well defined across studies; therefore for the purpose of the current paper it was presupposed to imply that the patients were considered to be medically stable, not requiring acute medical intervention, and the primary purpose of ongoing hospitalisation was rehabilitation. The exact days after stroke at the time of observation were only reported in five studies [31, 32, 34, 36, 39]. The remainder investigated activity in patients who were assumed to be between several weeks to several months following stroke. Three studies specifically focused on acute patients within 14 days of their stroke [31, 32, 44]. Two included studies may have investigated both acute and rehabilitation patients; however insufficient information was provided to confirm patient acuity [42, 43].

3.1.3. Care Settings. In 85% of the studies physical activity monitoring was conducted in a stroke unit setting. This was usually a stroke rehabilitation unit, but acute and comprehensive stroke unit settings were described in a small number of publications [31, 32, 44]. Some studies also investigated physical activity in mixed rehabilitation units, general medical wards, elderly care units, and general neurology wards.

In 12 of the included publications activity monitoring was conducted on several groups of patients who were grouped based on diagnosis, the period of observation, the site where the unit was based, the organisation of care, or the structure of the unit. The data for each separate group are presented in Table 2. Where the same patient group was analysed in another included study these data are reported only once. Where the group did not include stroke patients these data were excluded leaving a total of 35 patient groups ($n = 639$) across the 15 included publications.

Table 2: Included studies showing number of included patients and reason for grouping.

Study	Patient group	*n*
Bear-Lehman et al. [30]	Stroke patients	7
Bernhardt et al. [31]	Full sample	58
Bernhardt et al. [32]	Trondheim unit	37
De Weerdt et al. [33]	Swiss unit	8
De Weerdt et al. [34][1]	1st observation period	22
De Weerdt et al. [34][2]	2nd observation period	16
De Wit et al. [35][A]	Belgium unit	40
De Wit et al. [35][B]	United Kingdom unit	40
De Wit et al. [35][C]	Switzerland unit	40
De Wit et al. [35][D]	German unit	40
Esmonde et al. [36]	Full Sample	17
Keith [37][1]	1st observation period	24
Keith [37][2]	2nd observation period	23
Keith & Cowell [38][A]	Unit A	22
Keith & Cowell [38][B]	Unit B	21
Keith & Cowell [38][C]	Unit C	20
Lincoln et al. [39][1]	1st observation period	15
Lincoln et al. [39][2]	2nd observation period	15
Lincoln et al. [40][A]	Stroke unit	39
Lincoln et al. [40][B]	Conventional Care Unit	37
Mackey et al. [41][A]	Unit A	8
Mackey et al. [41][B]	Unit B	8
Pound et al. [42][A]	Stroke Unit	12
Pound et al. [42][B]	Elderly Care Unit	12
Pound et al. [42][C]	General Medical Ward	12
Tinson [43]	Full sample	15
Wellwood et al. [44][A]	United Kingdom unit	8
Wellwood et al. [44][B]	France unit	8
Wellwood et al. [44][C]	Lithuania unit	8
Wellwood et al. [44][D]	Russia unit	7

[1,2] denote different time periods of observation; [A,B,C,D] denote different locations.

3.1.4. Physical Activity. The activity of interest varied across studies; for example, some authors were interested only in the time patients spent inactive [30], while others were interested in the time patients spent engaged in moderate to high activity only [37]. Classification of the type of activity also varied across the included studies. In cases where activity over the entire observation period was not reported, or where observation points were missing due to patients moving away from the ward, we have grouped these together under the category "unobserved or unreported". In many studies it was not possible to distinguish between moderate and high level activities according to our predetermined categories. However, in all cases it was clear that the activities *at least* met the moderate category; therefore we elected to combine moderate and high level activities into the one category (moderate-high activity) for reporting purposes. We included participation in formal therapy and self-practice

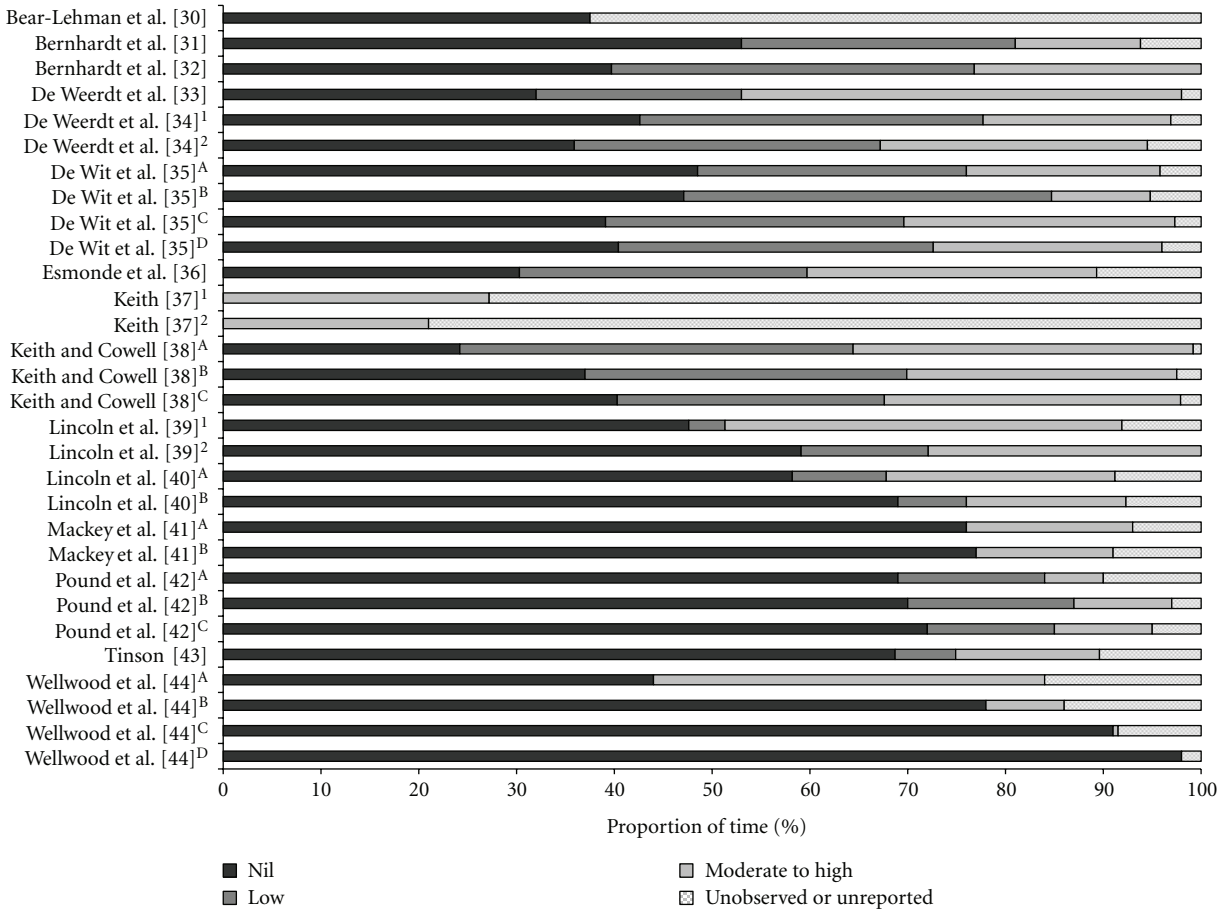

Figure 1: Physical activity across the day. 1 and 2 denote different time periods of observation; A, B, C, and D denote different hospital locations.

of therapy exercises in this moderate to high level activity category.

The proportion of time patients spent in the specified activity categories (nil, low, moderate-high) from each study is summarised in Figure 1. Patients were inactive or involved in nontherapeutic activity (nil activity) for between 24.2% and 98.0% of the day, with a median of 48.1% of the day spent inactive (IQR 39.6% to 69.3%). In comparison much less time tended to be spent in low physical activity (median 27.5%, IQR 13.0% to 32.2%) and even less still in moderate to high physical activity (median 21.0%, IQR 12.8% to 27.7%).

3.1.5. People Present. The proportion of time patients spent alone was reported for 14 of the 15 behavioural mapping studies. On average, patients were alone for approximately 50% of each observed day (median 53.7%, IQR 44.2%–60.6%) (Figure 2). However time spent alone was lower for two patient groups that took part in group therapy as part of their rehabilitation (17.0% [33] and 24.2% [34]).

Reporting of people present throughout the patient day varied across studies. For example, in some cases each profession was reported separately, such as nursing or physiotherapy; in other cases all therapists were grouped under the classification of "therapists". At times all staff were grouped together. We elected to group time with any staff member together under the heading "all treating staff". Using this classification, treating staff may include nurses, therapists, doctors, psychologists, social workers, and any other health professionals. As not every health professional was represented in the data reports (e.g., four studies reported only time spent with therapists and nursing staff [32–34, 42]) the time spent with "all treating staff" in these studies is likely to be an underestimate. While time spent with treating staff ranged from 9.2% to 45.0% across studies, patients spent a median of 24.0% of the day (IQR 17.3%–31.1%) with a member of the clinical team.

Little time was spent with visitors (median 11.0%, IQR 9.7%–13.1%), apart from three patient groups which spent approximately one quarter of the day with visitors. This included two patient groups admitted to stroke units (23% [42] and 27% [44]) and one patient group admitted to a conventional care unit (25% [44]). Little time was also spent with other patients across studies (median 5.3%, IQR 3.6%–8.9%). However time spent with other patients was much greater for two patient groups which both took part in group therapy as part of their rehabilitation (24.0% [33] and 32.2% [34]).

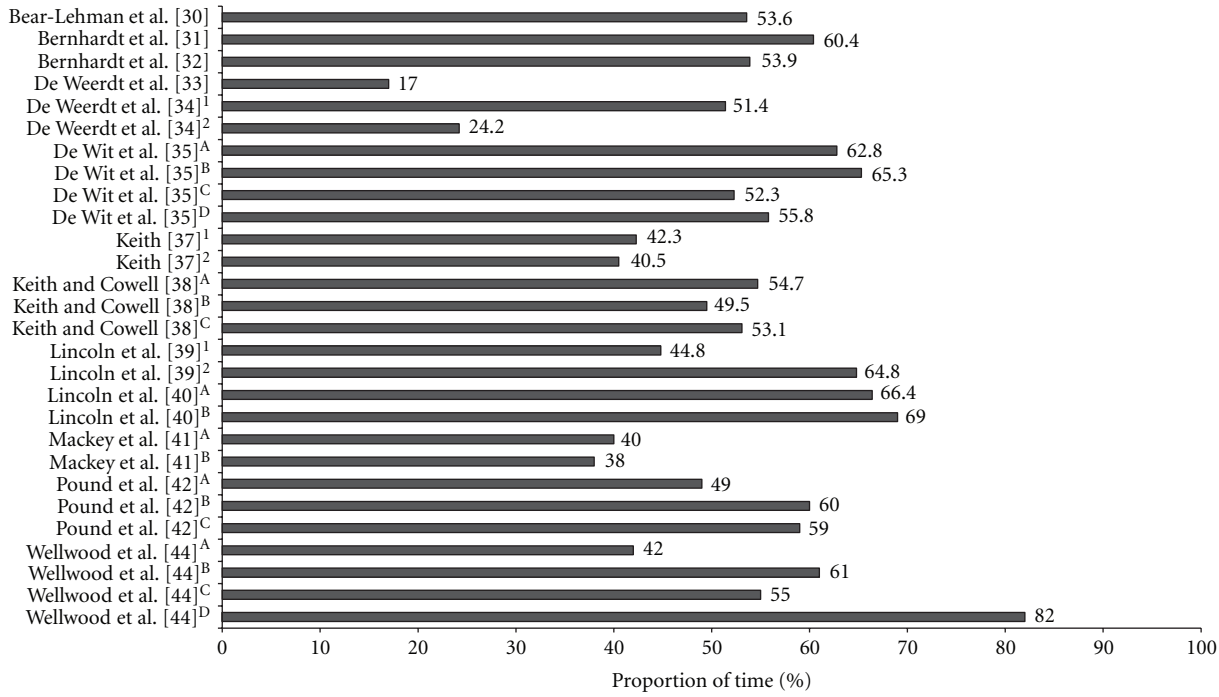

Figure 2: Proportion of time spent alone. 1 and 2 denote different time periods of observation; A, B, C, and D denote different hospital locations.

3.1.6. Patient Location. Discrepancies in the classification of patient location again made summarising data difficult. One study included time spent in lounge and dining areas with time spent in the bedroom [41], and a number of studies reported different groupings of locations such as bathrooms, corridors, lounge areas, and dining rooms. As illustrated in Figure 3 most studies reported that patients spent a substantial proportion of the day in their bedroom (median 56.5%, IQR 45.2%–72.5%). Very little time was spent in therapy areas (median 6.4%, IQR 3.4%–14.7%). However in a number of studies it was reported that therapy often took place in other areas such as the bedroom, hallway, lounge, or off the ward [32, 37, 39].

3.1.7. Organisation of Care and Time after Stroke. Variation in activity, time alone and with others, and location when data were grouped across the different patient settings and from an early time post stroke are presented in Figure 4. Patients within 14 days of their stroke and those managed in conventional care wards appear to spend a greater proportion of the day inactive (median 65.5%, IQR 46.3% to 87.8% and median 71.0%, IQR 69.3% to 86.3%, resp.). They also appear to spend a greater proportion of time alone (median 57.7%, IQR 54.2% to 60.9% and median 60.0%, IQR 59.0% to 69.0%, resp.). Patients admitted to conventional care appeared to spend less time with treating staff (median 15.0%, IQR 15.0% to 22.0%) than those admitted to stroke units or general rehabilitation (Figure 2). There did not appear to be any differences in time spent with staff based on the acuity of stroke. Patients observed within 14 days after stroke appeared to spend the most time by their bedside (median 82.1%, IQR 78.8% to 85.3%). They were also less frequently observed in therapy areas (Figure 4). The two studies that included details of the time patients within 14 days after stroke spent in therapy areas reported figures of only 0.2% [31] and 3.9% [32] of the day. Patients admitted under stroke unit care appeared to spend the least amount of time bedside (median 49.1%, IQR 35.2% to 62.9%). Patients admitted to general rehabilitation units appeared to spend the most time in the therapy area (median 12.5%, IQR 11.8%–13.3%).

3.2. Therapy Specific Activity

3.2.1. Activity Monitoring Methods. Ten studies were identified which examined the physical activity undertaken by patients specifically during therapy time (Table 3). Various methods of observation were used to determine patient activity including behavioural mapping, therapist report, and video recording. The number of therapy sessions observed also varied across studies, ranging from single sessions to all sessions across the length of admission. High interrater reliability was reported for the behavioural mapping method in two publications [32, 46]. Reliability was not reported in the remaining behavioural mapping studies, and there were no reports of the validation of mapping procedures. Video recording was also reported to have good interrater reliability in two studies [48, 51] and good intrarater reliability in another study [49], but again validity was not tested. The reliability of the therapist report method was not reported in any publication; however two studies reported that validity had been previously established for this method [32, 46].

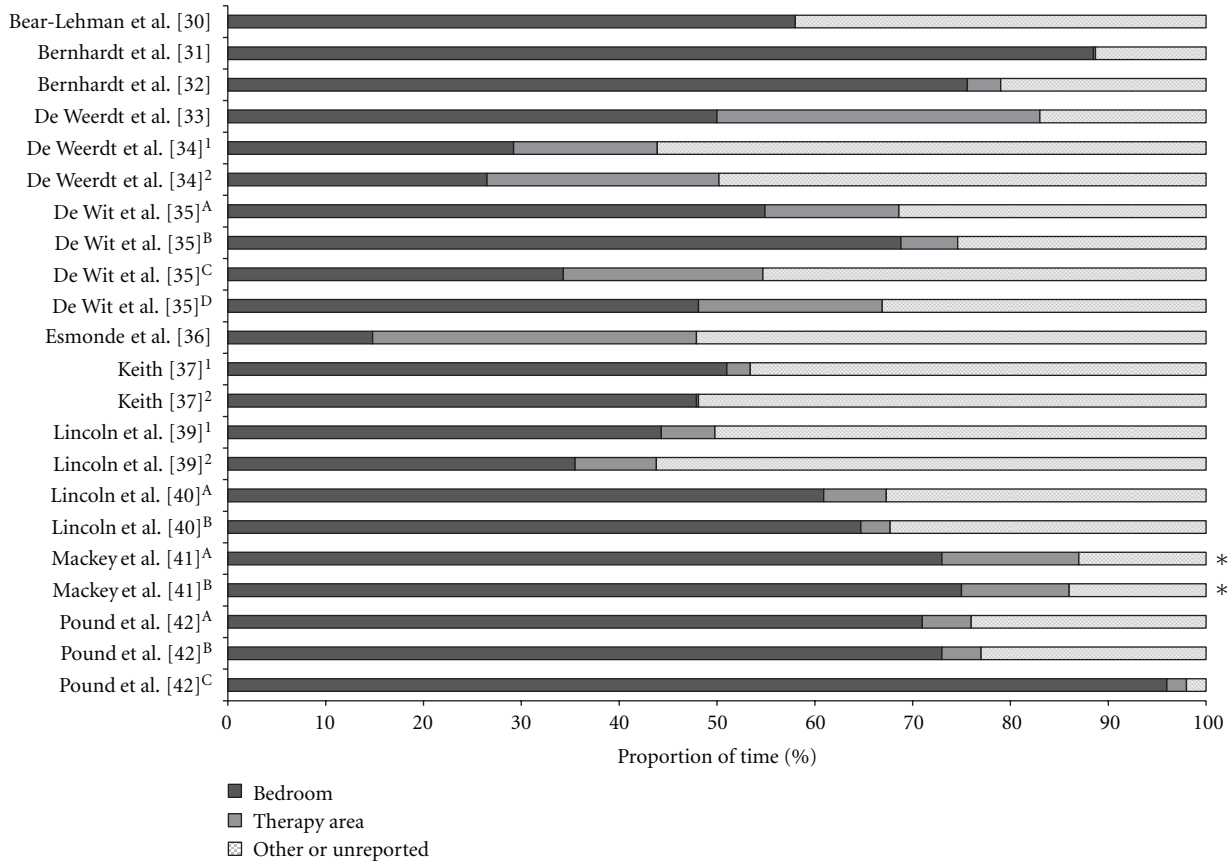

Figure 3: Patient location. 1 and 2 denote different time periods of observation; A, B, C, and D denote different hospital locations; *bedside time includes time in lounge and dining areas.

3.2.2. Participants Monitored. Patients were in the "rehabilitation phase" of their stroke recovery in the majority of studies; however once again this concept was not well defined across publications, and the exact time following stroke at the commencement of observation could only be determined from five studies [32, 46, 47, 51, 53]. All studies examining rehabilitation patients were carried out in either mixed rehabilitation units or stroke rehabilitation units. Two studies examined acute stroke patients (within 14 days after stroke) in either acute or comprehensive stroke unit settings [32, 46].

The average ages of patients across the therapy-specific studies ranged from 62.7 to 76.5 years. Stroke severity was again difficult to compare across studies due to the variety of impairment measures used. One study only reported data for less severe strokes during the second week of admission to rehabilitation [47] and in another study patients were excluded if they were unable to walk at least 14 meters with minimal assistance [49], thereby limiting the data to milder strokes for these two studies. In contrast De Wit et al. [48] excluded patients with a low level of motor impairment, thereby excluding the less severe strokes.

3.2.3. Therapy Settings. Five studies examined activity during both occupational therapy and physiotherapy sessions, four studies examined physiotherapy sessions alone, and one study investigated only occupational therapy sessions (Table 3). For the purpose of the current paper, occupational therapy and physiotherapy data are presented separately for each study, with the exception of one study [45] where only pooled therapy data was available (Table 4). Data from individual therapy sessions and from group therapy sessions are also presented separately for one study [49]. Four studies compared different patient groups based on the site where the unit was based or the total length of rehabilitation admission. Where available, the data for each group is presented separately in the current paper however patient groups were excluded where the same group was analysed in a previous study. Sample sizes for each data subset varied from 11 to 972 across the included studies.

3.2.4. Therapy Intensity. From the data available in each publication therapy intensity was determined in terms of minutes of therapy per session or minutes of therapy per day (Table 4). In all but one study this was determined separately for occupational therapy or physiotherapy. Median session time was 40.6 (IQR 31.4–45.7) minutes for physiotherapy and 35.8 (IQR 29.8–38.7) minutes for occupational therapy. Patients in the acute phase of stroke tended to have shorter therapy sessions [32, 46] (Table 4). Daily therapy time showed considerable variation for physiotherapy (median 63.2 minutes, IQR 36.0–79.5) and occupational therapy

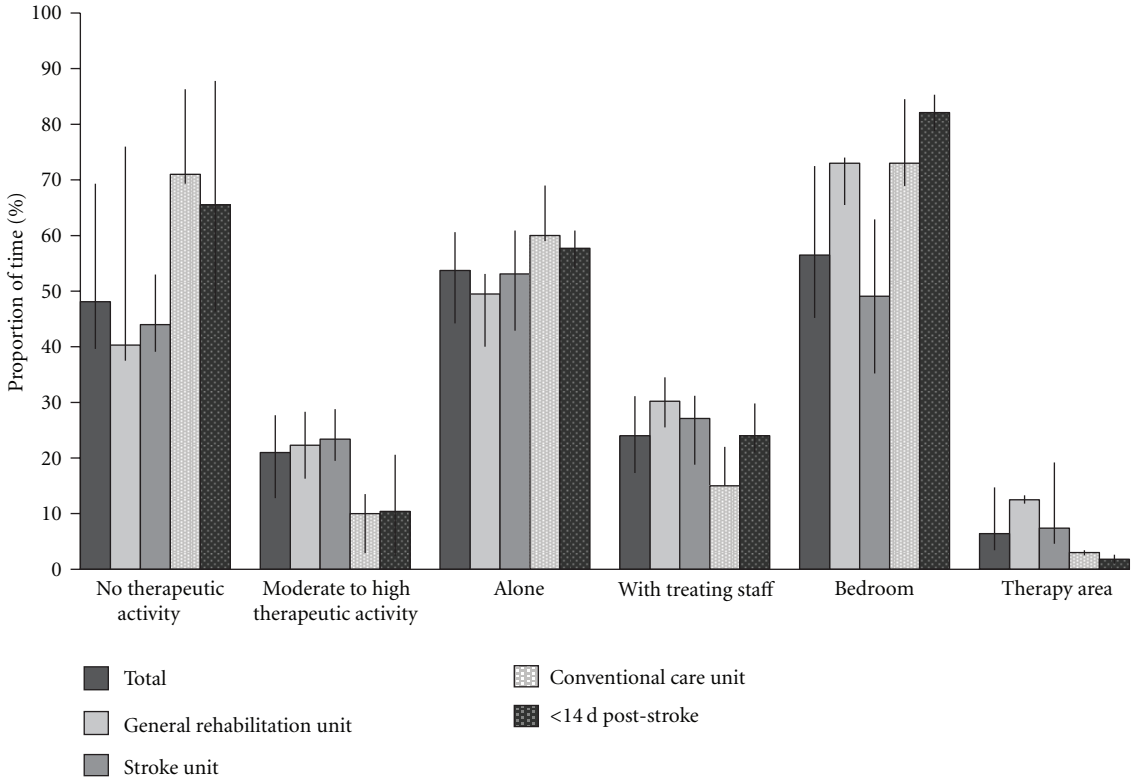

Figure 4: Patient activity, people present, and location according to organisation of care and time after stroke. median and IQR.

(median 57.0 minutes, IQR 25.1–58.5). This variation existed even across the acute stroke patients alone, with one study of acute strokes reporting a daily therapy time of only 18.1 minutes of physiotherapy and 10.7 minutes of occupational therapy [46] compared to another study reporting 57.4 minutes per day of physiotherapy [32].

3.2.5. Therapy Activity. The type of physical activity undertaken by stroke patients during therapy time was grouped in the same activity categories as for general patient activity. Although data were incomplete in some publications and there were differences in the classification of the type of activity across the included studies, in general it was possible to extract and classify activity into nil, low and moderate-high categories.

Figure 5 illustrates the proportion of time spent in the different activity levels from each study. Although the majority of reported activity in therapy time was in the low and moderate to high categories, in four studies patients were still inactive for more than 20% of therapy time [45, 46, 49, 51]. This included one study where patients were recorded as having nil physical activity for 58% of the therapy session [45]. A greater proportion of time appears to be spent in moderate to high physical activity during physiotherapy sessions compared to occupational therapy sessions.

Only one study focused on patients within 14 days of their stroke, and the proportion of moderate to high physical activity undertaken during therapy time from this study did not appear to be very different from the other studies [46].

3.2.6. Upper Limb Therapy. In six of the included publications the proportion of therapy time specifically spent treating the upper limb (Figure 6) was reported. Upper limb treatment time accounted for a median of 16.0% of therapy time (IQR 6.9%–22.9%).

4. Discussion

This paper has identified a range of methods applied across a number of hospital settings to monitor physical activity after stroke. Behavioural mapping, using structured observation at regular intervals throughout the day, was commonly employed in these studies and is reported to be reliable. In order to capture "typical" patient activity, all studies carried out mapping during the "usual working day" when patients are most active. In some studies patients were also mapped on weekends and after hours. Observations were most frequently carried out every 10 minutes, suggesting that this time frame was considered frequent enough to minimise missed activity, but not so frequent that observations were no longer feasible. Behavioural mapping was also used to monitor therapy specific activities; however as observations only occur on an intermittent basis, video recording and therapist report were also used and may provide a more accurate means of evaluating physical activity during formal therapy time.

Despite the similarity in activity monitoring procedures, there was large variation across publications in the way in which activity was categorised. Classification of the locations

Table 3: Therapy-specific activity studies.

Study	Method	Procedure	Therapy	Patient type	Organisation of care	*n*
Ada et al. [45]	Behavioural mapping	Every 10 mins for all sessions across 3-4 weekdays	PT and OT	Rehabilitation inpatients	GRU	16
Bernhardt et al. [46]	Behavioural mapping and therapist report	Mapping every 10 mins plus therapist report, for all sessions across 2 weekdays	PT and OT	Acute inpatients	SU	58
Bernhardt et al. [32][a]	Behavioural mapping and therapist report	Mapping every 10 mins plus therapist report, for all sessions over 1 weekday	PT	Acute inpatients	SU	37
Bode et al. [47][b]	Therapist report	All therapy sessions across admission recorded, but data only reported for 2nd week	PT and OT	Rehabilitation inpatients	GRU	101
De Wit et al. [48]	Video recording	Single OT and single PT session	PT and OT	Rehabilitation inpatients	SU	60
Elson et al. [49]	Video recording	Single individual session and single group session	PT	Rehabilitation inpatients	GRU	15
Jette et al. [50]	Therapist report	All therapy sessions across admission	PT	Rehabilitation inpatients	GRU	972
Kuys et al. [51]	Video recording and heart rate monitoring	Single session	PT	Rehabilitation inpatients and outpatients	GRU	30
Latham et al. [52]	Therapist report	All therapy sessions across admission	OT	Rehabilitation inpatient	GRU	954
McNaughton et al. [53][c]	Therapist report	All therapy sessions across admission	PT and OT	Rehabilitation inpatient	GRU	130

[a]Data for Trondheim patients only; [b]data for less impaired patients only, during second week of inpatient rehabilitation admission; [c]data for New Zealand patients only; GRU: general rehabilitation unit (includes mixed rehabilitation units); SU: stroke unit (includes acute stroke units, comprehensive stroke units and stroke rehabilitation units); OT: occupational therapy; PT: physiotherapy.

in which activity took place, as well as the people with whom it took place also varied across studies. This variation made comparison of patient activity across studies difficult and required us to make a number of assumptions when extracting data. Recreation, relaxation, and leisure activities were classified as nontherapeutic in terms of physical activity since recreation was commonly described as including activities such as reading, watching TV, watching others, and social interaction [42, 43]. Furthermore, patients were assumed to be in sitting when being transported or involved in self-care, which is commonly the case, and were therefore classified in the low activity category. Formal therapy and self-exercise described in five of the general activity studies [33–38] was classified in the moderate to high level activity category, since the majority of therapy time was spent with physiotherapists and occupational therapists who focus largely on physical function. However, data from the therapy-specific studies suggests that a considerable amount of therapy may have taken place with the patient involved in low or even no physical activity. It is not surprising that a proportion of therapy time is spent with patients inactive (during rest) or engaged in low levels of physical activity. The assumption that all 'formal therapy and self-exercise' was at a moderate to high level is likely to have resulted in a small overestimate of overall activity across the day. Within the therapy-specific studies in which therapy content was often reported, we classified impairment-focused therapy such as stretching, passive movements, selective movement facilitation, strengthening, and balance work as low physical activity and therapy described only as functional activity as moderate to high physical activity. This seems a very reasonable approach to classification of activity within therapy in the face of poor definition; nevertheless, it is also possible that the classification assumptions led to over-*or* underestimation of patient activity.

The use of assumptions to help summarise available data is not ideal. It became apparent early in the conduct of this paper that there is an urgent need for researchers to provide clear description of the activities observed, or better still, for the development and use of a standard classification system for physical activity categories for people after stroke. Such a system should probably be based to a larger extent on how hard the patients must work to engage in different levels of activity and include energy expenditure expressed as METS. However, while such a classification system exists in healthy subjects [54], further research on the energy expenditure of people with stroke during activity at different stages in recovery is needed. Until then, activity classification, particularly of observed activity, will continue to rely on clinical judgment.

Table 4: Therapy activity patient groups and therapy intensity.

Study	Therapy	Patient group	Setting	n	Minutes per session	Minutes per day
Ada et al. [45]	PT and OT	Full sample	Rehabilitation	16		64.0
Bernhardt et al. [46]—PT	PT	Full sample	Acute	58	24.5	18.1
Bernhardt et al. [46]—OT	OT	Full sample	Acute	58	22.8	10.7
Bernhardt et al. [32]	PT	Trondheim	Rehabilitation	37	27.6	57.4
Bode et al. [47]—2 wks PT	PT	2 week admission	Rehabilitation	34		69.0
Bode et al. [47]—3 wks PT		3 week admission	Rehabilitation	27		93.0
Bode et al. [47]—4 wks PT		4 week admission	Rehabilitation	19		93.0
Bode et al. [47]—5 wks PT		5 week admission	Rehabilitation	11		75.0
Bode et al. [47]—2 wks OT	OT	2 week admission	Rehabilitation	34		57.0
Bode et al. [47]—3 wks OT		3 week admission	Rehabilitation	27		57.0
Bode et al. [47]—4 wks OT		4 week admission	Rehabilitation	19		69.0
Bode et al. [47]—5 wks OT		5 week admission	Rehabilitation	11		60.0
De Wit et al. [48]—B, PT	PT	Belgium	Rehabilitation	15	46.0	
De Wit et al. [48]—UK, PT		United Kingdom	Rehabilitation	15	43.0	
De Wit et al. [48]—S, PT		Switzerland	Rehabilitation	15	44.8	
De Wit et al. [48]—G, PT		Germany	Rehabilitation	15	33.0	
De Wit et al. [48]—B, OT	OT	Belgium	Rehabilitation	15	36.4	
De Wit et al. [48]—UK, OT		United Kingdom	Rehabilitation	15	35.2	
De Wit et al. [48]—S, OT		Switzerland	Rehabilitation	15	40.4	
De Wit et al. [48]—G, OT		Germany	Rehabilitation	15	28.0	
Elson et al. [49]—indiv PT	PT	Individual therapy	Rehabilitation	15	30.9	
Elson et al. [49]—group PT		Group therapy	Rehabilitation	15	52.7	
Jette et al. [50]	PT	Full sample	Rehabilitation	972	51.6	
Kuys et al. [51]	PT	Full sample	Rehabilitation	30	39.4	39.4
Latham et al. [52]	OT	Full sample	Rehabilitation	954	38.1	41.9
McNaughton et al. [53]—PT	PT	New Zealand	Rehabilitation	130		15.3
McNaughton et al. [53]—OT	OT	New Zealand	Rehabilitation	130		6.9

OT: occupational therapy, PT: physiotherapy.

Regardless of these limitations some consistent trends in patient activity were revealed across the studies reviewed. A large proportion of stroke inpatient time is spent inactive or involved in nontherapeutic activity. Comparatively little time appears spent involved in moderate to high level physical activities such as standing and walking. Additionally hospitalised stroke patients tend to spend most of their time alone and in their bedroom area. Although few studies investigated patients in the acute phase of their stroke, it appears that this lack of activity and isolation are especially prevalent for patients within 14 days of stroke compared to those at later stages of recovery. The current paper suggests that hospitalised stroke patients are involved in an average of approximately one hour per day of formal physiotherapy and one hour per day of formal occupational therapy. Even during this time it was reported in a number of studies that patients were involved in little or no physical activity for part of the session. Patients frequently spent less than half their therapy time involved in moderate to high physical activities such as standing and walking, and even less time was spent on therapy for the upper limb.

It appears that patient activity may be influenced by the organisation of care. Patients admitted to conventional care units such as general medical wards, elderly care units, or general neurology wards appeared to be inactive, alone, and in their bedroom area for longer than patients admitted to stroke units or general rehabilitation units. Patients admitted to stroke units appeared to spend the most time involved in moderate to high physical activity and the least time located in bedside areas when compared with patients admitted to conventional care or general rehabilitation. These apparent differences however may be simply due to case-mix variation across the different samples studied. Further comparison across settings could provide insights into the barriers or facilitators to activity in different organisational settings. However this would require standard data to be available from each study to allow for adjustment for important patient and setting factors that may influence activity. The absence of even a common measure of stroke severity across studies hampered further exploration of these data.

Patients did appear to be more active during formal therapy time, and it is tempting to suggest that increasing the time spent in formal therapy may help to increase physical activity in hospitalised stroke patients. Group therapy may be one approach to increasing formal therapy time. Patients participating in group therapy were found to be involved in more formal therapy and more physical activity [33, 34, 37, 49] and to spend less time alone [33, 34]; however

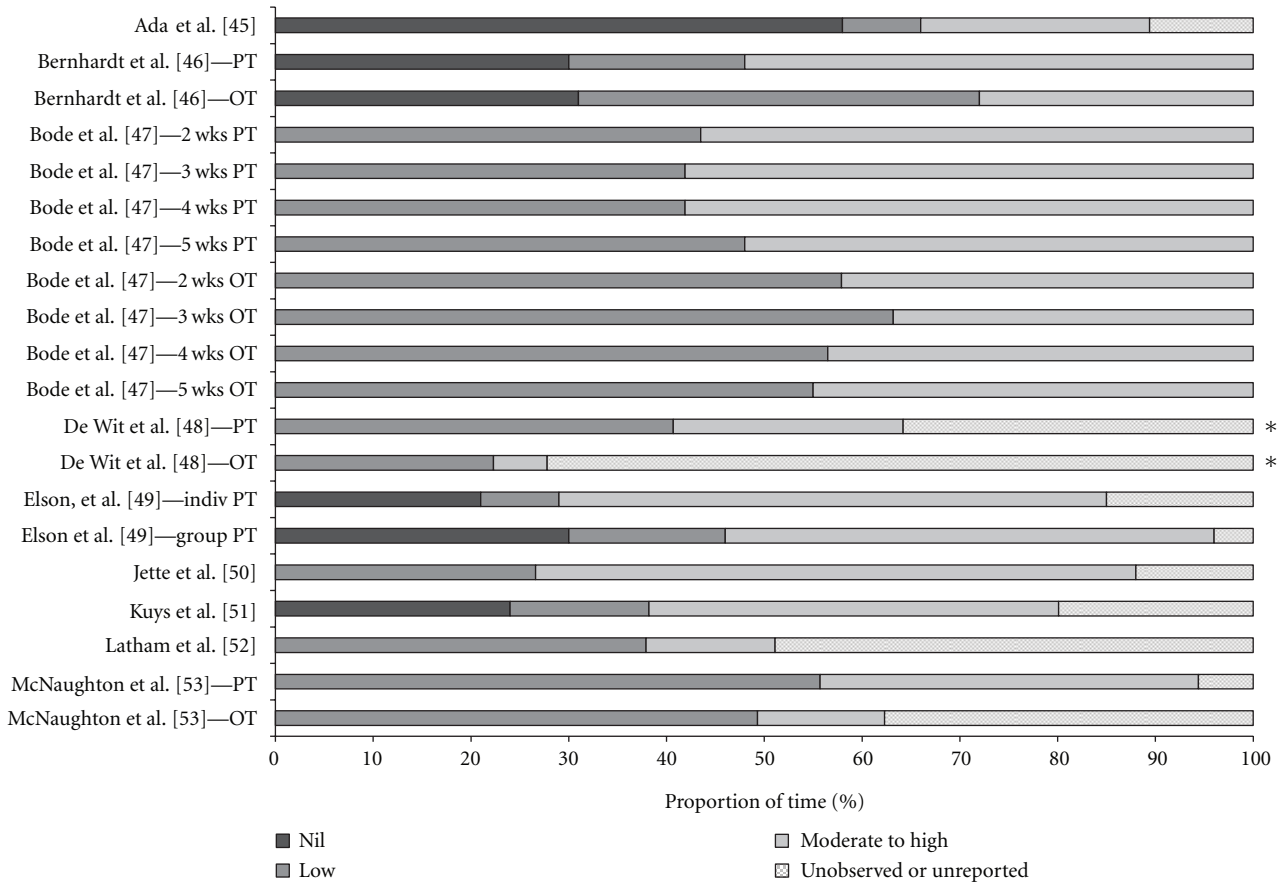

Figure 5: Therapy activity. *Data pooled across sites by authors of original study.

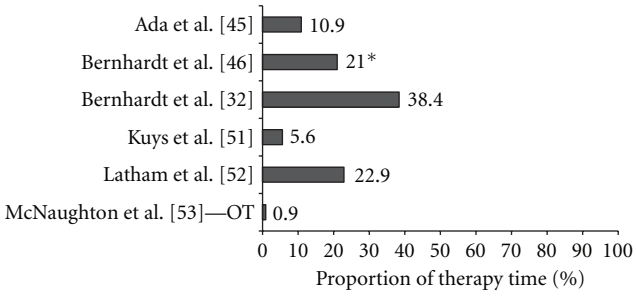

Figure 6: Upper limb therapy. *Affected upper limb use across physiotherapy, occupational therapy, and speech therapy time.

the proportion of time spent in high level activities such as walking was reported to be lower during group therapy than in individual sessions [49]. More structured therapy sessions with a formal schedule were also suggested as a means of increasing therapy time [35, 37]; however Mackey et al. [41] found that this made no difference to overall patient activity. In reality, we do not know the optimal dose or intensity of activity that stroke patients should engage in during the hospitalised phase of their care to help their recovery. Nevertheless, the low levels of physical activity commonly found in these studies suggest that more could be done. Increasing formal therapy time is only one way in which physical activity could be improved. Greater involvement of nontherapy staff, particularly nursing staff, in facilitating patient activity may help to increase physical activity in hospitalised stroke patients [32, 43]. This may be promoted through the education and training of nontherapy staff in facilitating patient activity [32, 40] and through therapists working together with other staff [32].

The current paper found that a median of less than one quarter of patient time was spent with treating staff. A number of authors suggest that increasing self-directed patient activity could be another means of increasing physical activity [29, 30, 33, 39, 40, 43]. Greater self-directed activity may be encouraged with patient education and instruction in self-directed exercises [30, 35] and activity diaries [29, 43]. Environmental modifications to promote self-directed activity are recommended [32, 35–38]. In addition greater family involvement [29, 33, 36, 40, 43] and the introduction of an activities coordinator [29, 39] are also suggested to assist with self-directed activity.

5. Conclusions

Physical activity is commonly monitored in hospitalised stroke patients using behavioural mapping which is easy to

conduct and which provides a rich source of data across a day. The use of accelerometers, step counters, and other devices is becoming more frequent and may provide more accurate monitoring of activity after stroke, although their reliability, accuracy in very low functioning patients, ease of use, and the comfort of patients when wearing the device need to be considered. Unlike accelerometers, observation also provides the researcher with information about the location of patients when they are active and who was with them during the activity. This paper has shown however that considerable improvements to how activity is described and classified would greatly improve our ability to compare activity across populations, settings, or time points in the recovery pathway. This paper has highlighted that many patients are inactive and alone while in hospital, and while we have summarised suggestions as to how patient activity can be increased, the importance of improving activity levels and the effectiveness of interventions to increase physical activity after stroke need to be tested further.

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Clinical Study

Effects of Walking Endurance Reduction on Gait Stability in Patients with Stroke

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Control of gait is usually altered following stroke, and it may be further compromised by overexertion and fatigue. This study aims to quantitatively assess patients' gait stability during six-minute walking, measuring upper body accelerations of twenty patients with stroke (64 ± 13 years old) and ten age-matched healthy subjects (63 ± 10 years old). Healthy subjects showed a steady gait in terms of speed and accelerations over the six minutes. Conversely, the patients unable to complete the test ($n = 8$) progressively reduced their walking speed ($-22 \pm 11\%$, confidence interval $CI_{95\%}$: -13, -29%, $P = 0.046$). Patients able to complete the test ($n = 12$) did not vary their walking speed over time ($P = 0.493$). However, this ability was not supported by an adequate capacity to maintain their gait stability, as shown by a progressive increase of their upper body accelerations ($+5 \pm 11\%$, $CI_{95\%}$: -1; $+12\%$, $P = 0.010$). Walking endurance and gait stability should be both quantitatively assessed and carefully improved during the rehabilitation of patients with stroke.

1. Introduction

The recovery of walking ability is one of the most relevant functional targets after a cerebrovascular event, but this goal is generally obtained by only 50–60% of patients [1]. In particular, Paolucci and colleagues showed that at discharge from a rehabilitation hospital about 5% of patients with stroke were independent even in stair climbing and 9% were able to walk outside, 14% to walk inside, and 27% to walk with cane or other aid, while 45% remained in wheelchair [2].

Prolonged walking in living environment is even more challenging than short distances walked in hospital settings. Furthermore, overexertion can be detrimental for physical and mental conditions of people with stroke: for these patients, fatigue prevalence has been estimated to be up to 70% [3, 4]. Fatigue can be defined as a feeling of lack of energy and weariness following a period of exertion, and it is characterized by a decreased capacity of work and reduced efficiency to respond to stimuli [5]. All these factors put the individuals with stroke at great risk of falling during prolonged walking [6]. Despite that the effects of fatigue, induced by extended effortful activity, have been investigated in relationship to spatiotemporal gait parameters [7, 8] and oxygen consumption [5] in people with stroke, far too little attention has been paid to the relationship between walking endurance and gait stability.

Gait dynamic stability could be defined as the capacity to move the body segments in a coordinated fashion so that the body could be displaced with a proper speed (i.e., functional to the required task, such as crossing the road safely) minimizing upper body oscillations [9, 10]. So, gait stability can be suitably assessed by measuring upper body accelerations [9], in terms of their dispersion and smoothness of upper body walking patterns [10–12]. In fact, in an unstable gait, walking speed fluctuates, causing higher accelerations and hence inertial forces and perturbations that need to be controlled.

The aim of this study is to quantify the potential effects of fatigue, induced by effortful walking, on gait dynamic stability of patients with stroke. The hypothesis that we wanted to test was if gait stability is reduced during prolonged walking

in people with subacute stroke. To achieve this goal, we have measured upper body accelerations during the six-minute walking test performed by ambulatory inpatients.

2. Material and Methods

2.1. Participants. Twenty patients with stroke and ten age-matched healthy subjects were enrolled in this study (see Table 1 reporting their demographic and clinical characteristics). The patients were tested the day before their dismissal from a rehabilitation hospital. Exclusion criteria were inability to walk, severe cognitive impairment, medical contraindications to exercise training, other chronic disabling pathologies (such as osteoarthritis and chronic inflammatory rheumatic diseases), orthopedic injuries, and hemispatial neglect. This study was approved by the Local Ethical Committee, and informed consent was obtained from each participant.

2.2. Clinical Assessment. To assess the independency in activities of daily living and the walking ability of our patients, we administered them the Barthel Index (BI) and the Functional Ambulation Classification (FAC), respectively. BI is one of the best known and commonly used scales to assess the degree of independence a patient demonstrates in various activities of daily living, including mobility and transfers (in particular, bowel and bladder function, grooming, toilet use, feeding, transfers, mobility, dressing, climbing stairs, and bathing). Its total score ranges from 0 (total dependence) to 100 (total independence) [13]. FAC is a six-point hierarchical rating scale that reflects the amount of assistance a person requires to walk. This scale allows to easily classify patients in respect of their walking ability, with maximum score identifying a person able to ambulate independently on nonlevel surfaces [14]. The median values (first, third quartiles) of these scales are reported in Table 1.

2.3. Walking Endurance Assessment. The six-minute walking test (6MWT) was used to measure walking endurance, as usually done in clinical settings [6, 8, 15, 16]. Participants were asked to cover the maximum distance in six minutes self-selecting their speed to do it. They were instructed that they could slow down and rest if necessary and then start again to walk. Patients were allowed to use a cane or a walker and/or to perform the test under physiotherapist supervision, if needed (slight contact might have been required at times). All the participants (patients and healthy subjects) were asked to walk with their common shoes for 6 minutes along a 20 m level walkway, from one extreme to another, in the rehabilitation gym of our hospital. They were told about the lasting time at the third and fifth minute of walking [8]. At the end of test, the walked distance was measured. This distance and the distances walked at the end of each one of the six minutes were evaluated using tape strips fixed on the ground every 2.5 m of the walkway. Patients able to walk for 6 minutes were grouped in PG1, whereas patients unable to complete the test were grouped in PG2.

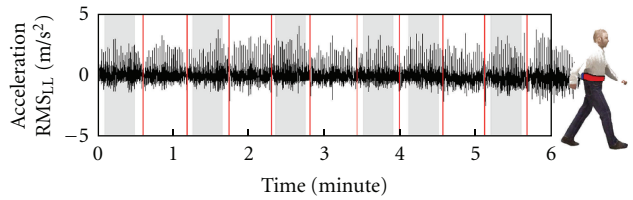

Figure 1: The acceleration signal along laterolateral direction of a patient. The grey large bands highlight the analysed part of the signal for each one of the 6 minutes of the test. The thin red lines indicate the end of each 20 m lap.

2.4. Gait Stability Assessment. During the 6MWT, the participants wore an elastic belt including a light wearable inertial sensor device (FreeSense, Sensorize s.r.l., Rome; sampling frequency = 100 Hz, weight = 93 g) located on their back in correspondence of L2-L3 spinous processes, close to their body centre of mass. This device contains a triaxial accelerometer to separately measure three accelerations, each one along one of the three body axes (anteroposterior AP, laterolateral LL, and craniocaudal CC).

Accelerometer signals were 20 Hz low-pass filtered, transformed to give a mean equal to zero, and summarized in their root mean square (RMS) [10–12]. RMS is a measure of acceleration dispersion and therefore of the smoothness of movement patterns. This makes RMS the parameter most commonly used to assess gait stability by means of accelerometry [9].

For each one of the six minutes of walking, the mean walking speed was computed as the meters walked in that minute divided into 60 s, and the mean RMS was computed on the accelerometric signals recorded in a central part of the linear walking performed in that minute (see Figure 1). Conversely, accelerometric data recorded during the two turning parts of the walkway were not analysed.

2.5. Statistical Analysis. Mean ± standard deviation and 95% confidence interval ($CI_{95\%}$) have been computed for continuous measures and median and 1st and 3rd quartiles for scale scores. Analogously, t-test was used for comparisons between two continuous measures (age, days, height, and body mass index), Mann-Whitney u test for scale scores (BI and FAC), and χ^2 test for binary variables (gender, side of hemiparesis, and types of stroke). The differences between walking speeds recorded at the 1st minute and the 6th minute for each subgroup of participants were assessed by means of paired t-tests.

An analysis of variance (ANOVA) was performed in order to compare the values of walked distance and walking speeds among the three groups (between subjects factor), followed by post hoc comparison performed with Tukey's test (see Table 2).

A repeated measure ANOVA was performed on the RMS values of participants able to complete the test (PG1 and CG) to assess the changes over time (within-factor: 1, 2, 3, 4, 5, and 6 minutes) and the effects of group (between-factor: PG1, CG) and body axis (between-factor: AP, LL, and CC). Conversely, for PG2, in which not all subjects walked for

Table 1: Demographic and clinical characteristics of participants. Mean ± standard deviation (95% confidence interval) or median (first and third quartiles) of demographic characteristics, clinical features and scale scores at the moment of the 6MWT. The fourth and the last columns report the P values obtained by t test for continuous measures, Mann-Whitney u test for BI and FAC, and χ^2 test for side of hemiparesis and types of stroke.

Characteristics	CG (n = 10)	PG (n = 20)	P CG versus PG	PG1 (n = 12)	PG2 (n = 8)	P PG1 versus PG2
Age (years old)	62.8 ± 9.7 (56.8; 68.8)	64.4 ± 13.0 (58.7; 70.1)	0.734	62.7 ± 14.7 (54.4; 70.1)	67.0 ± 10.0 (59.8; 74.2)	0.468
Height (m)	1.68 ± 0.10 (1.61; 1.74)	1.69 ± 0.11 (1.64; 1.74)	0.795	1.69 ± 0.13 (1.62; 1.76)	1.69 ± 0.09 (1.63; 1.75)	0.975
Body mass Index (kg/m^2)	25.5 ± 2.4 (24.0; 27.0)	26.29 ± 4.17 (24.5; 28.1)	0.594	26.86 ± 4.33 (24.4; 29.3)	25.43 ± 4.04 (22.6; 28.2)	0.469
Women	5	6	0.284	4	2	0.690
Men	5	14		8	6	
Time from the event (days)	—	132 ± 103 (86.9; 177.1)	—	101 ± 36 (80.6; 121.4)	180 ± 149 (76.7; 283.3)	0.091
Length of stay (days)	—	92 ± 41 (74.0; 110.0)	—	83 ± 32 (64.9; 101.1)	104 ± 51 (68.7; 139.3)	0.277
Barthel index	—	60 (44; 88)	—	70 (50; 88)	46 (38; 73)	0.341
Functional Ambulation Classification	—	4 (2; 5)	—	4 (3; 5)	3 (2; 4)	0.327
Right	—	12	—	7	5	0.852
Left hemiparesis		8		5	3	
Ischemic	—	18	—	11	7	0.761
haemorrhagic		2		1	1	

the same time, paired t-test was performed to compare the RMS values recorded at the 1st and at the last minute of their test. The linear fit and relevant determination coefficient (R^2) were computed for assessing the relationship between RMSs and time. For all the tests, the significance level was set at 0.05.

3. Results

3.1. Clinical Tests, Gait Speed, and Walking Endurance. Twelve of the twenty patients were able to complete the 6MWT (subgroup PG1) and eight patients asked to definitively stop the test before its planned conclusion (PG2). The clinical characteristics of PG1 and PG2 are summarized in Table 1. No significant clinical differences were found between these two groups, although the clinical picture of PG2 was quite worse (older, lower BI and FAC scores).

In terms of gait performance, a significant difference was observed in terms of walked distance among the three groups (Table 2). Healthy subjects covered a significantly longer distance than that covered by PG1 ($P < 0.001$) and PG2 ($P < 0.001$), and PG1 walked significantly more than PG2 ($P = 0.007$). On the other hand, the mean walking speed, computed over the entire test, was not statistically different between the two groups of patients (but both lower than that of CG, $P < 0.001$). This may be explained by the fact that the higher distance covered by PG1 in respect of PG2 was mainly due to the longer time spent walking (360 s for PG1 versus 245 ± 67 s for PG2). However, the walking speed recorded in the last minute of the test was significantly lower in PG2 than in PG1 (see Table 2). It was due to a speed reduction observed in all the subjects of PG2 between the first and the last minutes of walking (mean: −22 ± 11%; $P = 0.046$, paired t-test). The same analysis performed on PG1 (+1 ± 11%, $P = 0.493$) and CG (−1 ± 7%, $P = 0.537$) did not show any significant change in terms of walking speed over the course of the test.

3.2. Gait Stability Assessment. Despite the reduction of walking speed observed in PG2, their acceleration RMSs were not reduced between the first and the last minutes of the test ($P > 0.05$ for all the three RMSs measured along the three body axes). Conversely, 8 out of 12 patients able to complete the test showed an increase of accelerations at least along 2 body axes between the 1st and the 6th minutes of the test. It resulted in a mean progressive increment of all the RMS values of PG1 (about +5%, significant for RMS_{LL}: +7 ± 11%, $P = 0.048$), not observed in CG (about −1%). Figure 2 clearly shows this mean increment of acceleration in PG1; however 5 out of these 12 patients showed a reduction of their walking speed during the last minute of the test. A repeated measure ANOVA performed on all the participants who walked for all the 6 minutes (PG1 and CG) showed that the interaction between time and group significantly affected the RMS values ($F = 3.082$, $P = 0.010$), whereas neither the main factor time ($F = 1.981$, $P = 0.081$) nor its interaction with body axis has

Table 2: Gait parameters. Mean ± standard deviation ($CI_{95\%}$) of gait parameters recorded during 6MWT for the three groups of participants. The last two columns reported the statistical analyses. For PG2, the last minute walking speed was the minute before stopping.

Gait parameters	PG1 ($n = 12$)	PG2 ($n = 8$)	CG ($n = 10$)	Analysis	
				ANOVA PG1, PG2, CG	Post-hoc PG1 versus PG2
Walked distance (m)	226 ± 111 (163; 289)	94 ± 73 (43; 144)	413 ± 57 (378; 448)	$F = 31.03$ $P < 0.001$	$P = 0.007$
Walking speed (m/s)	0.63 ± 0.31 (0.45; 0.81)	0.37 ± 0.25 (0.20; 0.54)	1.15 ± 0.16 (1.04; 1.26)	$F = 22.72$ $P < 0.001$	$P = 0.082$
1st minute Walking speed (m/s)	0.62 ± 0.30 (0.45; 0.79)	0.43 ± 0.30 (0.22; 0.64)	1.17 ± 0.18 (1.05; 1.29)	$F = 19.69$ $P < 0.001$	$P = 0.271$
last minute Walking speed (m/s)	0.64 ± 0.32 (0.46; 0.82)	0.32 ± 0.18 (0.20; 0.44)	1.16 ± 0.13 (1.07; 1.25)	$F = 28.29$ $P < 0.001$	$P = 0.019$

a significant effect on the acceleration RMSs ($F = 1.810$, $P = 0.058$).

4. Discussion

In this study, we observed a progressive reduction of gait dynamic stability in patients with stroke during prolonged walking. To test the relationship between walking endurance and gait stability, we compared the performances of inpatients with those of an age- and height-matched group of healthy subjects, combining the 6-minute walking test with the measure of upper body accelerations.

As expected, the walked distance at the end of the test and the mean walking speed were both lower in patients than in healthy subjects. The lower walking speed of patients implied lower accelerations, facilitating their control of upper body stability [9, 11]. In this study, the need of RMS normalization to compare populations walking at different speeds [12] has been avoided by analyzing the within-subject variations of RMS values along the test.

During the six minutes of the test, neither walking speed nor trunk accelerations significantly varied for control subjects. Conversely, patients showed a progressive reduction of their walking speed and/or gait stability.

In healthy subjects, it was already found that a reduced gait velocity results in a corresponding reduction of acceleration amplitudes [9]. However, this association between velocity and acceleration was found altered in our patients during the 6MWT. In fact, despite the systematic speed reduction observed in PG2, their trunk accelerations were not reduced during the test. On the other hand, this association resulted reduced also in patients able to complete the test (PG1). In fact, they were able to maintain their self-selected walking speed over the entire test, but many of them also showed a progressive increment of upper body accelerations. The speed reduction observed in PG2 without any acceleration decrease and the increase of upper body accelerations mainly observed in PG1 keeping constant their walking speed indicate that the patients' walking endurance and gait stability were challenged during this test [17].

Our results suggest that patients used two possible alternative strategies to perform the 6MWT. Some of them were able to keep their speed quite constant during walking, despite a slight but progressive reduction of their upper body stability. These subjects were mainly those of PG1, that is, the group able to complete the test. Other subjects seemed to apply a compensation strategy based on the reduction of their walking speed. It probably facilitated the management of their progressive reduction of gait stability during this effortful walking task. As stated above, the reduction of walking speed is, in fact, a suitable strategy for reducing upper body accelerations [9, 11]. This last strategy has been observed especially in those patients who asked to stop the test before its planned conclusion.

In previous studies, for patients with chronic stroke performing the 6MWT, neither differences in velocities for each 1-minute interval [18] nor differences in energy consumption [5] were found significant over the course of the walk. The effects of fatigue were probably not highlighted by these measures [18]. Conversely, changes in gait symmetry [7] and in unaffected lower limb extensor power [5] were found associated with fatigue mechanisms over some minutes of walking.

However, far too little attention has been paid to the reduction of gait stability during prolonged walking, which may potentially increase the risk of falls [9]. In fact, the correlations between upper body accelerations and fall risk have been proven [19]. Falls are one of the most important problems among people after stroke, implying physical and psychological consequences associated with restricted activity as a result of fractures [20] and fear of new falls [21]. During level walking, the main causes of falling are quick walking speed in respect of the actual patient's locomotor capacity, anterior body mass carriage, and step timing delays [22, 23]. In daily living environment, it is conceivable that the patients who self-selected to keep constant their walking speed in spite of an increase of their upper body instabilities may be exposed to a high risk of fall.

In fact, in this study, we found an increment of patients' upper body accelerations, especially along anteroposterior and laterolateral directions over six-minute walking. These

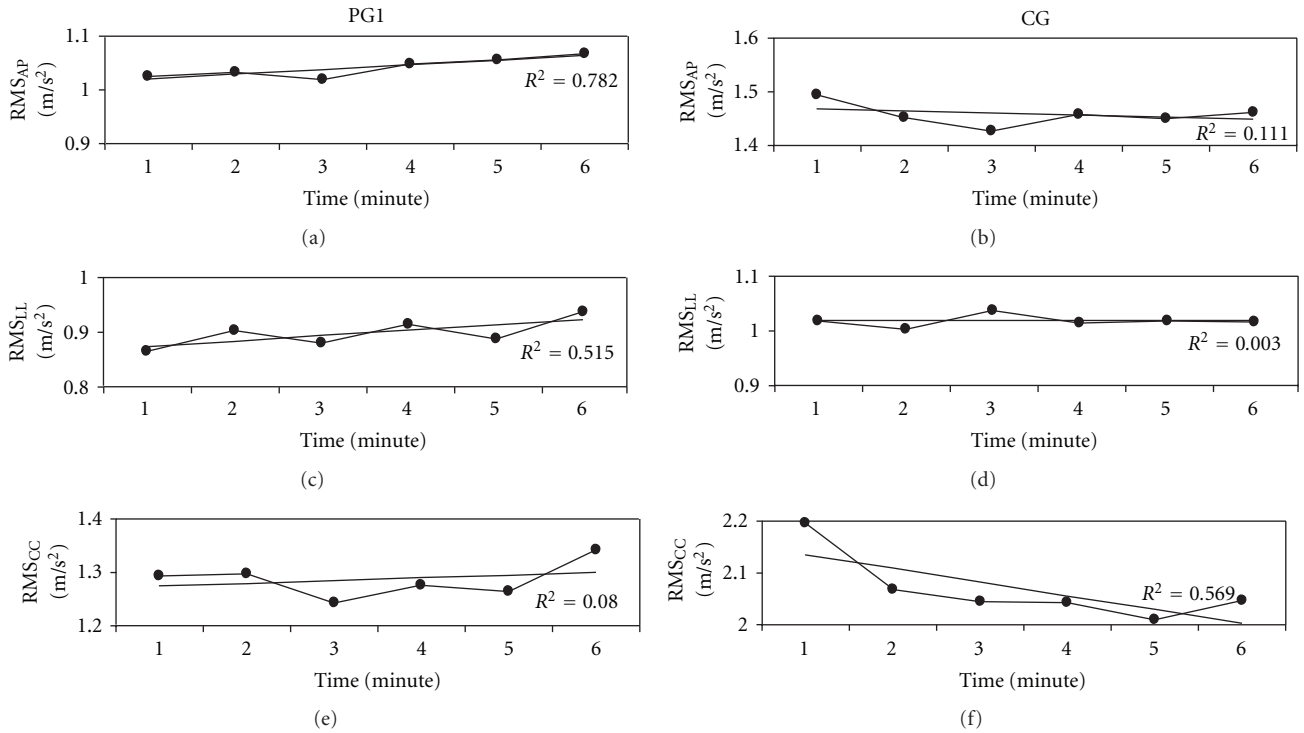

Figure 2: Acceleration RMS for PG1 ((a), (c), and (e)) and CG ((b), (d), and (f)) along anteroposterior ((a) and (b)), laterolateral ((c) and (d)) and craniocaudal ((e) and(f)) directions. Regression lines and relevant coefficient of determination R^2 are also reported.

accelerations have already been showed as the most informative for assessing the gait stability and also the most correlated with the risk of fall [11, 23]. These findings seem to be consistent with the changes in kinematic [7] and kinetic [5] gait parameters already observed during 6MWT performed by people with stroke. Further studies on wider samples of patients should investigate whether this reduction of gait stability is progressive, as our results seem to show, or it happens only after an identifiable threshold. On the other hand, the reduction of walking speed probably used by some patients to compensate the reduction of gait stability could be anyway dangerous during outdoor walking. By way of example, an adequate gait velocity can be needed to perform some specific tasks, such as crossing the street during the green phase of traffic lights [24].

The main limitation of our study is the reduced size of healthy and patient samples especially in respect of the many features of stroke. Wider samples are needed in future studies to further explore the differences between patients who could and those who could not complete the 6-minute walking test. Another important aspect that needs to be further investigated is the stabilizing effect of the use of a cane or of the therapist's touch during walking. It should be noted that in our study the needs of external helps were similar in the two subgroups of patients (as shown by similar autonomy walking level: see values of FAC scores in Table 1), affecting the upper body accelerations in a similar manner. Finally, the difficulties encountered by participants turning at the end of each lap and the upper body accelerations during turning have been not taken into account in this study. Further researches should deeply investigate this aspect of walking component that can lead to differences in upper body accelerations. Despite these limitations, our study provided important information about the relationship between upper body dynamic stability and walking endurance.

Our results should be read in conjunction with those of Lerdal and colleagues in which it has been shown how an increased mobility may increase exposure to fall opportunities [3]. Walking speed, gait stability, and endurance should be hence quantitatively assessed and improved during rehabilitation in order to allow patients to walk in a functional and safe manner. Furthermore, accelerometry has been recently proposed for assessing the patients' performances during robotic gait training [25] and daily life activities [26]. The quantitative assessment of ability and stability of gait can improve the effectiveness of an intensive training designed around the actual patient's locomotor capacity [27] and the "locomotor awareness" of the patients about his/her abilities and limits.

5. Conclusion

Patients with stroke showed a reduction of walking speed and/or a reduction of gait stability during prolonged walking. In particular, the patients able to complete the six-minute walking test maintained a steady speed over the course of the walk, but their upper body accelerations progressively increased, exposing them to the risk of falling.

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Clinical Study

Cardiopulmonary Response to Exercise Testing in People with Chronic Stroke: A Retrospective Study

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Background and Purpose. This study investigated the cardiopulmonary response and safety of exercise testing at peak effort in people during the chronic stage of stroke recovery. *Methods*. This retrospective study examined data from 62 individuals with chronic stroke (males: 32; mean (SD); age: (12.0) yr) participating in an exercise test. *Results*. Both males and females had low cardiorespiratory fitness levels. No significant differences were found between gender for peak HR ($P = 0.27$), or VO_2 peak ($P = 0.29$). Males demonstrated higher values for minute ventilation, tidal volume, and respiratory exchange ratio. No major adverse events were observed in the exercise tests conducted. *Discussion and Conclusion*. There are differences between gender that may play a role in exercise testing performance and should be considered when developing exercise programs. The low VO_2 peak of this cohort of chronic stroke survivors suggests the need for participation in exercise interventions.

1. Introduction

Recovery from stroke is challenging due to impaired neuromuscular control, decreased functional mobility, balance deficits, and reduced cardiorespiratory (CR) fitness [1, 2]. Emerging evidence suggests exercise training in the post-stroke population can facilitate improvements in the cardiovascular, respiratory, and neuromuscular systems [3, 4]. For a variety of reasons, stroke survivors are not routinely prescribed aerobic exercise during stroke rehabilitation [5], which likely exacerbates their decline in cardiorespiratory fitness. Research studies have demonstrated not only improvements in VO_2 peak after exercise interventions [3, 4, 6, 7] but also physical function (e.g., Timed Up and Go), walking [8, 9], and psychological well being [8, 10]. Yet, many clinicians do not employ aerobic exercise interventions, perhaps because of the limited amount of research that has identified appropriate screening protocols and optimal dosing of aerobic exercise for this population [11, 12]. Furthermore, the current literature available to healthcare professionals regarding the safety and feasibility of exercise testing in people with chronic stroke (i.e., ≥6 months [13]) has been limited by mostly smaller data sets (<35 participants with chronic stroke).

CR fitness is important for performing daily activities and mobility. It has been reported that VO_2peak values below $20\,\text{mL} * \text{kg}^{-1} * \text{min}^{-1}$ is associated with limited physical function for instrumental activities of daily living [14, 15]. After stroke, women, when compared to men, need more assistance for activities of daily living and walking [16]. In stroke rehabilitation, women may need to participate in aerobic exercise training to increase endurance for daily activities. While it is known that CR fitness is reduced after stroke, the majority of the studies to date have enrolled a higher proportion of men. In fact, most studies describing CR fitness after stroke have less than 25% [7, 13, 17, 18] or no women [19] enrolled. It is important to understand the cardiopulmonary response to exercise testing in both

men and women so that the physiologic and hemodynamic responses obtained from an exercise test can be used to appropriately guide exercise prescription [2].

While most studies report VO_2 peak and HR as outcomes from an exercise test in the stroke population, little information is available regarding other outcome measures involving the pulmonary system such as minute ventilation (VE), tidal volume, or ventilatory efficiency of carbon dioxide (VE/VCO_2) in this clinical population. In an early study of stroke survivors with left-sided hemiplegia, respiratory function was compromised and may have "contributed to fatigue that limits physical activity" [20].

Therefore, the aims of this retrospective study were to characterize and provide a comprehensive description of cardiopulmonary responses during an incremental exercise test in chronic stroke survivors (i.e., ≥6 months) and report on the range of responses to exercise testing between gender. We hypothesized that men, after stroke, would have higher values for CR fitness and pulmonary function when compared to women. We also wanted to determine which cardiovascular, pulmonary, and functional outcomes would predict CR fitness using peak oxygen consumption (VO_2 peak). Finally, we sought to determine if individuals in the chronic stage of stroke can safely participate in exercise testing using the data set available.

2. Methods

For the present work, data were gathered and analyzed from exercise testing results that were conducted in the University of Kansas, General Clinical Research Center (GCRC) during the time period from 2005 to 2009. These studies included individuals with chronic stroke who participated in peak effort exercise test. The admission criteria into the previous studies have been described elsewhere [21–23]. Briefly, inclusion criteria were (1) single ischemic stroke at least 6 months prior to enrollment, (2) ability complete sit to stand transfer, (3) independent with ambulation 30 feet with or without an orthotic or assistive device, and (4) Mini Mental Status Exam score of ≥24 [21, 22], and both studies excluded individuals with cardiac limitations that were absolute contraindications for exercise testing [24]. The modalities used for the exercise tests were either a cycle ergometer (Lode BV, Zernikepark 16, 9747 AN Groningen, Netherlands) (Lode BV, Groningen, Netherlands), or total body recumbent stepper (NuStep, Inc, 51111 Venture Dr., Ann Arbor, MI 48108) (NuStep, Ann Arbor, MI). Both exercise test protocols used 2-minute incremental stages. In our previous work, we reported a strong relationship between the cycle ergometer and total body recumbent stepper testing protocols for VO_2 peak ($r = 0.91$, $P < 0.001$) in people after stroke [22].

A brief description for the exercise testing protocols is provided. Individuals were instructed to abstain from consuming food and caffeine 3 hours prior to the scheduled test. Calibration procedures were performed on the metabolic cart (ParvoMedics, 8152 South 1715 East, Sandy, UT 84093) (ParvoMedics True One 2400, Sandy UT) according to the manufacturer specifications. An exercise physiologist familiarized each participant at the time of the visit with the exercise equipment, the mouthpiece, noseclip, exercise testing protocol, and procedures and explained the Borg rating of perceived exertion (RPE) scale. Participants were attached to a 12-lead electrocardiograph (ECG) to continuously monitor heart rate and rhythm. A 2-way, nonrebreathing valve, headgear, mouthpiece, and nose clip were worn by the participants. Blood pressure and RPE were acquired during the last 30 seconds of each stage. Expired gases were collected continuously, and oxygen uptake and carbon dioxide production was averaged at 15-second intervals. The exercise test was terminated if the participant reached volitional exhaustion or met absolute test termination criteria according to ACSM guidelines [24].

Sixty-two individuals with chronic stroke who participated in an exercise test in the GCRC were identified for inclusion into the study. Exclusion criteria consisted of missing or incomplete data. The study procedures were followed in accordance with the institutional guidelines and were approved by the University's Human Subjects Committee. Participant characteristics are listed in Table 1.

We examined the cardiopulmonary indices at peak effort for the entire group and across gender. Due to the variability in age range (26 to 81 years of age) of the study population, we performed a subanalysis of the data. We separated our data into age groups by decade as listed in the ACSM's *Guidelines for Exercise Testing and Prescription* [24]. This allowed for characterization of aerobic fitness levels across gender and age to describe our participant's percentile rank for maximal aerobic power.

Most individuals in this dataset had enrolled in an intervention study. To avoid any confounds associated with exercise interventions, we assessed the cardiopulmonary response to exercise testing data only from baseline exercise tests.

3. Data Analysis

The arithmetic mean and standard deviation were used for descriptive statistics. Primary outcome measures and body composition were tested for normality using a Kolmogorov-Smirnov 1 sample test. A univariate general linear model was used to examine gender differences for cardiopulmonary parameters. To account for differences in peak HR, medications that affect HR (beta blockers and Ca+ channel blockers) were used as covariates in the statistical analyses. To determine which parameters could have the greatest influence on VO_2 peak ($mL * kg^{-1} * min^{-1}$) for the cohort, a stepwise linear regression model was performed. In order to examine 5 factors in the regression analysis, we would need at least 50 people to be included in the sample. Therefore, the independent variables included in the regression analysis were peak VE ($L * min^{-1}$), peak HR, age, gender, and lower extremity Fugl-Meyer. Pearson correlation coefficients were used to examine the relationship between VO_2 peak and those significant factors in the regression model. All analyses were conducted using SPSS statistical software (SPSS, Inc, 233 S Wacker Dr., Chicago, Ill 60606) (SPSS, v 17) with the alpha level <0.05.

Table 1: Participant demographics.

Characteristics $n = 62$	Group mean (SD)[‡]	Males	Females
Sex: male		32	30
Age (years)	62.0 (12.0)	68.0 (10.5)	55.0 (11.9)*
Height (m)	1.7 (0.09)	1.8 (0.05)	1.6 (0.05)*
Weight (kg)	87.7 (18.0)	92.5 (14.8)	82.5 (19.9)
Body mass index	29.3 (5.4)	28.5 (4.2)	30.2 (6.5)
Race/ethnicity			
African American	11	2	9
Caucasian	46	28	18
Hispanic	4	2	2
Native American	1	0	1
Stroke characteristics			
Time (months) after stroke	61.0 (50.0)	62.9 (35.9)	57.9 (61.2)
Right side weakness	31	19	12
Bilateral deficits	1	1	0
LE Fugl-Meyer score	23.3 (7.2)	24.7 (6.3)	21.8 (7.8)
Comorbidities for cardiac risk			
Type 2 diabetes mellitus	21	12	9
Current smoker	0	0	0
Overweight (BMI 25.0–29.9) [24]	25	27.5 (1.5)	27.6 (1.6)
Obese (BMI 30.0 to $\geq$ 40) [24]	27	33.0 (1.7)	34.2 (4.6)
Medications:			
high blood pressure	40	20	20
beta blockers	21	9	12
calcium channel blockers	15	5	10
ACE inhibitors	30	16	14
hyperlipidemia	17	9	8

[‡] Data are "n" participants of 62 unless indicated by group mean (SD).

4. Results

4.1. Cardiopulmonary Response to Exercise Testing. Data for the primary cardiovascular and pulmonary outcomes and body composition were normally distributed (P-values > 0.310). Males were older, taller, and weighed more than their female counterparts (Table 1). Despite these differences in physical parameters, no significant differences were found between genders for peak HR even when controlling for medications ($P = 0.27$). Females were younger and their age-predicted HR max (APHRM) calculated by 220 minus age was significantly higher than males. However, peak HR at the end of the exercise test was lower than their male counterparts despite being younger. Furthermore, the number of males ($n = 28$) and females ($n = 29$) reporting the use of a beta blockade was similar. VO_2 peak (mL $*$ kg$^{-1}*$ min^{-1}) ($P = 0.29$) and lower extremity function using the Fugl-Meyer score ($P = 0.11$) were also not significantly different. Pulmonary function for minute ventilation (L $*$ min^{-1}) and tidal volume (L) were significantly higher in males while respiratory rate was not different between genders. We also report that males exercised beyond their anaerobic threshold with respiratory exchange ratio (RER) significantly higher. However, their perceived exertion at peak effortwas similar. Cardiopulmonary exercise parameters from the initial exercise test ($n = 62$) are listed in Table 2.

VO_2 peak is reported as the index for CR fitness and in the poststroke population, and these values have been reported well below age-matched, sedentary controls [18]. Therefore, according to the normative data provided in ACSM's *Guidelines for Exercise Testing and Prescription* [24], we divided the cohort into age groups by decade. All stroke survivors but one had VO_2 peak values below the first percentile, which classifies their CR fitness as very poor. Only one person in the 20–29-year-old age range had a VO_2 peak in the 10th percentile (poor category). Furthermore, only 10 of the 62 individuals had VO_2 peak values above 20 mL $*$ kg$^{-1}*$ min^{-1}. This is important to consider since VO_2 peak values below 20 mL $*$ kg$^{-1}*$ min^{-1} has associated with limited physical function for instrumental activities of daily living. Table 3 lists VO_2 peak values across age groups.

4.2. Regression Model. A stepwise linear regression was performed to examine which cardiopulmonary measures and stroke outcomes contributed to VO_2 peak. Our results showed that minute ventilation (VE) was the most predictive and significant measure of VO_2 peak for chronic stroke survivors

Table 2: Cardiopulmonary response at peak effort in chronic stroke.

Characteristics (n = 62 exercise tests)	Group	Males	Females
Relative peak VO_2 (mL $*$ kg$^{-1}*$ min^{-1})	15.6 (5.42)	16.3 (3.6)	14.8 (6.8)
VO_2 peak (L$*$min^{-1})	1.3 (0.42)	1.5 (0.4)	1.2 (0.4)*
HR reached at peak effort (bpm)	127.4 (28.8)	131.4 (29.6)	123.2 (27.8)
% of age-predicted HR Max (APHRM)		86%	75%
Age-predicted HR Max (bpm) (220 minus age)	158.3 (12.8)	152.3 (10.5)	164.7 (11.9)*
RER	1.06 (0.1)	1.10 (0.1)	1.02 (0.1)*
VE (L $*$ min^{-1})	51.3 (18.7)	61.2 (18.0)	40.7 (12.9)*
Tidal volume (L)	1.6 (0.5)	1.8 (0.4)	1.3 (0.5)*
Breathing frequency (breaths $*$ min^{-1})	33.0 (8.5)	34.0 (8.6)	32.0 (8.4)
Ventilatory equivalent for CO_2 (VE/VCO_2)	36.5 (6.4)	37.2 (6.0)	35.7 (6.8)
Rating of perceived exertion	16.0 (2.0)	16.5 (1.8)	16.0 (2.2)

VO_2 peak, peak oxygen uptake; HR: heart rate; RER: respiratory exchange ratio; Peak VE, minute ventilation, and CO_2: carbon dioxide. All values are expressed as mean (standard deviation). *denotes significance between males and females ($P < 0.01$).

Table 3: Age comparison of cardiopulmonary exercise test parameters and LE function.

Age group (years)	Gender (n =)	LE Fugl Meyer score	VO_2 (mL $*$ kg$^{-1}*$ min^{-1})	Percentile rank*
20–29	F (1)	34	28.7	10th
	M (0)	—	—	
30–39	F (1)	13	14.9	Below 1st
	M (1)	31	21.5	Below 1st
40–49	F (8)	19.4 (8.3)	12.1(3.8)	Below 1st
	M (1)	27	24.6	Below 1st
50–59	F (9)	23.4 (8.7)	16.9 (9.0)	Below 1st
	M (1)	22	19.2	Below 1st
60–69	F (7)	23.9 (4.9)	15.1 (6.6)	Below 1st
	M (14)	23.6 (7.2)	15.2 (3.2)	Below 1st
70–79	F (4)	18.8 (7.8)	11. 6 (2.4)	Below 1st
	M (12)	25.3 (5.6)	15.9 (3.6)	Below 1st
80–89	F (0)	—	—	No normative data
	M (3)	21.8 (7.5)	17.4 (1.9)	

* Normative data for percentile values for maximal aerobic power from American College of Sports Medicine's *Exercise Testing Guidelines and Prescription*. LE: Lower extremity.

($R^2 = 0.37$, $P < 0.001$) (Figure 1) although adding LE Fugl-Meyer scores markedly improved the model prediction $R^2 = 0.51, P < 0.001$).

Adding peak HR only slightly improved the overall model ($R^2 = 0.54$, $P < 0.001$). Age and gender did not improve the model. Pearson correlation coefficients suggest a significant relationship between lower extremity Fugl-Meyer scores and VO_2 peak (Figure 2; $r = 0.57$, $P < 0.001$).

4.3. Safety of Exercise Testing in Chronic Stroke. Major adverse events were defined according to the American College of Sports Medicine Guidelines for Exercise Testing and Prescription [24] (e.g., moderately severe angina, drop in systolic blood pressure of >10 mm Hg from baseline blood pressure, ST elevation, sustained ventricular tachycardia). In our data set, no major adverse events (i.e., death, heart attack) were observed. However, one cardiac complication (ST segment depression >2 mm) was reported. At the onset of this event, the exercise test was terminated and ST segment depression returned to baseline within 1 minute. The individual's cardiologist was notified, but hospitalization was not required. Another exercise test was terminated early because the participant experienced increased discomfort with the mouthpiece. Therefore, the mouthpiece was removed, and the test was terminated. One individual reported feeling dizzy after the exercise test was completed, although no cardiac symptoms were recorded (i.e., normal blood pressure and HR response), and the dizziness subsided after two minutes. All other exercise tests were terminated due to volitional fatigue.

5. Discussion

The primary aims of this retrospective study were to describe the cardiopulmonary response to an incremental exercise test and determine whether gender differences existed and had

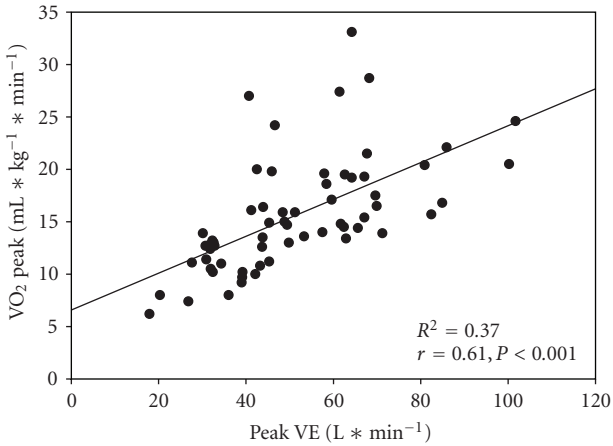

Figure 1: Scatterplot with a regression line overlay to demonstrate the relationship between VO_2 peak and *peak* minute ventilation (VE).

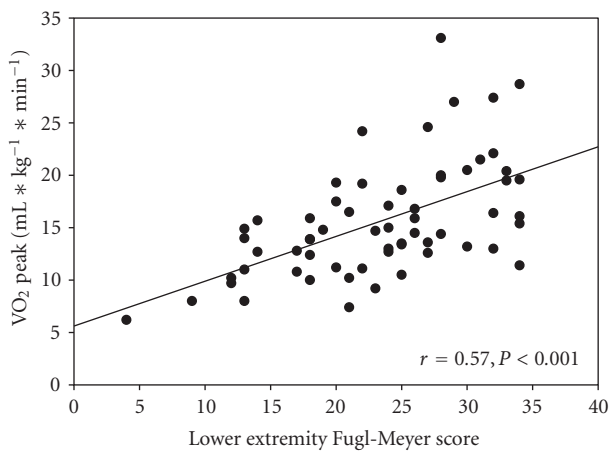

Figure 2: Scatterplot with a regression line overlay to demonstrate the relationship between VO_2 peak and lower extremity function using the Fugl-Meyer.

an effect on exercise testing performance. We sought to investigate which of the cardiopulmonary and functional measures would predict VO_2 peak, which may help emphasize the need for aerobic training programs in stroke rehabilitation. Finally, we wanted to assess the safety of exer-cise testing to peak effort in people with chronic stroke.

6. Cardiopulmonary Response to Exercise Testing

VO_2 peak has been consistently shown to be a useful measure of functional capacity. Specifically, two recent studies [14, 15] reported that VO_2 peak values below 20 mL ∗ kg^{-1}∗ min^{-1} is associated with limited performance in activities of daily living. In our cohort of chronic stroke survivors, approximately 84% had VO_2 peak values below this functional capacity. Further, in our study, the mean value for VO_2 peak (mL ∗ kg^{-1}∗ min^{-1}) in both genders after stroke was 55% and 43% lower in females and males, respectively, than those reported for healthy sedentary counterparts [25]. This severe reduction in VO_2 peak could have functional implications for independent living, return to work and community participation in people after stoke [18]. Since thepulmonary system is also essential during exercise but poorly described in people after stroke, we sought to examine these outcome variables in addition to the cardiac system. We found group mean VE values comparable to those reported by two previous studies in stroke survivors [18, 26] but less than those reported for healthy adults [26, 27]. We found only one other report by Tomczak and colleagues that examined tidal volume and breathing frequency for pulmonary function during exercise testing after stroke [26], and our results are similar in findings. Ventilatory equivalent for carbon dioxide (VE/VCO_2) reflects ventilatory efficiency, and values below 30 are considered normal [27]. The findings listed in Table 3 demonstrate an abnormal, high response with the group mean for VE/VCO_2 ratio at 36.5. The higher VE/VCO_2 ratio response, along with decreased VE and tidal volume, may be indicative of a high physiologic dead space fraction in the lungs [28, 29]. Rehabilitation professionals need to consider aerobic exercise interventions and inspiratory muscle training targeted towards increasing pulmonary function after stroke.

7. Gender Differences

Females had significantly lower values for absolute peak oxygen uptake (L ∗ min^{-1}), RER, VE, and tidal volume than males. However, VO_2 peak when normalized to body weight (mL ∗ kg^{-1}∗ min^{-1}) was lower than the males but not significantly different. Despite females being younger than their male counterparts, peak HR for females was also lower than males (123.2 (27.8) versus 131.4 (29.6), resp.) but not statistically different when we controlled for cardiac medications ($P = 0.27$). It is possible that with a larger sample size, we would find statistically significant differences between males and females for the cardiovascular outcomes. However, an article by MacKay-Lyons and colleagues [18] briefly mentioned gender differences in their data set, but they had a smaller sample size and an unequal distribution of males ($n = 22$) and females ($n = 7$). In their study, they reported that males had significantly higher VO_2 peak values than females early after stroke. We are unclear to the reason for this finding since our female group was significantly younger (55.0 (11.9) versus 68.0 (10.5)) than the males. Our available data does not lend insight to other cardiopulmonary or physical parameters (earlier onset of fatigue) that may have affected their exercise performance. Additionally, we also did not have information regarding other measures that can be clinically meaningful during submaximal efforts such as the oxygen uptake efficiency slope or the VO_2/Work rate slope. Since we performed a retrospective analysis, the data should be interpreted with caution. We acknowledge that future prospective studies examining gender differences should have a sample that is age matched

to determine the role of gender on these cardiovascular and pulmonary parameters.

When we compared the effect of gender on pulmonary outcomes at peak effort from the exercise test, we found that males had larger minute ventilation (VE) and tidal volume, but respiratory rates were similar to females. However, both groups were below normative values for ventilation at peak exercise effort [27]. VE and tidal volume for males in this study were 63% and 66% of normal values but had respiratory rates similar to healthy adults in these age ranges (94% of normal). Females' values were also lower with VE and tidal volume at 59% and 68% of the normative data, respectively. Females also showed near normal respiratory rates at 89% of normative values. The response of the respiratory system in people after stroke both at submaximal and maximal effort may provide insight towards potential explanations regarding shortness of breath during activity and fatigue experienced after stroke. As shown in our data, early fatigue onset may partially be due to respiratory insufficiency through decreased lung volumes [20, 30]. Impaired breathing mechanics could be related to the extent of motor impairment (e.g., paresis of the hemidiaphragm, intercostal and abdominal muscles) and these individuals could benefit from inspiratory muscle training to increase strength and excursion [31, 32]. Given the paucity of data on gender-based differences in the cardiopulmonary response of stroke survivors on exercise testing, we describe a rather diverse group of chronic stroke survivors to help define the gender effects on peak exercise capacity.

8. Regression Model

According to the stepwise linear regression, VE was the most predictive measure of VO_2 peak. We also report that the Lower Extremity Fugl-Meyer (LEFM) score was a significant contributor in VO_2 peak as suggested by the step-wise regression model. In fact, as demonstrated in Table 3, those with higher LEFM scores also had higher VO_2 peak values. Work done by Macko and colleagues suggests that the hemiparetic leg may not be the primary deciding factor in test termination [13]. While we cannot discount lower extremity function of the affected leg (Fugl-Meyer score), there are other underlying factors such as reduced (1) lean tissue [33], (2) blood flow [34–36], and (3) work performance [37] in the hemiparetic leg that may contribute to early test termination in people after stroke.

However, the mechanisms that may be fundamental to the severe reductions in VO_2 peak observed here cannot be acquired from this retrospective data set. We also acknowledge that different exercise modalities may elicit differences in VO_2 peak, HR, and exercise testing performance [24]. However, our previous work comparing the exercise testing protocols used for cycle ergometer and the recumbent stepper demonstrated a strong association for VO_2 peak ($r = 0.91, P < 0.001$) and HR ($r = 0.89$, $P < 0.001$) [22], and, in the present study, we had a similar distribution of males and females that used the two types of exercise equipment (bike, recumbent stepper) to avoid bias of exercise modality.

9. Exercise Testing Safety

The results of our study provide strong evidence that both baseline and repeated maximal effort exercise tests during the chronic stages of stroke recovery are safe and welltolerated by this high cardiac risk clinical population. We report a high percentage (99%) of participants that were able to complete the symptom-limited exercise test without a cardiac complication. Previous work demonstrated the safety and feasibility of exercise testing in the chronic stroke population but the sample sizes were small [13, 21, 22]. The data from this study supports the work of others that exercise testing is safe when conducted with the proper level of screening and monitoring [4, 37, 38].

This information regarding exercise testing safety is important and relevant for those professionals working with people after stroke. Our data suggest that males and females after stroke have very poor CR fitness. The American Heart Association's Scientific Statement, *Physical Activity and Exercise Recommendations for Stroke Survivors and The Best Practice Guidance for the Development of Exercise after Stroke Services in Community Settings* [39], states the importance of incorporating aerobic exercise into stroke rehabilitation [11] and beyond to improve the health and well being of stroke survivors [39]. Further, the current literature has demonstrated aerobic exercise to be beneficial for improving CR fitness [6, 14, 36, 40], quality of life [4], gait and six-minute walk test [4, 40], and functional performance [14]. On the basis of this study, it appears that aerobic exercise interventions to improve CR fitness should be incorporated into stroke rehabilitation programs.

Since the literature suggests that most individuals after stroke present with existing coronary artery disease (CAD) [30] along with other cardiac risk factors, exercise testing can be a useful screening tool for cardiovascular complications prior to beginning an exercise intervention. Despite these risk factors, a high percentage (99%) of individuals completed the exercise testing without minor cardiac complications, and we report no serious adverse events. Exercise testing in the post-stroke population can provide useful information related to cardiovascular and pulmonary performance, exercise prescription parameters, and reassurance to the individual after stoke that exercise is safe and beneficial.

It should be noted that these results may not be representative of the stroke population. For instance, the individuals in this dataset volunteered for exercise studies and may be more confident, as they were willing to participate in peak effort exercise testing. We tried to provide a comprehensive representation of cardiopulmonary parameters obtained during exercise testing. While the exercise testing protocols routinely assess blood pressure, some charts did not have the final values listed at peak effort, or it was unclear if the value was obtained at peak. Therefore, blood pressure was not included. Current medications were self-reported by the participant on the day of the exercise test to

the exercise physiologist. It is possible that there may be some inaccuracies in reporting, which may have unintentionally confounded the data. However, we made every effort to obtain the recent medication list from the participant or family member.

10. Conclusion

Rehabilitation professionals should encourage people after stroke to participate in exercise interventions to improve cardiorespiratory health. We report that gender differences do exist in cardiopulmonary variables obtained through exercise testing with HR response below the APHR max, defined as 220 minus age suggesting that other methods (e.g., rating of perceived exertion) may be more reliable. These findings for gender and poor CR fitness should be considered by rehabilitation professionals when developing exercise prescription parameters in rehabilitation and community settings to optimize the cardiorespiratory benefits associated with exercise. Regardless of age, individuals after stroke have severe and significant reductions in peak oxygen uptake. However, for stroke survivors who wish to return to independent living, work, or community activities, their functional capacity and participation may be limited due to CR fitness. In conclusion, our findings suggest that exercise testing is safe in people with chronic stroke and may be beneficial in guiding exercise prescription.

Acknowledgments

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Research Article

Physical Activity, Ambulation, and Motor Impairment Late after Stroke

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Objective. To assess walking capacity and physical activity using clinical measures and to explore their relationships with motor impairment late after stroke. *Subjects*. A nonrandomised sample of 22 men and 9 women with a mean age of 60 years, 7–10 years after stroke. *Methods*. Fugl-Meyer Assessment, maximum walking speed, 6 min walk test, perceived exertion, and heart rate were measured, and the Physiological Cost Index was calculated. Physical activity was reported using The Physical Activity Scale for the Elderly. *Results*. Mean (SD) 6 min walking distance was 352 (±136) m, and Physiological Cost Index was 0.60 (±0.41). Self-reported physical activity was 70% of the reference. Motor impairment correlated with walking capacity but not with the physical activity level. *Conclusion*. It may be essential to enhance physical activity even late after stroke since in fairly young subjects both walking capacity and the physical activity level were lower than the reference.

1. Introduction

Ambulation is an essential part of daily physical activity. After stroke, about 65% of survivors have reduced ambulatory capacity [1] and after 6 months 50% still have impaired muscle function [2]. Damage of motor and sensory pathways results in altered motor function [3] and, over time, intramuscular changes [4, 5]. A reduction in active muscle mass may partly explain why peak oxygen uptake (VO_2) can be reduced to half of that of age-matched controls [4].

Impaired muscle function implies increased mechanical work and reduced walking speed to less than half of reference values [6]. A low walking speed together with poor muscle function and low aerobic capacity may result in a twofold increase in energy costs, defined as VO_2 per unit distance walked [6, 7]. Several studies confirmed a relationship between walking speed and motor impairment and some showed relationships between aerobic capacity and activity assessments [8].

A high energy cost of walking might affect the ability to perform daily activities and participation and thereby lead to a vicious circle where physical activity is avoided. In one study, stroke subjects walked 50% of the daily amount of matched sedentary persons' step counts and used 75% of their VO_2 peak for walking at a submaximal rate [9].

Physical activity and exercise are significant in disease prevention, and a low daily physical activity level may involve a general health risk [4, 10]. A survey in the USA revealed that 56% of people with disabilities were not engaged in physical activity and a study using focus groups found multifactorial reasons for this [11]. Studies on the actual physical activity level after stroke are few and are mostly performed in elderly populations [12]. A recent stroke study found very low daily activity levels as measured by accelerometer counts and self-reports, which could explain the poor quality of life to a certain extent [13].

One hypothesis is that the level of physical activity late after stroke is lower than in a nonstroke population and that walking capacity, general physical activity, and motor impairments are associated. The aim of the current study was to use clinically applicable methods to assess walking habits and capacity, energy costs, and physical activity levels in

a fairly young sample several years after stroke and to explore whether or not motor impairment was associated with walking capacity and self-reported physical activity levels.

2. Materials and Methods

Fifty-four persons with a first event of stroke who had taken part in a previous study at a rehabilitation unit [14] were invited by post, followed by a telephone call, to participate. The criteria for participation were stroke according to the WHO definition, >18 years of age, the ability to communicate in Swedish, and to walk with or without a walking aid without personal assistance for 6 minutes. The study was approved by the Regional Ethical Review Board/Gothenburg and the participants gave their informed, written consent.

The subjects were asked to refrain from nicotine and coffee for at least 2 hours before the test. Two tests of walking capacity were performed. First, the maximum walking speed was measured on a 30 m track in an undisturbed corridor. The test of maximum walking speed has been shown to be reliable after stroke [8], and the 30 m distance was chosen in order to make comparisons with age- and sex-matched reference values for this distance, taken from a population-based sample of people living in the same recruitment area as the stroke subjects [15]. A heart rate (HR) monitor (Polar S625X, Polar Elektro Oy, Kempele, Finland) with a storage function was attached with a chest strap, and the resting HR was measured while each subject sat in silence for 10 minutes; the mean of the last 5 minutes was used as the baseline value. As a second test of capacity, each subject was then instructed to walk at self-selected speed round a cone at each end of the 30 m walking track and to cover as much distance as possible in 6 minutes (6MWT) [16] while the HR was recorded. Each subject was asked to rate the perceived exertion on the Borg CR10 [17] scale after stopping, and the distance covered was estimated to the nearest metre. Two 6MWT tests were carried out separated by seated rest for 10 minutes or until return to the baseline HR. The longest distance of the two 6MWT was chosen for analysis, and each individual's 6MWT distance was compared to a reference value estimated by a gender-specific equation correcting for age, height, and weight [18]. The energy cost was estimated using the Physiological Cost Index (PCI) based on the relationship between oxygen consumption and heart rate [19], which has been investigated regarding reliability after stroke [20, 21] and considered to give a rough measure of the energy cost. Dividing the difference between walking and resting HR by the walking speed in m/min gives the PCI value expressed as heartbeats/m. To ensure a steady state, the mean of the last 3 minutes of walking was used as the walking HR value.

Weight and height were recorded and the body mass index (BMI) was calculated. Medical problems besides stroke were reported using the Self-Administered Comorbidity Questionnaire [22] and any current medication that could possibly affect the heart rate was recorded.

The motor impairment of the affected leg was assessed using the Fugl-Meyer Sensorimotor Assessment [23], where the maximum score of 34 indicates good performance. Each participant was interviewed using the following questionnaires: the frequency of continuous outdoor walking distances during the last 3 months was covered by the Walking Habit Score comprising five questions from a questionnaire on walking ability [24]. The answers were divided into two groups: one that was classified as inactive walkers who never or at most once a week walked a distance of 500 m, and another group that walked 500 m or further more often. Leisure, household, and work-related physical activities during the most recent week were assessed using the Physical Activity Scale for the Elderly (PASE) [25]. The PASE was originally developed through a large population study on middle-aged and elderly people where self-reported physical activity was validated against accelerometer counts and each activity was weighted according to metabolic equivalents. By multiplying each activity's weight by time, a total score is calculated; a maximum score is not specified. In the original study [25], the test-retest reliability was r 0.68–0.84 and the PASE was found to be valid in elderly people with disabilities [26] and has been used for stroke subjects [27]. In the present study, each individual's PASE value was compared to age- and sex-matched normative values taken from a population-based sample of 113 persons in age cohorts between 40 and 69 years of age, living in the same recruitment area as the study subjects.

2.1. Statistics. Descriptive statistics were given as the mean and standard deviation (SD) for continuous data and the median and interquartile range (IQR) for ordinal data. Differences between participants' values and reference values were analysed using a paired t-test, and any subgroup differences were explored using the Mann-Whitney U-test. Spearman's rho was calculated to investigate correlations between variables. The significance level was set at $P < 0.05$.

3. Results

Thirty-one persons between 36 and 73 years of age volunteered for this study a median of 8 years (range 7–10) after the first stroke event, and only one had suffered a second stroke. Sixteen persons refrained from participating, five declined due to transportation problems, one did not understand Swedish, and one could not be reached. The people who were included and excluded did not differ in sex, age, or length of hospital stay in the early stage. Demographic and clinical data of the participants are given in Table 1.

The Fugl-Meyer motor score in the affected leg ranged from 14 to 34 (Table 1). The maximum walking speed measured over 30 m ranged from 0.3 to 2.3 m/s, which corresponded to 62% of the sex- and age-matched reference values [15], and the 6MWT distance varied between 93 and 577 m, corresponding to 52% of the calculated reference values [18] (Table 2). At the end of the 6MWT, the median (IQR) perceived exertion was 2 (2–4) and the mean (SD) heart rate was 96 (±18) beats/min. Eight participants used a cane, two used a walker, and seven used an ankle-foot orthosis during the walking tests.

The energy cost estimated using the PCI showed no statistically significant differencebetween the two

Table 1: Demographic and clinical characteristics ($n = 31$).

Sex, female/male, (n)	9/22
Age, (y), mean (SD)	59.7 (±8.1)
Body mass index, mean (SD)	27 (±4.7)
Cerebral infarction/cerebral haemorrhage/cerebellar haemorrhage (n)	18/10/3
Right/left/bilateral lesion (n)	15/15/1
Time since stroke (y)	8.5 (±0.9)
Cardiovascular disease/pulmonary disease/diabetes/musculoskeletal pain/depression (n)	20/3/7/16/11
Smoking (n)	6
Beta blocker/calcium channel blocker/ACE inhibitor/angiotensin antagonist/alpha blocker/diuretics (n)	15/9/6/4/2/5
FMA, median (IQR)	29 (22–34)
Walking aid, (n)	14[a]
Ankle-foot orthosis (n)	7
Wheelchair (n)	4[b]

SD: standard deviation: FMA: Fugl-Meyer Assessment. Motor score lower extremity, maximum 34. IQR: interquartile range: [a]occasional use in four subjects: [b]occasional use.

Table 2: Six minutes walking distance, maximum walking speed, energy cost, physical activity, and their associations with motor impairment of the affected lower extremity ($n = 31$).

		Spearman's rho
6MWT distance (m), mean (SD)	352 (±136)	0.80**
Maximum speed over 30 m (m/s), mean (SD)	1.30 (±0.57)	0.82**
PCI (beats/m), mean (SD)	0.60 (±0.41)	−0.57**
PASE, mean (SD)	124 (±67)	0.24

6MWT: 6-minute walk test: PCI: Physiological Cost Index: PASE: Physical Activity Scale for the Elderly. **correlation significant at $P < 0.01$.

measurements ($P = 0.678$) and the PCI from the longest 6MWT distance chosen for analysis varied from 0.19 to 2.5 beats/m (Table 2). Neither cardiopulmonary problems nor the use of beta blockers caused any statistically significant differences in the mean PCI values.

The physical activity level assessed using the PASE ranged from 31 to 241 (Table 2). In the 28 cases where age- and sex-matched reference values were available, the mean (SD) PASE score of 120 (±64) corresponded to 72% (±66) of the reference sample. Seventeen participants never, or once a week at most, walked a continuous distance of 500 m, as shown in Figure 1.

Motor impairment was significantly correlated (Table 2) with the maximum walking speed, the 6MWT distance, and the PCI, but not with the PASE. There was no significant correlation between the PASE and PCI.

Medical problems other than stroke-related problems were reported by 30 participants (Table 1), of whom 18 experienced activity limitations due to these. Of the 20

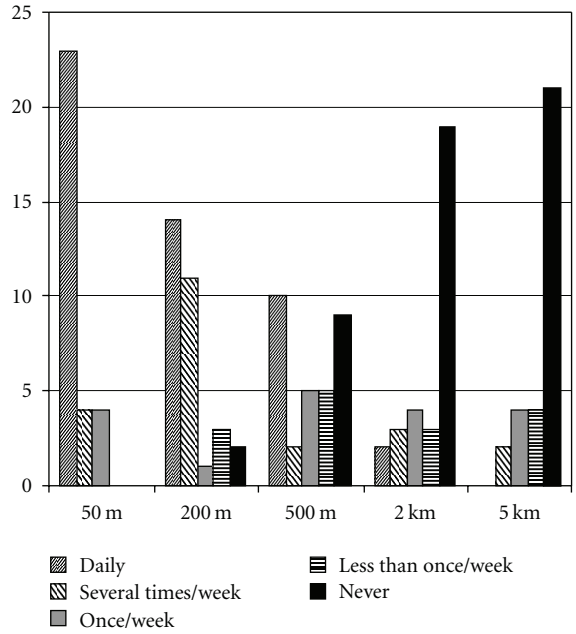

Figure 1: Frequency of walking specified continuous outdoor distances during the last 3 months.

participants with cardiopulmonary comorbidity, 5 stated activity limitations due to this. One subject had known atrial fibrillation with a frequency within normal boundaries.

4. Discussion

Our study of fairly young persons for whom several years had passed since stroke showed a reduced physical activity level and walking ability compared to healthy reference people. There was a large variation in motor impairment and walking capacity in the study group. The group's mean Body Mass Index indicated a tendency towards being overweight. The sample of the present study was small and highly selected, which limited the statistical power and generalisability of the results; however, our data adds information obtained using clinically feasible methods to previous findings.

Physical capacity, measured as the maximum walking speed, was well below normal as the mean was about 60% of the reference value. The mean 6MWT distance was half of the estimated normative values [18, 28], which was similar to the results found in another study at a later stage after stroke [29]. The energy cost measured using the PCI was approximately double compared to healthy people [19, 20, 30] and comparable to another study of the energy costs involved in over-ground walking in stroke subjects [21]. However, both the heart rate and the ratings of perceived exertion indicated that the walking tests in the current study were not very strenuous, probably because of the low velocity. As the energy cost is expressed per unit of distance, a high value can be partly explained by a low walking speed, in addition to inefficient gait mechanics due to impaired muscle functioning. The PCI as a measure of energy cost is a clinical measure that is not as robust as measurements of VO_2, which would have been preferred

if portable equipment for gas analysis had been available. The measurement of heart rate may be unreliable in cases of arrhythmia, and several factors, for example, stress or other environmental factors, may influence the heart rate, which is the basis of the PCI equation. However, in the current study the presence of cardiopulmonary problems or beta blockade did not show any difference in the PCI. The fact that there was no difference between the groups with and without cardiopulmonary comorbidity may be explained by the relatively low walking speed that did not demand a high increase in heart rate compared to the resting HR. Findings published on the reliability and validity of PCI in general, as well as after stroke, vary [20, 21]; however, in the present study the values from the two tests were similar and currently PCI is one of the few methods applicable in a clinical setting, providing a rough measure of energy cost.

The level of physical activity measured by the PASE reached approximately 2/3 of the reference values, which was somewhat higher than expected. A selection bias could be one possible explanation as more physically active participants could have volunteered and less-active people could have declined participation in the study. The walking activity reported, however, was approximately half of the frequency of the distances specified by healthy people in another study [24]. Based on the available data, it is difficult to say whether or not the participants fulfilled the health recommendations for a daily dose of physical activity as the intensity required is difficult to rate from the available data.

Both physical activity and walking habits were assessed by questionnaires; these might not be as accurate as accelerometer recordings, but in the current study no such equipment was accessible. Sufficient reliability of the self-report method was shown after stroke [31], although the method may be questionable due to memory, insight, and communication problems. However, we noticed that those who reported low walking distances on the questionnaires also gave a poorer performance in the 6MWT, which strengthens the validity.

Our hypothesis that the level of motor impairment of the lower extremities is associated with walking capacity was supported by the high correlations between the Fugl-Meyer score and the speed and distance measures. However, the correlation between motor impairment and energy cost was lower. The energy cost was not associated with the general physical activity level, which could have been expected. An uncertain accuracy of the PCI measure may be one reason for this result. Another explanation could be that physical activity is a complex construct with many possible influencing factors. Coexisting disease may have an impact [32], and almost all of the participants in the present study had some comorbidity with 2/3 feeling that this limited their activity levels. Depression was reported by 1/3, but other factors that could determine performance such as fatigue, cognitive impairment [33], a previous experience of or attitudes towards physical activity were not investigated. Beyond physical capacity, walking habits might be influenced by the physical environment or by social or psychological factors [34].

5. Conclusions

In this sample of fairly young persons several years after stroke, walking capacity was approximately half the normal level, the energy cost of walking was twofold, and self-reported physical activity levels were lower compared to healthy reference people. Motor impairment was associated with walking capacity but not with physical activity level. There are indications that physical activity after stroke is undertaken less often than recommended, and for health reasons it may be important to assess and support feasible, regular physical activity sessions, even a long time after the end of rehabilitation.

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Review Article

The Importance of Psychological and Social Factors in Influencing the Uptake and Maintenance of Physical Activity after Stroke: A Structured Review of the Empirical Literature

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Background. People with stroke are not maintaining adequate engagement in physical activity (PA) for health and functional benefit. This paper sought to describe any psychological and social factors that may influence physical activity engagement after stroke. *Methods*. A structured literature review of studies indexed in MEDLINE, CinAHL, P&BSC, and PsycINFO using search terms relevant to stroke, physical disabilities, and PA. Publications reporting empirical findings (quantitative or qualitative) regarding psychological and/or social factors were included. *Results*. Twenty studies from 19 publications (9 surveys, 1 RCT, and 10 qualitative studies) were included. Seventeen studies reported findings pertinent to psychological factors and fourteen findings pertinent to social factors. *Conclusion*. Self-efficacy, physical activity beliefs, and social support appear particularly relevant to physical activity behaviour after stroke and should be included in theoretically based physical interventions. The Transtheoretical Model and the Theory of Planned Behaviour are candidate behavioural models that may support intervention development.

1. Introduction

Long-term engagement in physical activity (PA) after stroke is increasingly being recognised as important for maintaining functional gains after rehabilitation and for general health benefits such as prevention of stroke recurrence and obesity, diabetes, and coronary heart disease. There is now a substantial body of work to demonstrate the effectiveness of regular PA on fitness and health parameters in this population [1]. However, it is also vitally important that clinicians, health promotion professionals, exercise instructors, and others involved in stroke care after rehabilitation understand the determinants of PA in this often elderly and frequently disabled population. Understanding these factors will allow development of appropriately targeted effective interventions that are contextually appropriate for increasing the uptake and maintenance of PA in this typically sedentary population.

A number of recent randomised controlled trials and systematic reviews [1–9] have demonstrated significant benefits of PA on a range of physical and functional parameters including muscle strength, gait, balance, function, and general fitness. Engaging in PA has also been shown to positively influence psychosocial outcomes such as quality of life and confidence [10]. This evidence is recognised by clinical guidelines which recommend long-term participation in PA after stroke because of its potential impact in reducing risk of cardiac events, diabetes depression, obesity, and recurrent stroke [11, 12]. Thus there is an evidence-based consensus that after stroke people should engage in long-term PA behaviour as part of, and as followup to, rehabilitation.

Despite the robust evidence regarding the many benefits of PA, people with stroke are not maintaining adequate long-term levels of engagement in PA for health and functional benefit. Many survivors adopt or return to sedentary lifestyles after rehabilitation [13] with between 58% and 68% of individuals with stroke undertaking minimal postrehabilitation PA [14, 15]. Furthermore, studies show that even where physical and functional improvements from organised programmes are significant, benefits are typically lost at followup [5, 16]. This suggests that survivors are

either choosing not to undertake self-directed PA or are encountering barriers that prevent them from engaging in activity. In order to support people with stroke to start or return to be physically active and to maintain engagement in PA, it is important that factors influencing uptake and long-term maintenance in PA in this population are fully understood. However, the determinants of PA behaviour are complex, and are known to be influenced by interlinked psychosocial, personal, and environmental factors [17, 18]. A starting point to understand and explain the role of these interlinked concepts is therefore to examine the *psychosocial* factors that might influence uptake and maintenance PA after stroke.

One approach to understanding the role of factors that may influence PA is the application of health behaviour models to explain the importance and relationship of such factors. Social cognition models of health behaviour and their component theoretical constructs, for example, have been applied at the level of the individual, to explain PA behaviour [17–19]. Theories such as Social Cognitive Theory [20] the Transtheoretical Model [21], Self-Determination Theory [22], and the Theory of Planned Behaviour [23] are models that currently dominate the PA behaviour change literature [17]. These models incorporate a range of potentially modifiable cognitive constructs believed to influence behaviour [17, 24, 25]. Some of the most important of these for PA behaviour in general appear to be attitudinal beliefs which evaluate the positive and negative aspects of the behaviour. Expected outcome and self-efficacy beliefs, and perceived competence, as well as perceived behavioural control relate to confidence in one's ability to perform the behaviour and are important determinants of PA behaviour [17, 18, 24, 25]. Other important constructs involve intention to undertake the behaviour, which incorporates setting goals and committing to the behaviour through use of self-regulatory skills [17, 18, 21, 24]. Prestroke exercise history may influence these beliefs and cognitions and should also be examined as a determinant of PA after stroke [26].

Understanding the role of psychological constructs in relation to PA behaviour after stroke is clearly important if effective interventions are to be developed to support long-term engagement in PA in this population.

The psychological literature from the general population also suggests that social constructs are important in determining PA, and these factors may apply after stroke [18]. Social normative beliefs relate to beliefs of others about one's engagement in PA, vicarious beliefs about others who are engaging in the behaviour [20]. More pragmatically, and moving away from an individualistic to a social model of behaviour, socioenvironmental factors may influence PA behaviour. Support from family and friends appears important in influencing motivation for PA in adults, and group exercise is known to be important in influencing motivation [18, 26]. Furthermore, sociodemographic factors such as ethnicity, gender, education, income, and age may also be influential in determining likely engagement in PA [26, 27]. Given the evidence from the general population that social environment may influence uptake and maintenance of PA, it is clearly important to also examine what is known about these factors in relation to stroke if interventions to address the psychosocial complexities of PA behaviour are to be appropriately developed and applied.

Table 1: Search terms used and databases searched.

Search architecture	
(1)	(MH "Stroke") or (MH "Arthritis+") or (MH "Cerebral Palsy") or (MH "Multiple Sclerosis") or (MH "Muscular Dystrophy+") or (MH "Muscular Dystrophies+") or (MH "Parkinson Disease")
(2)	TI stroke or AB stroke
(3)	1 or 2
(4)	(MH "PA") or (MH "Exercise+") or (MH "Physical Mobility") or (MM "PA") OR (MM "Exercise")
(5)	3 and 4

Databases searched: Medline; Cumulative Index to Nursing and Allied Health Literature (CinAHL); Psychology and Behavioural Sciences Collection (PBSC); PsycINFO.

The purpose of this structured review of the existing empirical data was to find and describe the role of psychological and social factors in influencing uptake and maintenance of PA engagement after stroke. Given the potential for health behaviour models to account for and explain the relative role of such factors, it was important to consider if data existed within the literature concerning these models. We used three clinically relevant questions to guide and structure our review. (1) What is the role of psychological factors in influencing the uptake and/or maintenance of PA after stroke? (2) What is the role of social factors in influencing the uptake and/or maintenance of PA after stroke? (3) Within the literature that explores the role of psychosocial factors in the uptake and/or maintenance of PA after stroke, which health behaviour models have been investigated?

2. Methods

We conducted a structured review of the literature. Relevant primary and secondary literature was identified by searching four online electronic databases via the EBSCO Host platform (Medline, CinAHL, Psychology and Behavioural Sciences Collection (P&BSC), and PsycINFO).

Search terms included relevant subject headings related to physical disabilities with mobility impairment or stroke (the presence of the word stroke in the title and abstract of a publication were also searched for). This search string was combined, using the Boolean operator "AND" with subject headings relevant to PA or exercise (see Table 1).

Publications were limited to the English language only. No other limits or filters were applied. Identified publications were scrutinised independently by two members of the study team, and a decision made as to whether or not publications should be included or excluded was made according to criteria reported in Table 2.

Publications assessed as meeting all inclusion criteria were retrieved in full. Two members of the research team independently examined full-text copies of all selected papers. Consensus was reached by consultation with the rest

Table 2: Criteria for including and excluding publications in the review.

	Criteria
Include if publication	(i) included participants with diagnosed stroke
	(ii) focuses on psychological or social factors
	(iii) focuses on issues pertinent to the uptake of or maintenance of PA/exercise after stroke
	(iv) reports empirical data whether quantitative (e.g., RCT, survey, cohort, case-control, interrupted time series) or qualitative (e.g., in-depth interview, focus group, and ethnography)
	(v) reports primary or secondary derived data
Exclude if publication	(i) does not include a sufficient focus on people with stroke
	(ii) is not primarily focused on PA or exercise after stroke
	(iii) does not report data pertinent to understanding psychological or social factors
	(iv) is not empirical

of the team. All publications included in the review were then categorised based on methodology. Data were extracted regarding (1) the methods used; (2) the primary study aims; (3) key findings specifically related to the review research questions.

The included studies were assessed for methodological quality according to individual elements of quality rather than a summary scale approach. For the assessment of quantitative studies (e.g., randomized controlled trials) the use of such summary scales is not supported by empirical evidence [28] and is actively discouraged [29]. Methodological components assessed for RCTs were randomisation, blinding, allocation concealment, and whether or not there had been an intention to treat analysis. Components for surveys were sampling strategy, response rate, use of validated instruments, and appropriate statistical testing.

Assessing the methodological quality of qualitative studies using composite scales has also been hotly debated and contested [30]. We therefore performed a global assessment of study quality, dichotomised according to whether it appears to be strong or weak. Strong studies are likely to include triangulation of data, respondent validation, clear exposition of methods of data collection and analysis, and reflexivity. We also considered the nature of the evidence reported in the qualitative studies and assessed these in terms of the "typologies" of their findings as described by Sandelowski and Barroso [31]. According to Sandelowski, the findings of qualitative studies in the health domain can be classified on a continuum of data transformation from findings that are not qualitative (no finding, topical survey), to ones that are exploratory (thematic survey), descriptive (conceptual/thematic description), or explanatory (interpretive explanation).

3. Results

Of the 1,470 publications returned from the search strategy, 1,426 were excluded following screening of the title and abstract (see Figure 1). 46 publications were retrieved and reviewed in full. A further 27 were excluded (see Table 3 for reasons) leaving 19 publications, which met inclusion criteria (see Table 4). Two publications [32, 33] reported a qualitative and a quantitative study. The quantitative study reported in Maher et al. [32] was quasiexperimental and did not report outcome data so was excluded. The studies reported in the paper by Galvin et al. [33] did meet inclusion criteria thus were both included. Thus from 19 publications included, 20 studies met all inclusion. 1 study was a randomized controlled trial (RCT), 9 were surveys, and 1 was qualitative (see Table 4).

4. Overview of the Studies

The overview contains design, setting, participants, interventions, measures, types and reported levels of PA reported, and methodological quality.

5. Design

5.1. Quantitative Studies. There were eight cross-sectional surveys [14, 33–39] and one longitudinal survey [40]. The only RCT was an international multicentre trial [41].

5.2. Qualitative Studies. Two qualitative studies involved focus groups only [33, 42], three conducted face-to-face or telephone interviews [10, 32, 43], and three conducted focus groups an interviews [44–46]. One study [47] produced longitudinal case studies.

6. Setting

Study setting is reported in Table 4.

7. Participants

Details of participant age, time since stroke, and proportion of participants with stroke in quantitative and qualitative studies are reported in Table 4.

7.1. Quantitative Studies. Most participants were community dwelling, however, two studies [33, 40] recruited hospital inpatients. One study [40], had followup at one and six months after hospital discharge. The RCT recruited participants 90 days after stroke onset with followup at 3 monthly intervals then at 18 and 24 months [41].

Most surveys included only people with stroke, however, three involved mixed disabled populations (Table 4). Mean reported age ranged from 47.1 years [36] to 69.4 years [40]. Time since stroke onset ranged from 10 days [40] to 5.2 years [14] most studies did not report this [33–38].

7.2. Qualitative Studies. Most participants were community dwelling. One study [33] involved inpatients receiving physiotherapy. Seven studies included only people with

Table 3: Excluded publications with reasons for exclusion by publication/study type.

Publication	Reason for exclusion			
	No stroke population focus	No focus on psychosocial factors	No focus on maintenance or uptake of exercise	Not empirical
Surveys				
Bohannon 2004	—	√	√	—
Cliodhna 2007	—	—	√	—
Junker 2011	√	—	—	—
Michael 2006	—	—	√	—
Bonetti 2008	—	—	√	—
Cohort				
Molloy 2008	—	—	√	—
CT/RCTs				
Boysen 2009a	—	√	√	—
Coyle 1995	√	—	√	—
Gillham 2010	—	√	—	—
Harrington 2010	—	√	—	—
Huijbregts 2008	—	—	√	—
Langhammer 2008	—	√	√	—
Marsden 2010	—	√	√	—
McLellan 2004	—	√	√	—
Michael 2009	—	√	√	—
Patterson 2010	—	√	√	—
Stuart 2009	—	√	√	—
van der Ploeg 2006	—	√	√	—
Qualitative				
Pound 1999	—	—	√	—
Commentaries/reviews/ recommendations/letters				
Ada 2006	—	√	—	√
Blennerhassett 2008	—	√	—	√
Boysen 2009b	—	√	√	√
Gordon 2004	—	—	√	√
Lawrence 2009	—	√	√	√
Mead 2009	—	√	—	√
Morris 2009	—	√	—	√
Shaughnessy 2009	—	—	—	√

CT: controlled trial; RCT: randomized controlled trial.

stroke; however, two [32, 47] interviewed mixed disabled populations (Table 4).

8. Interventions

The RCT included an intervention to increase PA [41] which involved repeated encouragement and verbal instruction about PA from a physiotherapist.

9. Measures

Several surveys used measures developed by the researchers to assess family involvement in exercise [33] self-efficacy, social support for PA [36], and exercise coping [40]. Other surveys used standardised tests to assess barriers to PA [34], barriers to health activities among disabled populations [38, 39], self-efficacy and outcome expectancy [14, 35, 37, 38], and locus of control [39, 40].

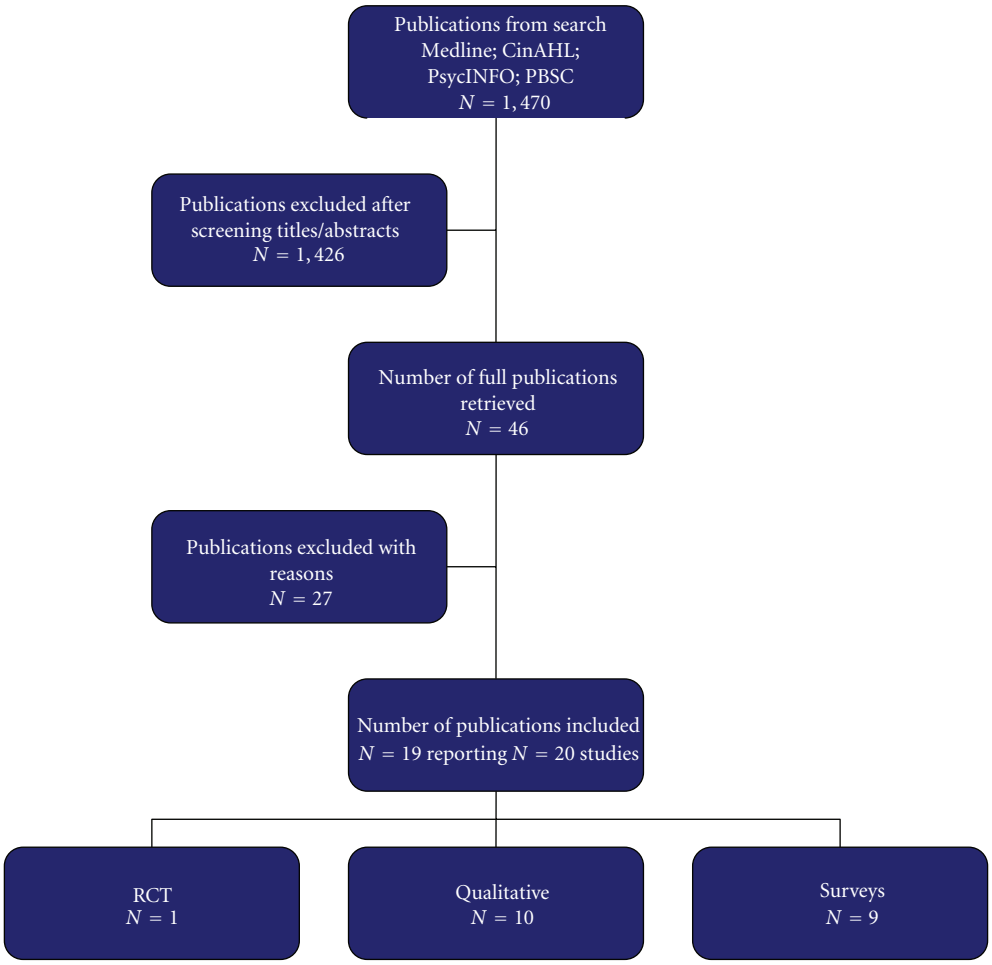

Figure 1: Flow diagram of publications found and included or excluded.

Where they were assessed, PA levels were measured using self-report. For the RCT, the primary outcome measure was the PA Scale for the Elderly [41], the Yale PA Survey was also used [35], and another study used measures developed by study researchers [36]. No study measured PA levels using pedometers or accelerometers.

10. Types of PA

10.1. Quantitative Studies. Types of PA ranged from passive exercise to aerobic exercise [36]; any type of PA aimed at improving a particular skill or ability [33]; type of PA defined by the Yale PA Survey [35]; walking, jogging, swimming, biking, rowing, wheelchair racing, off-road pushing arm-cranking, and so forth [37]; PA of at least 20 minutes duration that caused sweating or increases in respiratory of heart rate [14] and items included in the Physical Activities Scale for the Elderly [41]. Barker examined exercise for the upper limb [39]. Some surveys did not define the type of PA [34, 38, 40].

10.2. Qualitative Studies. Qualitative studies examined views and perceptions of people with stroke in relation to engagement in various physical activities including a seated exercise class [47], treadmill walking [45] exercise on prescription [46], and a conditioning class [32]. Engagement in upper limb exercise [44], exercise and physiotherapy [33], PA in general [42], and exercise versus relaxation classes [10] were also examined. One study did not define type of PA [43].

11. Reported Levels of PA

11.1. Quantitative Studies. The proportion of participants undertaking regular PA varied between 31% reporting regular PA for six months or more [38] to 68% of participants undertaking an unspecified amount of PA since their stroke [34]. One study [34] reported that 32% of participants had stopped PA since their stroke whilst another [14] reported that 27% undertook no PA since the stroke—an increase of 12% from Prestroke levels.

11.2. Qualitative Studies. No qualitative studies reported level of PA undertaken by participants.

12. Methodological Quality

Survey quality was good overall (Tables 5 and 6); however, four [33–35, 38] demonstrated sampling strategies with low

Table 4: Summary of included studies.

Study (first author)	Year	Country of study	Study type	Participants (time since stroke)	Ethnicity	Reports data pertinent to	
						psychological factors	social factors
Kinne	1999	USA	Survey	Not reported	91% Caucasian; 3% African American; 3% Asian American; 1% Hispanic	√	—
Johnston	1999	UK	Survey	10 days–6 months	Not reported	√	—
Cardinal	2004	USA	Survey	Not reported	91.9% Caucasian	√	—
Shaughnessy	2006	USA	Survey	60.2 months	70% Caucasian; 22% African American; 7% other	√	√
Nosek	2006	USA	Survey	Not reported	80.8% Caucasian; 9.6% African American; 6.0% Hispanic	√	√
Resnick	2007	USA	Survey	Not reported	57% Caucasian	√	—
Barker	2007	Australia	Survey	4.9 years	98% nonindigenous; 2% indigenous	√	—
Rimmer	2008	USA	Survey	Not reported	9% Caucasian; 80% African American; 10% Hispanic	√	√
Galvin	2009	Ireland	Survey	Not reported	Not reported	—	√
Boysen	2009	Denmark/Poland/ China/Estonia	RCT	<90 days	Not reported	—	√
Maher	1999	USA	Qualitative	Not reported	Not reported	√	√
Barker	2005	Australia	Qualitative	Mean 4.9 yrs	Not reported	√	√
Damush	2007	USA	Qualitative	<12 months	85% African American, 15% white	√	√
Wiles	2008	UK	Qualitative	Not reported	Not reported	√	√
Resnick	2008	USA	Qualitative	6 months+	47% black, 48% white, 5% mixed, Hispanic or Asian-Pacific	√	√
Graham	2008	Canada/N. Ireland	Qualitative	Not reported	Not reported	√	√
Reed	2009	UK	Qualitative	15–40 months	Not reported	√	√
Carin-Levy	2009	UK	Qualitative	Not reported	Not reported	√	√
Galvin	2009	Ireland	Qualitative	Not reported	Not reported	—	√
Patterson	2009	Australia	Qualitative	Not reported	Not reported	√	√

likelihood of generalisability, due to convenience sampling. All but one study [33] used previously validated measures. Qualitative studies were more varied in quality. All except one [46] were either topical surveys or thematic analyses without sufficient analytical depth to develop conceptual themes or interpretive explanation. Therefore whilst the studies reflected emerging themes, their interpretive contribution towards development of theories that might facilitate new understandings about PA engagement after stroke was limited.

13. Findings from the Included Studies

Detailed information of findings from the quantitative and qualitative studies is provided in the appendix.

Seventeen studies (8 surveys and 9 qualitative studies) reported findings pertinent to the role of psychological factors. Fourteen studies (all qualitative studies, the RCT and 3 surveys) reported findings pertinent to the role of social factors. Table 7 lists the range of psychological and social factors.

Table 5: Methodological quality assessment of the 10 quantitative studies included.

Study	Methodological element			
Surveys	Sampling strategy indicates likelihood of generalizability	Reported good response rate (60%+)	Use of validated instruments	Appropriate statistical testing
Barker et al. [39]	√	Not stated	√	√
Cardinal et al. [37]	√	√	√	√
Galvin et al. [33]	×	√	×	×
Johnston et al. [40]	√	√	√	√
Kinne et al. [38]	×	√	√	√
Nosek et al. [36]	√	√	√	√
Resnick et al. [35]	×	√	√	√
Rimmer et al. [34]	×	×	√	√
Shaughnessy et al. [14]	√	×	√	√
RCT	Adequate allocation concealment	Adequate randomisation	Adequate blinding	Intention to treat analysis
Boysen et al. [41]	√	√	√	√

Table 6: Global assessment of study quality and typologies of study findings of the 10 qualitative studies included.

Study		Typology of study findings				
Qualitative studies	Global assessment of study quality	No findings	Topical survey	Thematic survey	Conceptual thematic description	Interpretive explanation
Barker and Brauer [44]	Strong	—	—	√	—	—
Carin-Levy et al. [10]	Strong	—	—	√	—	—
Maher et al. [32]	Strong	—	—	√	—	—
Reed et al. [43]	Strong	—	—	—	√	—
Wiles et al. [46]	Strong	—	—	√	—	—
Damush et al. [42]	Weak	—	—	√	—	—
Galvin et al. [33]	Weak	—	√	—	—	—
Graham et al. [47]	Weak	—	—	√	—	—
Patterson and Ross-Edwards [48]	Weak	—	—	√	—	—
Resnick et al. [45]	Weak	—	—	√	—	—

Findings from included studies are tabulated in the appendix and summarized in the following section, starting with the psychological factors.

14. The Importance and Role of Psychological Factors

Eight surveys reported data pertinent to understanding the role of psychological factors in the uptake and maintenance of exercise after stroke.

14.1. Self-Efficacy. Four surveys found that self-efficacy for PA, which can be described as appraisal of confidence or capability to perform PA, predicted greater involvement in PA [14, 36] or maintenance of exercise behaviour [37, 38]. Another study [39] demonstrated that confidence to do what needs to be done and helpful information from own efforts were important for self-directed physical activity. Self-efficacy beliefs also varied with activity type [36], with perceived efficacy higher for gentle flexibility than for aerobic exercise. Only one study found that self-efficacy and self-reported exercise levels were not associated [35].

In the qualitative studies, physical impairments after stroke reduced confidence to engage in PA [42, 43]. Stroke led to loss of role and purpose, and unwillingness to participate outside a perceived safe environment [43]. Feeling vulnerable caused anxiety about attending an exercise class [10]. For participants overcoming that barrier, worries about difficulty with speech and social interaction [10] and negative attitudes from others created desire to give up [44].

14.2. Locus of Control. Related to the construct of self-efficacy, greater perceived locus of control for recovery was predictive of recovery in two surveys [39, 40]. However

Table 7: Psychological and social factors for which findings exist.

Psychological factors	Social factors
Self-efficacy	The role of family and friends in supporting PA after stroke
Locus of control	The role of health professionals
Competence to be physically active	The role of exercise professionals
Beliefs about the nature of PA	The role of other people with stroke and disability
Motivational barriers to becoming or remaining physically active	Group exercise
Self-determination as a facilitator to becoming and remaining physically active	
Beliefs about positive and negative outcomes of being physically active	

in one study [40] frequency of exercise at one month after hospital discharge was not correlated significantly with perceived control, suggesting that engagement in exercise was not the coping mechanism by which perceived control improved disability. Furthermore, the relationship between perceived control and disability existed only at one month after hospital discharge, and was not apparent at six months. No study directly examined the role of perceived control on exercise behaviour.

14.3. Competence to Be Physically Active. Beliefs about competence to exercise influenced behaviour. Not knowing how or where to exercise, and beliefs that exercise was too difficult were barriers to PA [34, 38].

In the qualitative literature, focusing on physical limitations, making unfavourable comparisons with previous health and function, coupled with negative comparison to others affected perceived competence to engage in PA [47]. Feeling ill-equipped to engage in PA owing to physical impairments and associated cognitive impairments led to difficulty understanding and remembering information on how to competently engage in PA [42–44]. Furthermore, previous negative experiences leading to repeated failures and frustrations were overwhelming and limited trying [44].

14.4. Beliefs about the Nature of PA. One survey [34] found that lack of interest in exercise and beliefs that it was boring were barriers to PA engagement.

In the qualitative studies, PA was viewed as a meaningful activity and a way to fill time. Having someplace to go and something to do created a sense of purpose [42]. Engaging in regular PA brought structure and routine, all of which encouraged adherence [10, 45]. In contrast, negative attitudes towards PA were also evident. Age limited the amount and type of PA deemed appropriate [42]. PA was considered formal and planned, and not something that could be incorporated into daily life. Leisure time PA such as walking and gardening were not classed as PA [42]. Furthermore, gains from engaging in organised PA were not maintained at home because individuals felt that they had learnt all there was to learn [10].

14.5. Motivational Barriers to Becoming or Remaining Physically Active. Higher perceived motivational barriers were associated with lower levels of PA [37, 38]. Lack of motivation, perceptions of being too lazy, and being tired were barriers to uptake or maintenance of PA [34, 38]. A study of the transtheoretical model [37], also known as the stage of change model, reported different behavioural processes at different stages of behaviour change. Behavioural processes to support the behaviour, such as laying out exercise clothes and sharing intention to be active with others for support were apparent when people were beginning to be active, but were less prevalent in people who maintained PA over a long period. Similarly, cognitive processes such as evaluating and monitoring progress and making oneself consciously aware of the commitment to be active were less prevalent in people who maintained PA over a long period.

Similar motivational barriers were evident in the qualitative studies. Lack of energy and fatigue limited motivation to be physically active [42], and low mood and feelings of depression led to no hope of recovery and reduced motivation to engage [44].

14.6. Self-Determination as a Facilitator to Becoming and Remaining Physically Active. Self-determination, a feeling of "having to do it oneself" was examined in the qualitative studies. It resulted in a "can do" attitude and pushed individuals to engage in PA [32, 42, 44, 45]. Negative attitudes from others acted as a motivator to "prove them wrong" and to push the boundaries of what is achievable, despite physical impairments [44, 47].

14.7. Beliefs about Positive and Negative Outcomes of Being Physically Active. Two surveys demonstrated that belief in positive outcomes of PA predicted increased engagement in PA. In one study [14], advice from a physician enhanced outcome expectations, and positively influenced PA behaviour. Similarly, one study examining the decisions that people made about being active demonstrated that perceived benefits about exercise became greater and perceived disadvantages became lower as people became more active and maintained PA behaviour over a long period [37].

Conversely, beliefs in negative outcomes of PA also potentially influenced engagement. One study showed that health concerns prevented 28% of participants from engaging in PA and also that 36% of participants believed that exercise would not improve their condition [34].

Beliefs around the outcomes of PA were also evident in the qualitative studies. Feeling physically stronger, walking better, improved balance, and less falling were recognised as benefits of PA and acted as motivators to continue [45]. Stroke survivors saw being physically active as essential for recovery and a way to improve fitness and health [43, 44, 46, 47]. Being physically active was seen as an alternative

Table 8: Details of the qualitative studies included in the review regarding method, participants, setting, summary of findings pertinent to psychological and social factors, and notes regarding theoretical models.

Study	Method	Participants	Setting	Summary of findings	Notes
Damush et al. [42]	Qualitative: focus groups $N = 13$	Age: mean = 59 Gender: M = 8, F = 5 Time since stroke = < 12 months 85% AA, 15% white	Country: USA Service: Academic researchers, recruited from health service—local hospital	Barriers and facilitators to engage in PA. Barriers: Psychological: low mood, lack of motivation, and fear (pain, damage, and recurrence) Facilitators: intrinsic motivation, PA as meaningful activity Social: support from family, GP, physio, and other stroke survivors	No theoretical model used to underpin findings
Maher et al. [32]	Mixed methods Qualitative: interview $N = 16$ (4 with stroke)	Age: mean for whole sample ($n = 16$) = 47.5 years Gender: whole sample ($n = 16$) M=40%, F=60% Time since stroke: not reported	Country: USA Service: local government researchers—recruited from local authority run conditioning classes	*Psychological*: PA increased personal control, self-esteem, and feeling of autonomy *Social*: increased self-esteem and independence lessens burden on carers and relationships. PA reduces social isolation, offers chance to meet others with disability—shared experience. Exercise in group acts as motivator to participate and adhere	No theoretical model used to underpin findings
Reed et al. [43]	Qualitative: interviews $N = 12$	Age: >60–73+ Gender: M = 5, F = 7 Time since stroke: 15–40 months, mean 26 months	Country: UK Service: university researchers—recruited from community stroke scheme	*Psychological*: loss of confidence, loss of role/purpose and doubts over competence limit engagement in PA PA increased self-esteem, confidence, and gave sense of achievement—negated fear of falling PA seen as substitute to physio and central to recovery *Social*: ex-instructors important for support and recovery Shared experience—PA offers learning from others, helped reestablish role in life and positive view of social self Group PA fun, increased self-esteem, and encouraged progress	Developed own theoretical model to underpin findings
Barker and Brauer [44]	Qualitative: focus groups and interviews $N = 19$	Age: mean = 64 Gender: M = 12, F = 7 Time since stroke: 4.9 years	Country: Australia Service: physiotherapy researchers—recruited from stroke support groups	*Psychological*: fear of pain and harm, frustration, previous failure, low mood, feelings of incompetence (physical/cognitive), negative attitude from others, lack of self-determination, lack of access all limit engagement in PABut, negative attitudes from others also act as a motivator, and PA seen as important for recovery and progress *Social*: family often supportive but conversely also seen to encourage dependence Therapist important for support and recovery—but need to encourage self-management.Group PA offers camaraderie, humour, and information exchange	Developed own theoretical model to underpin findings

Table 8: Continued.

Study	Method	Participants	Setting	Summary of findings	Notes
Carin-Levy et al. [10]	Qualitative: interviews $N = 14$	Age: range 45–85 Gender: M = 8, F = 6 Time since stroke: not reported	Country: Scotland Service: academic researchers, recruited from RCT	*Psychological*: vulnerability, anxiety, fear of falling, and concerns about communication act as barriers to PA Once engaged in PA: increased confidence and reduced anxiety PA offered feeling of empowerment—increased feelings of control PA class either acted as motivator to exercise at home or conversely PA not maintained as had learned all there was to learn *Social*: shared experience important—not feeling alone PA in group important for social self, valued social interaction, and group exercise fun	Locus of control discussed in part explanation of results
Resnick et al. [45]	Qualitative: focus groups or telephone interviews $N = 29$	Age: over 45 Gender: M = 55, F = 45 Time since stroke: at least 6 months after stroke	Country: USA Service: academic researchers, recruited from community, attended university medical centre	*Psychological*: intrinsic self-determination, sense of routine, monitoring of health, and feeling physically better all motivators to engage in PA Offered increased sense of independence, offered something to do, helped keep active, and was enjoyable *Social*: support from family, health professionals, ex instructors encouraged adherence Not group based, but social interaction during transportation also encouraged adherence	Aspects of SCT self-efficacy used to underpin findings
Galvin et al. [33]	Mixed methods Qualitative: focus groups (10 physios) stroke 40 male, 35 female	Age: not reported Gender: not reported Time since stroke: not reported	Country: Ireland Service: physio researchers	*Social*: physios see family/friends play important role in rehab—continue work of physio Eases transition from acute to community family members often motivated to help with rehab although also acknowledged that family can be too critical, too intense, or too emotional	No theoretical model used to underpin findings

Table 8: Continued.

Study	Method	Participants	Setting	Summary of findings	Notes
Graham et al. [47]	Qualitative: interviews $N = 11$ (5 stroke) Interviewed initially, 3 months, and 6 months	Age: not reported Gender: M = 5, F = 0 Time since stroke: not reported	Country: Northern Ireland/Canada Service: clinical psych researcher (NHS), recruited from community day centre	*Psychological*: focusing on disability and comparison with premorbid function and others = low self-confidence = barrier to PA. Conversely, PA seen as way to improve mood and offers encouragement to try other things and improve health PA offers way to replace loss of identity/role—competent and athletic versus disabled PA seen as way to push boundaries of society's idea of disability PA retained role of active person and continued engagement in competitive sport—change perceptions of disablement *Social*: PA with others provides reference point for one's own physical ability—either offers encouragement or conversely not conducive to progress—"no hopers" group PA fun and important opportunity for interaction and way to connect socially and regain degree of independence	Aspects of SCT self-efficacy used to underpin psychological factors Self-determination theory—increased autonomy and competence and social interaction increases intrinsic motivation to engage in PA
Wiles et al. [46]	Qualitative interviews with stroke survivors ($N = 9$) and ex-professionals ($N = 6$) and focus groups and interviews physios ($N = 15$)	Age: mean = 18–78 Gender: M = 8, F = 1 Time since stroke: not specified 1993–2003	Country: UK Service: community EoP	*Psychological*: stroke survivors motivated to engage to maintain health and fitness and as alternative to physio after rehab, but ultimately just want more physio Physio see EoP as a bridge, ex professional see it as way to control own ex-regime *Social*: physios role seen as very important—stroke survivor seeks presence of physio throughout EoP—want more interaction between physio and ex professional. Physio uncomfortable as could encroach on ex professional domain Ex professional role—stroke survivors "left to own devices" and concerns reexpertise from stroke survivors, carers and physio. Ex professional confident in own ability but open to specialised training Group exercise: limited interaction with other stroke survivors. Physio see opportunity for learning but acknowledge limited interaction based on own experience. Ex professional think EoP social	No theoretical model used to underpin results

Table 8: Continued.

Study	Method	Participants	Setting	Summary of findings	Notes
Patterson and Ross-Edwards [48]	Qualitative interviews with stroke survivors ($N = 10$)	Age: mean = 59.8 Gender: M = 6, F = 4 Time since stroke: not reported	Country: Australia Service: community Stroke maintenance exercise class	*Psychological*: PA improved confidence and increased motivation, within group exercise class setting, but also in achieving goals within the community Offered hope for recovery when see others with greater disability engaging and progressing in PA, which motivated to continue Self-efficacy: exercise class offered practical, emotional, and social support. PA increased feelings of confidence, motivation, and associated improved self-efficacy, leading to minimisation of physical symptoms and perceived improved functioning in daily activities *Social*: presence of health professionals important role in guiding exercises to do, but also in accessing ongoing support not accessible in community Observing other stroke survivors achieving personal goals/making progress motivator to continue with PA and achieve own goals. Social support from other group members offered encouragement to attempt new exercises and challenge self-perceived limitations Social benefits of exercising in a group setting important as they allow for exchange of experiences, support, and information with other stroke survivors. Created feeling of belonging and sense of community	Aspects of SCT self-efficacy

Table 9: Details of the quantitative studies included in the review regarding: method, participants, setting, summary of findings pertinent to psychological and social factors, and notes regarding theoretical models.

Study	Methods	Participants	Setting	Findings	Notes
Rimmer et al. [34]	Survey: barriers to physical activity and disability survey	$N = 83$ 54.2 (8.2) 30 M, 70 F not reported	USA Health promotion programme	*Psychological*: competence: not knowing how and where to exercise main personal barriers to exercise, reported by 46% and 44% of participants. Motivation: lack of motivation ranked 4th personal barrier by (37%) of participants. Too lazy to exercise ranked 6th personal barrier by 33% of participants. Beliefs: 36% reported belief that exercise will not improve condition *Social*: importance of exercise professionals: personal trainer or exercise instructor unable to help reported by 36% of participants	No theoretical model used to underpin questionnaire or findings
Galvin et al. [33]	Survey: family-mediated exercise survey	$N = 73$ people with stroke 40 F, 35 M Age not reported $N = 100$ family members/friends 71 F, 29 M	Ireland Hospital physiotherapy services	*Social*: 91% of respondents with stroke believed that family member/friend had a role in assisting them with exercise after rehabilitation. 99% of family members/friends reported they would be willing to help with exercise after rehabilitation	No theoretical model used to underpin questionnaire or findings Not clear how questionnaire was developed. Validity and reliability not reported
Shaughnessy et al. [14]	Survey using the Short Self-Efficacy for Exercise Scale and the Short Outcome Expectations for Exercise Scale	$N = 321$ Age 62.9 (11.7) F 177, M 127 60.2 months after stroke	USA Mailed survey distributed via the National Stroke Association	*Psychological*: self-efficacy, outcome expectations, exercise behaviour before stroke, and physician advice to exercise significantly associated with exercise behaviour. These variables predicted 33% of variance in exercise behaviour. Older participants and those experiencing fatigue had lower self-efficacy for exercise. Exercise history also significantly predicted exercise behaviour	Low response rate from national survey, attended stroke support groups therefore likely to be motivated
Johnston et al. [40]	Longitudinal survey assessing outcomes at 10–20 days, one month after discharge, and six months after discharge Measures: (i) the recovery locus of control scale (ii) Exercise coping self-rating for frequency and duration (iii) HADS (iv) Barthel Index (v) Observer assessed disability	$N = 71$ Age 69.4 years 35 F, 36 M 10–20 days after stroke to 6 months after stroke	Scotland Acute inpatients followed up after discharge	*Psychological*: perceived control predicts recovery from disability after stroke. Frequency of exercise not correlated with one month recovery locus of control ($P > 0.05$), nor with observer assessed recovery at 6 months ($P > 0.05$), suggests that exercise not a coping response that medicates between control cognitions and recovery	Amount of explained variance is small Some measures designed for the study—validity and reliability not tested fully

Table 9: Continued.

Study	Methods	Participants	Setting	Findings	Notes
Cardinal et al. [37]	Survey National cross-sectional survey of individuals with disability Stage of change algorithm to assess stage, process of change measure, self-efficacy scale, decisional balance scale, and exercise barriers scale	$N = 322$ 52.5 (13.9) years 62% F Disabled population Stroke: $n = 18$	USA Recruitment by targeting voluntary organisations and hospitals	*Psychological*: transtheoretical model used to examine what constructs associated with stages. All major constructs associated with the stages of change. Largest portion of variance derived from behavioural processes of change and self-efficacy. Cognitive processes decrease and behavioural processes increase with stage progression. Cons decrease and pros increase with stage progression, self-efficacy increases with stage progression *Social*: helping relationships significantly associated with stage	Stroke participants formed only small proportion of sample therefore generalisation difficult Unable to extract specific data about behavioural processes and cognitive processes used
Nosek et al. [36]	Survey Physical activity Social support Environmental factors Impairment and functioning (SF-36 physical functioning and role limitations) Psychological factors (SF36 mental health, role functioning emotional, self-efficacy) Social factors CHART short form and MOS social support survey	$N = 386$ 47.1 (10.1) years 386 F Stroke $n = 25$ (6.5%)	USA National survey recruitment via disability service organisations and print and broadcast media	*Psychological*: self-efficacy highest for gentle flexibility, lowest for aerobic exercise 3 × per week. Physical activity significantly correlated with self-efficacy ($r = 0.50$, $P < 0.0001$) Model predicted 33.5% of variance. Self-efficacy predicts greater involvement in physical activity, pain and duration of disability predictive of less physical activity ($F(7, 268) = 19.27$; $P < 0.0001$) *Social*: physical activity significantly correlated with level of personal assistance ($F(6, 269) = 2.23$, $P < 0.05$)	Physically active population with 73% engaging in physical activity once a week. Self-report of physical activity Disabled sample, self-selected, and few people with stroke
Kinne et al. [38]	Survey Sickness Impact Scale Stage of change Self-rated abilities for health: self-efficacy and outcome expectancy Barriers to health Activities for disabled persons	$N = 83$ Age 47 (1.4) years Stroke 7% of sample	USA Community dwelling, recruited via disability support groups	*Psychological*: self-efficacy significantly higher for participants maintaining exercise ($P < 0.0001$) Motivational barriers scores significantly lower for exercise maintainers ($P = 0.0006$) People with higher motivational barriers less likely to maintain exercise ($P = 0.01$). Those with higher maintenance self-efficacy higher probability of maintenance Information about what to do a barrier to exercise behaviour ranked 4th behind impairment, money, and accessible facilities	Small proportion of sample are people with stroke Although some participants indicated that they were less active in previous year, reasons for this not explored External factors, access to facilities, transportation, money, social support, and physical and functional status not predictive of maintenance
Boysen et al. [41]	RCT primary outcome: Physical Activity Scale for the Elderly	$N = 314$ people with stroke able to walk unassisted Intervention group $n = 157$ Control group $N = 157$ Age 69.6 years (59.6–77.7) <90 days after onset	Centres in Denmark, China, Poland, and Estonia stroke units	No significant difference between the groups on PASE at 3,6,9,12, 18 or 24 month followup	Self-reported levels of physical activity—not assessed by accelerometer, pedometer, and so forth, or by other fitness measures. No qualitative evaluation of involvement in PA made

to physiotherapy, although more physiotherapy was the preferred option [43, 44].

With regards to affective outcome expectations [17], fear of falling, pain, failure, stroke recurrence, and worries about doing the wrong thing or being embarrassed were seen as negative outcomes of PA and acted as barriers to engaging [10, 32, 44]. However, PA was also seen as being fun and enjoyable, and as a way to help ease feelings of depression, and increase energy levels [10, 43, 47]. Being physically active eased anxiety, built confidence, increased self-esteem, and offered a sense of achievement and pride [10, 32, 43]. This had a cumulative effect as improved confidence and higher self-esteem negated fears [43] and motivated individuals to engage in new activities both within the exercise setting, but also in achieving goals within the wider context of their life [32, 47, 48].

15. The Importance and Role of Social Factors

15.1. The Role of Family and Friends in Supporting PA after Stroke. The study by Galvin et al. [33] focused on the role of the family in exercise after stroke. The study was methodologically weak but demonstrated that 91% of participants with stroke agreed that a family member or friend had a role in their exercises after stroke. 91% of family or friends reported willingness to assist in physiotherapy and 85% to assist in more complex exercises involving walking and transfers. A small proportion of the participants with stroke indicated that they felt that this was not the role of their family or friends, and they did not feel confident in their capacity to assist or felt that family or friends would put them under too much pressure.

Differing views regarding the role of family and friends in supporting PA were also evident in the qualitative studies. For some stroke survivors, family and friends were central to recovery, and their support and encouragement motivated engagement in PA [44, 45]. Others, who lived on their own, felt being alone forced them to be more independent and to do more for themselves [44].

15.2. The Role of Health Professionals. Barker reported that lack of help from health professionals was negatively associated with uptake or maintenance of activity. Shaughnessy et al. [14] concurred with that finding, demonstrating that recommendations to exercise predicted higher levels of activity. In contrast, in the RCT, repeated instructions from a physiotherapist to be physically active did not increasing PA levels more than information about possible benefits of PA [41]. One survey reported that having a personal assistant was important for PA [36]. Cardinal et al. [37] also reported that helping relationships were predictive of stage of change for PA.

In the qualitative studies, physiotherapists were perceived as central to recovery after stroke, and therapy was considered essential to improving physical function and maintaining progress. Physiotherapy exercises were seen as a way to maintain PA levels, within rehabilitation and community settings [42, 44, 46, 48]. Physiotherapists were also seen as important for emotional support. Stroke survivors sought continued access to physiotherapists when engaging in PA in community settings, for guidance and reassurance [46, 48]. However, although support from physiotherapists was highly valued, it was acknowledged that they offered little information on self-directed exercise, and that they should place more emphasis on teaching stroke survivors how to exercise independently [44].

Stroke survivors in one study [44] felt supported by physicians, and followed their advice to engage in PA. In contrast, stroke survivors in another [42] experienced negative attitudes from health professionals regarding their physical recovery. This acted as a motivator to engage in PA to "prove them wrong."

15.3. The Role of Exercise Professionals. In the qualitative studies, exercise professionals were seen to play an important role in teaching stroke survivors how to exercise independently [43]. Their presence increased feelings of safety, and their verbal encouragement and support led to improved confidence and increased self-efficacy [45]. Some concerns emerged about the level of support they could offer. Survivors were concerned about lack of monitoring and being "left to their own devices" too much [46]. The level of stroke expertise of exercise professionals concerned stroke survivors, carers, and physiotherapists [46]. This led stroke survivors to seek physiotherapist attendance during community exercise programs.

15.4. The Role of Other People with Stroke and Disability. The qualitative studies discussed the role of other people with stroke and disability. In one study [47], exercising with others with disability was viewed as a negative experience by one individual who felt that exercising with "no hopers" did not encourage progress. Otherwise, exercising with other stroke survivors and people with disabilities was viewed positively, offering opportunities to interact with individuals who had insight into the physical consequences of stroke [32, 43]. The sense of shared experience reduced feelings of loneliness and social isolation [10, 42, 43]. Being with "others in the same boat" invoked a sense of camaraderie and was seen as an opportunity to give and receive information and support [43, 44]. It was also seen as an opportunity for comparison. Facing disabilities of others acted as a reference point for one's own physical ability, and challenged self-perceived limitations [32, 47]. Observing other stroke survivors with a greater degree of disability engaging in PA and progressing, also offered hope for recovery [48]. Further, seeing others achieving acted as a motivator for continued engagement in PA to achieve personal goals [47, 48].

15.5. Group Exercise. Group exercise was seen as enjoyable and fun in the qualitative studies [10, 43]. It offered opportunities to connect socially and cultivate friendships [32, 47]. However, social involvement depended on the type of activity undertaken. Group exercise in a gym was seen as offering limited potential to meet other people [46].

Group exercise acted as a motivator to engage in PA. Perceiving oneself as being part of social group, resulted in implicit pressure to maintain attendance, as group members were reluctant to let both the instructor and other members down [42, 45]. Group exercise also increased levels of participation in PA. Social support from other group members offered encouragement to attempt new exercises and challenged negative perception of ability [43, 48].

16. Discussion

Studies of the general population indicate that psychological and some social influences on PA behaviour may be modifiable through intervention [17, 19]. In this structured review we considered the extent to which psychosocial factors influencing uptake and maintenance of PA after stroke is understood. Beliefs and attitudes about the activity, self-efficacy beliefs, or perceived control over behaviour, in addition to social support did in fact appear to be important for exercise behaviour after stroke.

It is clear from the nature and focus of the 20 studies included in this review, whilst relevant data exists to understand the role of psychosocial factors in exercise uptake and maintenance, this field of enquiry in stroke is in its infancy. The majority of included studies were exploratory qualitative studies examining experiences of participants with stroke, or cross-sectional surveys involving correlation-based theory testing. Only one trial, examining the effects of an intervention on reported PA levels, provided data regarding psychosocial factors. Furthermore, only two quantitative studies [40, 41] involved longitudinal assessment. Thus little is known about factors influencing patterns of uptake and maintenance of activity over time in this population.

Nevertheless, this review demonstrates the emerging evidence base examining PA behaviour after stroke that is mostly methodologically sound. However, studies have been predominantly conducted in the USA, often with minority ethnic populations [34, 42], therefore generalisation of findings internationally is not yet possible.

16.1. The State of the Evidence Base. Despite limitations of the field, and the necessary limits on our search strategies, one of the strengths of this evidence base is that it includes both qualitative and quantitative studies. Whilst the quantitative studies examined researcher derived theoretical constructs, the qualitative studies explored and described experiences and views of people with stroke, identifying what factors were important to stroke survivors. Consideration of qualitative and quantitative findings may enable us to identify and develop strategies to address gaps in the quantitative literature that are highly relevant to peoples' experiences and perceptions.

Most studies were conducted with community-dwelling participants, with only two recruiting in-patient participants [33, 40]. Strategies to support self-management of long-term engagement in PA necessarily occur in community settings after rehabilitation is complete, therefore the target population for these studies was appropriate. However, the time of transition between the end of rehabilitation and living in the community may present an opportunity for targeted interventions in which to shape long-term self-directed PA behaviour therefore understanding factors that might influence behaviour at this time is vitally important. Only one study was undertaken during this period [40].

Of the ten survey studies, only seven exclusively examined a stroke population. Similarly, two qualitative studies included participants with other disabling conditions. We included these mixed studies since all involved some participants with stroke, whilst acknowledging that differences in psychological, cognitive, and physical differences between conditions may make generalising findings to a purely stroke population difficult.

Definitions of PA varied across studies, from passive exercise to [36] undefined exercise that caused sweating and increased heart rate [14] to PA in general [42]. Participants in the qualitative studies referred to a greater range of activities, and activities for leisure and enjoyment such as walking and fishing were not classified as PA [42]. The lack of clear definition of what is meant by PA after stroke, presents a challenge to researchers, since their definition of PA may vary from that of participants. Participant definitions of PA may also be diverse, depending on previous experiences and opportunities available after the stroke. For progress in terms of understanding engagement in PA to occur in this field, clarity in terms of exertion involved, types of PA should be clearly defined, as well as mode of engagement, such as dose frequency and intensity, since these parameters may influence enjoyment, perceived confidence to participate, and likely uptake. Of those studies that did measure PA levels, measurement was undertaken using subjective self-report rating scales. None of the studies conducted objective measurement of PA level using pedometers or accelerometers, therefore assessment of impact of psychosocial factors on actual PA levels may not be accurate. Future studies should include more accurate assessment of PA.

16.2. Psychological Factors. The use of health behaviour models in the reviewed literature was limited, with few studies explicitly using any theoretical models in their entirety. Generally models were applied to investigate a single mediating construct such as self-efficacy or outcome expectations, outside a complete theoretical framework [14, 35, 36, 38]. Whilst it is clearly of importance to understand the correlations between individual variables and exercise behaviour, for theoretically based intervention development it is necessary to understand all the constructs likely to determine behaviour change. The qualitative studies rarely analysed findings in relation to health behaviour models or developed new theoretical models to explain the findings. The studies including participants with disability and not just stroke applied constructs from theoretical models of behaviour more consistently [36–38], a finding that may reflect the greater maturity of that field of study. The limited use of application of theoretical models to explain or change PA in the stroke studies may be an indication of immaturity of this field of study, and possibly reflects the fact that it falls at the intersection between therapy

and physical outcomes research and behavioural psychology. If the field is to mature and optimal interventions are to be developed, tested and applied in practice, it is vitally important for multidisciplinary research to emerge that evaluates the behavioural as well as the physical aspects of PA.

Although there was no evidence of evaluation or application of theoretical models to develop interventions to support PA, the reviewed literature hints at some approaches that might be taken to progress the body of knowledge and practice. Of the psychological constructs examined in the extracted survey research, the mediating variable self-efficacy was the most common and most reliable predictor of exercise behaviour in the quantitative literature. It was also evident in the qualitative studies as loss of confidence for getting to places in which supported exercise occurs and for interacting with people there as well as for the PA itself, reflecting a range of specific self-efficacy beliefs that impact on the likelihood of a person with stroke becoming physically active. The observation of the importance of self-efficacy beliefs in determining PA behaviour is in line with many studies of the general population [17, 26], the elderly [49], clinical populations such as cardiac patients in rehabilitation [50], and people with multiple sclerosis [51].

Two studies showed that internal locus of control influenced physical *outcome* [39, 40] as opposed to PA behaviour. Possibly because it appears to apply to general perceptions of health construct than self-efficacy which is behaviour specific, there is limited evidence that locus of control is predictive of exercise behaviour from other populations [18, 49]. However, given the findings reported in our included studies that it may influence physical outcomes, perceived locus of control requires more investigation with stroke populations.

Beliefs about positive or negative effects of PA emerged from many of the studies [10, 14, 32, 34, 37, 39, 43–47]. These beliefs are considered theoretically to be important determinants of attitude and intention to be active and have been shown to be associated with exercise behaviour in many studies with clinical populations [17, 26, 49, 51].

Affective responses appear important in influencing PA after stroke. Feelings of depression, fatigue, and lack of motivation led to decreased desire to be physically active [42, 44]. These barriers are known to influence engagement in PA in clinical and general populations [26, 51–53]. Dwelling on previous health and functioning and drawing unfavourable comparisons with others led to a lack of confidence and trust in ability to negotiate barriers to PA [44, 47]. In addition, loss of purpose and the perceived attitudes of others towards disability after stroke led to reluctance to try new things, and instead stay in a safe environment [43]. The negative influence of the perceptions and attitudes of others is well documented in studies with disabled and clinical populations [54–56]. Clearly, feeling uncomfortable, self-conscious, and socially anxious undoubtedly limits the likelihood of a person with stroke engaging in PA.

However, some findings point to links between positive affect and PA. An inner drive and self-determination pushed individuals to engage in PA and facilitated goal-setting. Goal achievement was viewed as a step towards recovery and acted as motivator for continued PA [32, 42, 44, 45]. The importance of self-determination in physical activity behaviour is congruent with studies of the general population, where engaging in PA is most likely to occur when the person has internal motivation to do so [57, 58].

Competence in knowing what to do and how to do it was associated with better recovery [44] whilst perceiving that exercise was too difficult was reported as a barrier to PA [34]. The qualitative literature supported this finding, showing that negative experiences in which success did not occur influenced perceptions of competence and motivation for PA [44, 47]. Clearly, perceptions of skillfulness are important in influencing motivation for PA after stroke. Several theoretical models include perception of competence, suggesting that where achievement can be demonstrated, motivation is likely [54].

16.3. Social Factors. Social factors received comparatively less attention from researchers than psychological factors. Furthermore, the discussion of social factors was far less embedded in theoretical frameworks than the identified psychological factors.

Help from health professionals appears important in determining recovery [42, 44], and advice and helping relationships appear important in determining PA levels [14, 37]. However, the only included trial shows that an atheoretical intervention delivering advice and information from health professionals was not effective in increasing PA [41]. This finding is in line with many studies which demonstrate that information provision is not enough to change behaviour [59].

Many benefits were perceived from exercising in a group with other stroke survivors [10, 32, 42, 43, 47, 48]. Group exercise was seen as being fun and providing social opportunities and motivation through group pressure and hope for recovery. These findings concur with quantitative research in general populations which show that social support is a consistently important correlate of PA [26].

Opportunities to exercise together are clearly important to consider when developing intervention strategies to support PA after stroke given that being with others appears to enhance adherence and activity levels and to challenge perceptions of self as a disabled individual. Clearly strategies to encourage people to attend organised activities will be critical to achieving these benefits.

Family were seen on the whole as being helpful [33, 44, 45]; however, some studies also reported that they could be too critical or emotional [33], or not sufficiently confident to help [33]. The over protective or critical role of family when someone is recovering from stroke has been previously reported [60] and suggests that interventions to support PA need to involve the entire family. Interventions need to address attitudes and beliefs about their role and raising self-efficacy beliefs for supporting their family member with stroke.

16.4. Candidate Theoretical Models for Intervention Development. The psychological and social factors identified in this

review point to candidate theoretical frameworks that may be useful in development of behavioural interventions that support uptake and maintenance of physical activity. One such model is the Transtheoretical Model [21] which is also known as the Stages of Change Model. This model evaluates and individual's readiness to change their behaviour. It suggests that people change behaviour in stages, from not being interested in the behaviour (precontemplation stage) to thinking about it (contemplation) to adopting (action stage) and to engaging in it long-term (maintenance). The model provides strategies to guide the individual through five stages to long term maintenance and includes self-efficacy as a key construct. Movement through the stages is underpinned by a number of social and psychological processes of change [21].

One of the disability studies in this review [37] found that the social and psychological factors did predict stage of change suggesting that the model is applicable to disabled populations. The model has been used in a number of clinical populations to improve PA behaviour and outcomes [61]; however, its effectiveness in supporting long-term adoption of PA has been challenged [59, 60]. Other stroke research has shown that the stages of change apply to stroke populations [61]. The fit of the social and psychological factors at each stage and through stage progression, however, requires replication in a stroke population before it is possible to be certain of this model as a candidate for behaviour change interventions in this population.

Another candidate theoretical model commonly used in PA research [59] is the Theory of Planned Behaviour (TPB) [23], which specifically targets intention to change behaviour, and has been used successfully in PA research [60]. Our findings show that friends and family are very important in supporting PA behaviour after stroke. With its emphasis on beliefs as a precursor to intention and its consideration of subjective normative beliefs, or beliefs about what others think about the behaviour, this model may be of particular use in encouraging adoption of PA in stroke. The evidence suggested that self-efficacy was also important for physical activity after stroke. The TPB includes perceived behavioural control as a construct that is allied to self-efficacy and suggests that strategies to enhance control over the behaviour may be effective in enhancing PA [59]. These might include experience of successfully enacting the behaviour, vicarious experience, that is, observing others perform the behaviour, and physiological feedback compatible with successful performance [59].

Strategies to apply these models to behaviour change may include individualised and tailored information provision and persuasion, approaches to increase skills through rehearsal and modelling, planning of behaviour, and setting goals as well as provision of social support, such as stroke specific group exercise or buddying support [59]. Self-monitoring and other self-regulatory skills, including setting and reviewing behavioural goals and obtaining feedback on performance are considered key to the effectiveness of behaviour change interventions [61]. With the exception of the study examining the Transtheoretical Model in which self-regulatory processes are incorporated [37]; these skills were not discussed or included in the stroke review. Clearly in developing new theoretically based interventions to support PA behaviour after stroke, it is of critical importance to evaluate how best to incorporate such strategies into interventions.

Another challenge is that individuals with stroke probably experience activity limitations due to more than only one condition, especially with increased age. The cumulative impairment may be modulated differently through psychosocial factors, compared to people who only have single diagnosis. Moreover, stroke is a complex condition, which may not only affect mobility but also communication, cognition, affective expression, and opportunities for social engagement. The literature so far has not sufficiently addressed the diversity of this population. For example, it is not clear whether psychological constructs hold true for people with altered cognitive functioning. Similarly, the social barriers and facilitators to exercise for people who experience aphasia after stroke are not well understood. Finally, as pointed out in the introduction, psychosocial factors are only one piece of the puzzle in the understanding of exercise activity after stroke. They interact with demographic, environmental, value, and societal factors, which have not been considered as part of this review. However, not acknowledging these factors would unjustly locate issues around nonadherence to exercise recommendations exclusively in the individual, while failing to acknowledge the physical environment and socioeconomic context in which people live.

17. Conclusion

This review demonstrated that there is an evidence base that begins to help us understand the role and importance of psychosocial factors in the uptake and maintenance of PA after stroke. Self-efficacy and PA beliefs appear particularly relevant constructs and should be taken cognisance of enhancing the development of theoretically based physical interventions. Theoretical frameworks such as the Transtheoretical Model and the Theory of Planned Behaviour are candidate models that may support intervention development. However, whilst our review shows that psychological constructs have been examined in relation to PA after stroke, it is clear that behavioural change theories are often not discussed in empirical publications on physical activities after stroke, and this is an area for future investigation. Social factors such as family support and opportunities to participate in group exercise are likely also to be important in PA engagement. However, the psychosocial factors are only part of a very complex picture of determinants of PA and further evaluation of health, sociodemographic, and environmental factors must be also evaluated.

Appendix

See Tables 8 and 9.

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Clinical Study

Previous Leisure-Time Physical Activity Dose Dependently Decreases Ischemic Stroke Severity

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In the present subanalysis of a cross-sectional study showing the favorable effect of prior transient ischemia, leisure-time physical activity, and lipid-lowering drug therapy on stroke severity, we aimed to evaluate whether previous physical activity was dose dependently associated to minor stroke (NIHSS 0–3) and to identify possible underlying factors. Among 362 consecutive patients, less severe stroke was related to weekly exercise duration prior to stroke (no exercise: 36.1%; <2 hours: 49.3%; 2–5 hours: 58.8%; >5 hours: 64.0%; $P = 0.003$). Only weak and moderate exercise practices were protective (weak: 50.0%; moderate: 79.3%; heavy: 22.2%; $P < 0.0001$). Such a beneficial effect was observed independently of age and was associated with a trend to a lower frequency of arterial hypertension, alcohol abuse, and a better metabolic profile. Besides other therapeutic approaches, physical activity may be a simple way to decrease cerebral ischemia severity.

1. Introduction

Meta-analyses of epidemiologic studies have consistently suggested the risk reduction of both ischemic and hemorrhagic strokes when practicing regular physical activity [1–3]. Such a preventive effect, that may be more important in men than in women [3], could be very impressive, since the relative risk of stroke incidence and mortality could be reduced from 25% (cohort studies) to up to 64% (case-control studies) in active individuals as compared to nonactive counterparts [1, 2]. Several plausible mechanisms by which physical activity might reduce stroke risk has been discussed as reducing blood pressure or improving lipid profiles, endothelial function, and haemostatic and inflammatory parameters [1]. Beyond the decrease of stroke incidence, it could also be postulated that physical activity could lead to the reduction of stroke severity, since both experimental and clinical data provide some arguments about a possible preventive neuroprotection [4–8].

In a previously published study [6], we showed that previous leisure-time physical activity as well as prior transient ischemic attack and lipid-lowering drugs therapy are independent predictors of lesser stroke severity and better short-term outcome. In this context, at least 2 other studies provide similar results, but little is known about the possible underlying mechanisms [7, 8]. In the present analysis, we aimed to focus on the impact of previous leisure-time physical activity on initial stroke severity. To provide some explanations about such a possible beneficial effect, we analyzed patients' clinical and biological profiles. Taking into account both the duration and the type of previous physical activity and adjusting on a number of possible confounders, we evaluated whether previous physical activity was dose dependently associated to minor stroke.

2. Materials and Methods

2.1. Study Population. Population characteristics and methodological design of the study have been already published

and extensively detailed [6]. Briefly, we studied consecutive patients with an acute ischemic stroke who were admitted to the stroke unit of the Lille University Hospital, France. The inclusion criteria were (1) clinical symptoms and signs attributable to cerebral ischemia of <24-hour duration (onset of symptoms was defined as the last time the patient was free of any symptoms) and (2) acute or subacute cerebral computed tomography or magnetic resonance with changes typical of acute hemispheric cerebral infarction.

2.2. Main Data Recorded. For each patients, we recorded the following data: demographics, vascular risk factors, previous treatments, severity of the neurological deficit by the National Institutes of Health Stroke Scale (NIHSS), blood pressure, body temperature, fasting glycemia, cholesterol, triglycerides, and fibrinogen at admission, the presence, weekly duration (less than 2 hours, between 2 and 5 hours, more than 5 hours), and intensity (weak, moderate, or heavy) of previous leisure-time physical activity [6, 9], and cognitive status with the mini mental state when assessable and functional outcome as measured with the modified Rankin scale (mRS) and the Barthel index (BI) at 8 days. An NIHSS of 0 to 3 at admission was considered as minor stroke, while an mRS of 0 to 1 or BI of 95 to 100 at 8 days was considered favorable short-term outcome.

2.3. Statistical Analysis. To precisely analyze the impact of previous regular physical activity on the occurrence of a minor stroke and to determine the possible underlying factors, we performed univariate analysis comparing patients with previous physical activity and patients without using the $\chi 2$ test with Yates' correction or Fisher's exact test when appropriate, odds ratio (OR) with 95% confidence intervals (CI), and the unpaired t-test or Mann-Whitney U test. In a second step, we performed stepwise logistic regression analyses with NIHSS 0 to 3 as dependent variable and previous leisure-time physical activity, physical activity duration, or physical activity intensity as main criteria. Other covariates included in the model were those assessable at admission. These variables were selected from the results of previous univariate analyses with a $P < 0.25$ level as screening criterion [6]. Colinearity between variables (defined as $r > 0.6$) was also excluded. Adjusted OR and their 95% CI were then calculated. Logistic regression analyses were also performed to measure the possible interactions between previous leisure-time physical activity and variables selected to adjust the model. Finally, we also compared patients with previous physical activity and patients without by taking into account different age subgroups (<65 years, 65–75 years, >75 years). All the statistical procedures were computed using the SPSS-15.0 for windows package.

3. Results

Main characteristics of the study population have been extensively described before [6]. Of the 362 patients (median age 70, range 16–97) included in the study, 167 (46.1%) were men, and 132 (36.5%) had a regular physical activity before stroke. According to predefined criteria [6, 9], the intensity of previous leisure-time physical activity was considered as weak in 94 patients (26.0%), moderate in 29 (8.0%), and heavy in 9 (2.5%) when weekly duration was less than 2 hours in 73 (20.2%), between 2 and 5 hours in 34 (9.4%) and over 5 hours in 25 (6.9%). Patients with previous leisure-time physical activity were more likely to have a minor stroke or a better short-term outcome, but the proportion of TIA and brain infarction remained similar (Table 1). Concerning possible underlying factors, patients with a previous physical activity were more likely to be younger and men (Table 1). Apart from smoking, they also were less likely to have vascular risk factors and to receive chronic treatments (Table 1). Physiological and biological parameters at admission were also more likely to have better values, while stroke etiologies were more likely to be cervical artery dissections rather than the consequence of cardiac embolism or atherosclerosis disease (Table 1).

Adjusting on age, sex, arterial hypertension, diabetes, smoking, previous ischemic or congestive heart disease, and peripheral arteriopathy (according to colinearity prior treatments were not included in the model), we found a dose-dependent effect of physical activity duration on the initial stroke severity (Figure 1). The proportion of patients admitted for a minor stroke increased in parallel to the weekly duration of previous physical activity (no exercise: 83 (36.1%); <2 hours: 36 (49.3%); 2–5 hours: 20 (58.8%); >5 hours: 16 (64.0%); $P = 0.003$). In terms of intensity, the favorable effect of previous physical activity was observed in patients who did weak or moderate exercises when heavy exercise may lead to deleterious consequences (proportion of minor stroke; weak: 47 (50.0%); moderate: 23 (79.3%); heavy: 2 (22.2%); $P < 0.0001$)(Figure 1). Furthermore, none of the interactions between previous leisure-time physical activity and covariates used to adjust the model was positive (result not shown).

Finally, the favorable effect of previous physical activity on initial stroke severity or short-term outcome remained whatever the age subgroups (Table 2). In this way, there also was a trend for an association between previous physical activity and a lower frequency of deleterious conditions such as arterial hypertension and alcohol abuse, while the metabolic profile of such patients was better (Table 2).

4. Discussion

The present study confirms that previous regular physical activity could lead to a possibly dose-dependent decrease in stroke severity. While both weak and moderate regular physical activities contribute to this possible neuroprotective effect, practicing heavy exercise may be deleterious. Analyzing all patients' characteristics, the protective effect of previous regular physical activity remains whatever the age group and may be related in part to a better vascular or metabolic profile.

The present analysis confirms the benefit of previous regular physical activity on stroke initial severity and outcome [6–8]. One of the most important points underlined

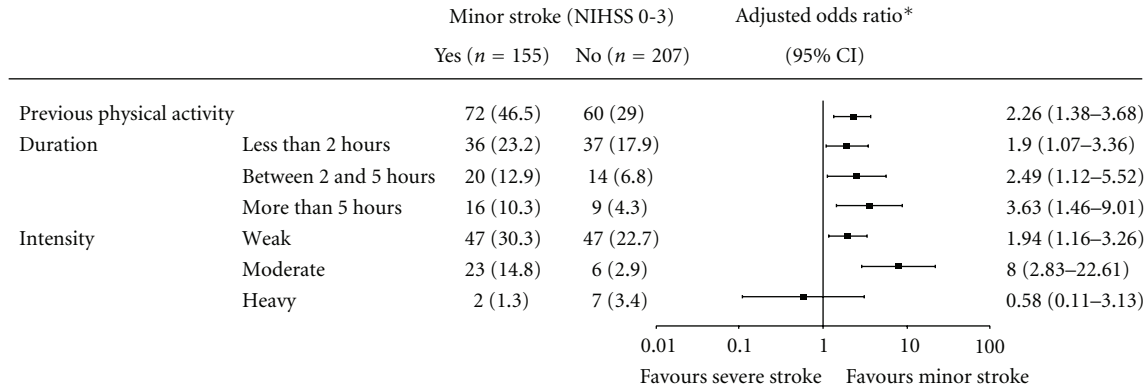
Table 1: Main characteristics according to physical activity status before stroke.

	Previous physical activity				
	Yes (n = 132)	No (n = 230)	OR	95% CI	P
Demographic characteristics					
Age*	56 (16–86)	73 (25–97)	1.62	1.05–2.50	<0.0001
Men	71 (53.8%)	96 (41.7%)			0.027
Medical history					
Arterial hypertension	56 (42.4%)	161 (70.0%)	0.32	0.20–0.49	<0.0001
Diabetes	23 (17.4%)	65 (28.3%)	0.54	0.31–0.91	0.022
Smoking	47 (35.6%)	55 (23.9%)	1.76	1.10–2.81	0.017
Ischemic heart disease	15 (11.4%)	46 (20.0%)	0.51	0.27–0.96	0.041
Congestive heart disease	6 (4.5%)	40 (17.4%)	0.23	0.09–0.55	<0.0001
Peripheral arteriopathy	4 (3.0%)	20 (8.7 %)	0.33	0.11–0.99	0.047
Previous treatment					
Antiplatelet therapy	35 (26.5%)	88 (38.3%)	0.58	0.36–0.93	0.028
ACE inhibitors	21 (15.9%)	63 (27.4%)	0.50	0.29–0.87	0.014
Angiotensin receptor antagonists	9 (6.8%)	35 (15.2%)	0.41	0.19–0.88	0.019
Diuretic	26 (19.7%)	80 (34.8%)	0.46	0.28–0.77	0.003
Nitrate derivatives	4 (3.0%)	27 (11.7%)	0.23	0.08–0.69	0.003
Digoxin	3 (2.3%)	24 (10.4%)	0.20	0.06–0.68	0.003
Other antiarrhythmic drugs	4 (3.0%)	25 (10.9%)	0.26	0.09–0.76	0.008
Index stroke					0.273
Cerebral infarction	102 (77.3%)	189 (82.8%)	0.74	0.43–1.25	
TIA	30 (29.4%)	41 (17.8%)	1.36	0.80–2.31	
Stroke etiology					0.001
Atherosclerosis disease	19 (14.4%)	54 (23.5%)	0.55	0.31–0.97	
Cardioembolic stroke	21 (15.9%)	65 (28.3%)	0.48	0.28–0.83	
Lacunar stroke	22 (16.7%)	30 (13.0%)	1.33	0.73–2.43	
Cervical artery dissection	15 (11.4%)	7 (3.0%)	4.08	1.61–10.33	
Undetermined etiology	54 (40.9%)	74 (32.2%)	1.46	0.93–2.28	
Stroke severity and outcome					
NIHSS at admission*	3 (0–27)	5 (0–35)			0.002
Minor stroke (NIHSS 0–3 at admission)	72 (54.5%)	83 (36.1%)	2.13	1.37–3.29	0.001
Barthel 95–100 at 8 days	100 (75.8%)	72 (31.3%)	3.59	2.23–5.79	<0.0001
Rankin 0-1 at 8 days	76 (57.6%)	96 (41.7%)	1.89	1.23–2.93	0.003
Mini mental state†	27 (5)	24 (10)			0.003
Physiological parameters‡					
Systolic Blood Pressure (mm Hg)	142 (27)	151 (30)			0.003
Fibrinogen (μmol/L)	10.41 (2.70)	11.70 (3.27)			<0.0001
Glycemia (mmol/L)	5.94 (1.83)	6.55 (2.55)			0.017
Total cholesterol (mmol/L)	5.03 (1.01)	5.39 (1.26)			0.005
LDL cholesterol (mmol/L)	2.89 (0.85)	3.17 (1.03)			0.005

OR: odds ratio; CI: confidence interval; ACE: angiotensin converting enzyme. *Result is reported as median (range). †Result is reported as mean (SD) in patients for whom the test was assessable. ‡All results are given as mean (SD). All other variables did not differ between both groups.

here is the possible dose-dependent effect according to the weekly duration of physical exercise [6, 7]. Indeed, our study suggests an exercise duration-dependent neuroprotective effect of physical activity. Besides the duration, the type and level of physical exercise seem also particularly important. Patients with regular heavy exercises may be exposed to more severe stroke, but the small number of subjects in this subgroup did not allow a definitive conclusion. A recently published study also underlined that regular physical exercise may be protective, while only practicing bout of physical exercise may contribute to the occurrence of an ischemic stroke [10]. The neuroprotective effect of previous regular physical activity may also contribute to the apparent decrease in stroke incidence, by reducing cerebral infarct size to levels that are not symptomatic [1–3].

Our findings support the results of experimental studies in which physical activity before ischemia induced neuroprotection [4, 5]. In rats, both voluntary running and



*Results were adjusted according to age, sex, and the presence of arterial hypertension, diabetes, smoking, previous ischemic or congestive heart disease, and peripheral arteriopathy (according to colinearity prior treatments were not included in the model).

Figure 1: Impact of previous leisure-time physical activity on initial stroke severity.

Table 2: Main characteristics associated to previous leisure-time physical activity according to age.

	Previous physical activity				
	Yes (n = 132)	No (n = 230)	OR	CI 95%	P
Age < 60 years	*n = 71*	*n = 51*			
Alcohol abuse	7 (9.9%)	15 (29.4%)	0.26	0.10–0.71	0.006
Arterial hypertension	18 (25.4%)	21 (41.2%)	0.49	0.22–1.05	0.065
Peripheral arteriopathy	—	3 (5.9%)	NA		0.071
Minor stroke (NIHSS 0–3 at admission)	39 (54.9%)	16 (31.4)	2.67	1.25–5.68	0.011
Barthel 95–100 at 8 days	62 (87.3%)	32 (62.7%)	4.09	1.66–10.10	0.003
Age 60–75 years	*n = 40*	*n = 85*			
Men	26 (65.0%)	34 (40.0%)	2.79	1.27–6.10	0.012
Minor stroke (NIHSS 0–3 at admission)	22 (55.0%)	30 (35.3%)	2.24	1.04–4.83	0.037
Glycemia (mmol/L)*	6.16 (1.44)	7.05 (2.83)			0.061
LDL cholesterol (mmol/L)*	2.92 (0.72)	3.30 (0.93)			0.017
Age > 75 years	*n = 21*	*n = 94*			
Arterial hypertension	11 (52.4%)	77 (81.9%)	0.24	0.09–0.67	0.004
Barthel 95–100 at 8 days	12 (57.1%)	27 (28.7%)	3.31	1.25–8.78	0.010
Mini mental state†	25 (6)	21 (9)			0.079

OR: odds ratio; CI: confidence interval; NA: non assessable. *Results are given as mean (SD). †Result is reported as mean (SD) in patients for whom the test was assessable. All other variables did not differ between both groups.

forced exercise have a neuroprotective effect [4], which could result from an improvement of cerebral blood flow through an increase in eNOS expression or angiogenesis or from the modulation of neuroplasticity through nerve growth factor or brain-derived neurotrophic factor expression [4, 5]. As it is suggested by the present results, the stroke protection induced by regular physical activity in human might be due to lower heart rate, peak systolic pressure and circulating catecholamine levels [11, 12], improved lipid profile [11, 13], and lower levels of arteriosclerosis [14] and inflammation [15], a number of factors that may decrease plaque vulnerability [13]. As in animal models, physical activity in human may have antithrombotic effects through enhancing fibrinolysis and reducing blood viscosity, fibrinogen levels, and platelet aggregation [1].

The improvement of all these biological conditions may also contribute to explain that previous leisure-time physical activity is less likely to be associated with atherosclerosis disease as an etiology of ischemic stroke. Here, we also found that leisure-time physical activity is also less likely to be associated with cardioembolic stroke. Cardioembolic strokes are mainly the consequence of atrial fibrillation of which both incidence and prevalence is increasing with age and the presence of arterial hypertension [16]. The relationship between physical activity and a decrease in the risk to develop an atrial fibrillation has been recently discussed [17], but the presence of other vascular diseases may be confounding factor [18, 19]. On the other hand, we found that cervical artery dissection is more likely to be the etiology of stroke in patients having prior leisure-time physical activity. Even if

minor trauma including those produced by physical activity may be implied in the pathophysiology of cervical artery dissection, patients are usually younger and have less or no vascular risk factors [20], a profile that is also more likely to be associated with regular physical activity.

The vascular profile of the subjects may not be the only cornerstone of such a protection that could be observed not only in stroke, but also in various diseases such as cognitive, depressive, or anxiety disorders. Indeed, as it is observed here according to MMS values, regular physical activity may prevent cognitive decline and decrease the risk of vascular dementia [21]. A randomized control trial also demonstrates that a 6-month program of physical activity could afford a modest improvement in cognition over an 18-month follow-up period in older adults at risk for Alzheimer's disease [22]. In the field of psychiatry, several studies also provide evidence about the ability of physical activity to decrease the incidence of both depression and anxiety disorders as well as to improve depressive and anxious symptoms [23]. In this context, it is of particular interest to underline that the effects of physical activity on the brain can be enhanced by concomitant consumption of natural products such as plant polyphenols or omega-3 fatty acids, some compounds that may share the same mechanisms of action [24, 25].

Our study also has limitations. It was a nonrandomized hospital-based study and thus present data should be considered hypothesis generating. Results probably could not be generalized to all patients with ischemic stroke. Because of the observational study design, we cannot rule out that the association between previous leisure-time physical activity and stroke outcome was confounded by other factors that were not taken into account in our analysis such as diet habits.

Because looking for pharmacological agents that may have neuroprotective properties in stroke and other various brain diseases is particularly complex and still remains disappointing, the time has come to optimize the natural resources through education about regular physical activity and also possibly appropriate food intake that may be the easiest and more effective ways to protect the brain.

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Review Article

Reduced Cardiorespiratory Fitness after Stroke: Biological Consequences and Exercise-Induced Adaptations

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Evidence from several studies consistently shows decline in cardiorespiratory (CR) fitness and physical function after disabling stroke. The broader implications of such a decline to general health may be partially understood through negative poststroke physiologic adaptations such as unilateral muscle fiber type shifts, impaired hemodynamic function, and decrements in systemic metabolic status. These physiologic changes also interrelate with reductions in activities of daily living (ADLs), community ambulation, and exercise tolerance, causing a perpetual cycle of worsening disability and deteriorating health. Fortunately, initial evidence suggests that stroke participants retain the capacity to adapt physiologically to an exercise training stimulus. However, despite this evidence, exercise as a therapeutic intervention continues to be clinically underutilized in the general stroke population. Far more research is needed to fully comprehend the consequences of and remedies for CR fitness impairments after stroke. The purpose of this brief review is to describe some of what is currently known about the physiological consequences of CR fitness decline after stroke. Additionally, there is an overview of the evidence supporting exercise interventions for improving CR fitness, and associated aspects of general health in this population.

1. Introduction

Little is known about the biology surrounding decrements in cardiorespiratory (CR) fitness after stroke, but evidence has gradually begun to track the damage caused to multiple physiological systems by stroke-related chronic inactivity [1–8]. Collectively, these changes negatively impact morbidity and mortality prospects and contribute to reduced quality of life [9]. Because CR fitness is a measure that quantifies the ability of the heart, lungs, blood vessels, and skeletal muscles to work together to deliver oxygen and remove metabolic byproducts during exercise, it is indirectly reflective of broad categories of cardiovascular, metabolic, and functional health. Most often, CR fitness is measured using a metabolic cart for gas analysis and exercise equipment (e.g., treadmill, recumbent stepper, or cycle ergometer) to determine peak oxygen-consuming capacity (VO_2 peak) and is quantified during exercise to complete exhaustion [10–16].

CR fitness varies according to age, gender, physical activity levels, body composition, and the absence or presence of chronic disease or disability. In the poststroke population, the literature suggests that CR fitness is reduced by as much as 50% when compared to age-matched sedentary counterparts [12, 14]. The extent of deterioration is associated with several clinically relevant biological correlates which were the focus of this review.

It remains unclear whether reduced CR fitness after stroke is due primarily to premorbid conditions, direct effects of the stroke itself, or poststroke physical inactivity. All are likely contributors but understanding the relative

contributions of each will require further research into biological/etiological mechanisms [17]. Whatever the cause, it is important to assess the capacity of stroke survivors to physiologically adapt in response to aggressive rehabilitation therapy interventions. Hence, this review also outlines some of the preliminary progress made in deciphering the physiological benefits of exercise training after stroke. Arriving at a better understanding of the cardiovascular, metabolic, and functional adaptations resulting from a variety of therapy protocols and how these contribute to improved CR fitness is especially important for healthcare providers, rehabilitation specialists, and others working towards the common goal of improving overall health and quality of life in this clinical population.

2. Biological Consequences Contributing to Reduced CR Fitness after Stroke

Sequelae of an upper motor neuron lesion include hemiparesis, reduced mobility, impaired balance and in coordination, and diminished proprioceptive feedback [17]. Secondary conditions such as changes in muscle physiology and inflammation [5, 6], impaired hemodynamic response [1, 3, 8], altered metabolic health [18], and, to a lesser extent, respiratory dysfunctions [19] can also negatively influence daily activities and exercise performance. The neuromotor system relies on effective motor unit recruitment and efficient mechanical movement to sustain physical activity and prevent early fatigue [11, 20–22]. Altered neurological input to the periphery and associated disuse profoundly alters skeletal muscle tissue composition in the paretic limb, thereby, contributing to reduced CR fitness and related health problems.

2.1. Muscle Physiology after Stroke

2.1.1. Tissue Composition. Major structural and molecular abnormalities have been observed in hemiparetic leg muscle [4–7] with serious implications for impairment of strength [23–25], insulin sensitivity [26, 27], mobility function [10, 11, 25], and CR fitness [10, 13, 14, 16, 28]. In addition to severe unilateral muscle wasting and increased intramuscular fat after stroke [7], there is a dramatic shift towards a higher proportion of fast twitch muscle fibers [4, 6], which are more insulin resistant and fatigue prone [29]. There is also preliminary evidence of a reduction in the number of capillaries per muscle fiber in paretic leg muscles with significant relationships between low capillary density and glucose intolerance in this population [30]. Finally, there is a nearly three-fold elevation in the expression of paretic leg muscle tumor necrosis factor-alpha (TNF-α) [5], an inflammatory cytokine implicated in both muscle atrophy [31], and insulin resistance [32]. These pathological alterations in skeletal muscle represent novel targets for exercise rehabilitation strategies during the poststroke recovery period. Given the increasing numbers of elderly disabled by stroke [33], alternative rehabilitation strategies are needed to specifically address and reverse the effects of paresis on muscle tissue quantity and quality.

On the basis of physiological principles, there is little question that unilateral skeletal muscle changes after stroke contribute to worsening CR fitness and related health changes. A reduction in lean tissue, especially in the larger leg muscles, negatively affects VO_2 and CR fitness [34]. Furthermore, muscle metabolism and the ability to perform specific activities are heavily influenced by fiber type. For example, the ability to successfully engage in endurance activities relies on aerobic metabolism which is primarily driven by slow myosin heavy chain (MHC) isoforms and type I muscle fibers while high-intensity, quick movements depend on the availability of fast myosin heavy chain isoforms and type II muscle fibers [35]. There is evidence that the increased proportion of fast myosin heavy chain isoforms in the paretic limb is inversely correlated with gait speed [6].

These fatigue prone muscle fibers negatively affect community ambulation through decreased gait efficiency and increased energy expenditure. This increased energy expenditure leads to chronic fatigue and can limit ability to perform activity after stroke [36]. Feelings of fatigue and tiredness may further inhibit performance of activities of daily living (ADLs) and instrumental activities of daily living (IADLs).

Sedentary, nondisabled individuals expend approximately 10.5 mL of oxygen/kg/min (3 metabolic equivalents, METS) during light IADLs and about 17.5 of oxygen/kg/min (5 METs) during heavy IADLs and are able to reach a maximum of 8–10 METS [37]. In contrast, people after stroke are only able to reach a maximum of 4-5 METS, making higher level ADLs impossible and lower level ADLs unsustainable [38]. A vicious cycle results when feelings of fatigue during daily activities further reduce activity participation, thereby, compounding CR fitness decline.

2.1.2. Proinflammatory Markers and Pathways. Beyond localized up-regulation of inflammatory markers in paretic skeletal muscle, there are also systemic changes in circulating levels with disabling conditions. Specifically, circulating cytokinessuch as TNF-alpha and IL-6, have been shown to increase with acute myocardial infarction, heart failure, and obesity [39–41]. Elevated levels of proinflammatory markers have also been reported after stroke [42–44] and have been strongly associated with larger infarct size and poor outcomes (i.e., early neurological decline) [44, 45]. Increases in oxidative stress are purported to interfere with vascular function [40, 46, 47] and other aspects of physiology relevant to CR fitness and metabolic health. New onset of hypertension has been reported in individuals after an acute stroke with elevated levels of proinflammatory markers (TNF alpha, IL-6, and VCAM-1) [45]. This suggests that elevated levels of proinflammatory markers may alter peripheral biological mechanisms such as those associated with the endothelial nitric oxide system, contributing to increased vascular resistance,and negatively affecting participation in rehabilitation or adaptive capacity. However, the pathogenesis for the potential relationship between the inflammatory markers and impaired endothelial function after acute stroke is still unclear. Although a detailed description of complex cytokine networks in the context of general health and health

improvement is beyond the scope of this brief review, a more detailed account of this subject is provided in a recent review by Ploeger et al. [48]. Importantly, the causes behind elevated circulating cytokines are complex, and there are gaps in our knowledge about how to intervene against chronic inflammatory disease in stroke and beyond [48].

Altered Glucose Metabolism after Stroke. Beyond stroke-induced changes to paretic side tissue composition secondary to altered neurological input, sedentary living and reduced CR fitness also partially contribute to a severe decline in metabolic status. Specifically, insulin resistance and glucose intolerance are highly prevalent after stroke [26, 27], leading to progressive cardiovascular disease risks [49] and predisposition to recurrent stroke [50].

Kernan et al. originally identified a high prevalence of insulin resistance during the subacute stroke recovery period [26]. Subsequent findings in chronic stroke [27] revealed a 77% prevalence of abnormal glucose metabolism. This is clinically relevant given that impaired glucose tolerance and diabetes prospectively predict two- and three-fold increased risk for recurrent cerebrovascular events, respectively [50]. Prospective studies showed that fasting hyperinsulinemia [51] and postload insulin areas during an oral glucose tolerance test (OGTT) [52] predicted risk of future stroke and cardiovascular events. Notably, a large Scandinavian study showed that those in the highest quintile of postload insulin area had a greater than two-fold relative risk of stroke than those in the lowest quintile of insulin area [52]. Thus, epidemiologic research based upon surrogate measures of insulin sensitivity provides powerful evidence that insulin resistance is strongly associated with vascular event risk and recurrent stroke. Generally, physical inactivity is a well-recognized contributor to altered glucose metabolism and insulin sensitivity in all aging populations [53] and may play a particularly large role in stroke survivors [26, 27].

2.2. Cardiovascular Regulation after Stroke

2.2.1. Autonomic Control of Cardiac Function. The central nervous system (parasympathetic and sympathetic branches) regulates heart rate, cardiac contractility, blood pressure, and vasomotor tone of the blood vessels. Impairments related to autonomic control of blood flow and cardiac regulation can occur after stroke, specifically if the stroke occurs around the parietal and insular cortex [54–56]. One study reported that those individuals with left insular stroke had an increase in cardiac events such as heart failure within one year after stroke [57]. These cardiac complications could have significant effects for cardiac function during activity and exercise. It is well known that people post-stroke have lower heart rates and oxygen consumption at peak effort during a graded exercise test when compared to healthy sedentary age-matched peers [12, 14]. This may be a result of impaired autonomic control of the cardiovascular system in addition to pharmacologic therapy (beta blockers).

2.2.2. Blood Flow and Vascular Function. Blood flow distribution is governed by central cardiovascular command (parasympathetic/sympathetic activity) [54] and peripheral mechanisms, such as metabolic demands, peripheral resistance, and changes in pressure [55, 56]. Changes in either central or peripheral regulation can interrupt normal vascular function. Stroke-related changes in the brain, specifically in areas that regulate autonomic function, can have significant implications for blood pressure control and cardiac function during the acute phase of stroke recovery [57, 58].

In chronic stroke, blood flow in the paretic leg is significantly lower at rest [1–4] and during exercise [4], when compared to the nonparetic limb. These unique unilateral adaptations, not observed in nondisabled young and older adults, can influence performance of ADLs and quality of life [59, 60]. Research suggested that reductions in blood flow occur secondary to decreased levels of physical activity [59, 61], which can affect blood flow velocity, endothelial function, and arterial diameter. A recent study determined that vascular remodeling in the femoral artery occurs in the paretic lower extremity after stroke [2]. The femoral artery diameter and blood flow velocity were significantly reduced in the paretic limb when compared to the nonparetic limb. The femoral artery wall thickness was also significantly greater in the paretic limb, potentially contributing to impaired flexibility of the vessel wall to vasodilate during activity to allow for adequate blood and oxygen delivery.

Most recently, interhemispheric differences in blood flow velocity (BFV) of the middle cerebral artery (MCA) have been shown [62]. The MCA BFV on the ipsilesional side was substantially lower than the contralesional vessel, suggesting that systemic vascular deterioration extends to the brain. More work is needed to determine how systemic and cerebral vascular functions interrelate and the systemic consequences of each phenomenon.

Respiratory Function after Stroke. Although not all patients after stroke have overt pulmonary disease [63], respiration may be compromised as a direct result of the stroke itself (particularly brain stem stroke), associated complications (e.g., weakness of respiratory muscles, impaired breathing mechanics), comorbidities (e.g., chronic obstructive pulmonary disease, cardiovascular dysfunction), or lifestyle factors (e.g., physical inactivity high incidence of smoking) [64]. The excessive fatigue experienced by some people after stroke may be partly due to respiratory insufficiency as manifested by low pulmonary diffusing capacity, ventilation-perfusion mismatching, or decreased lung volumes (e.g., vital capacity, total lung capacity, inspiratory and maximal inspiratory capacity, and expiratory reserve volume) [65, 66]. Impaired breathing mechanics with restricted and paradoxical chest wall excursion and depressed diaphragmatic excursion have been also reported [64, 67]. Expiratory dysfunction appears to be related to the extent of motor impairment (e.g., paresis of the hemi-diaphragm and intercostal and abdominal muscles) [65, 68–70]. Inspiratory limitations, manifested by reduced maximal inspiratory pressure [71], are related to reduced chest wall excursion secondary to the gradual development of rib cage contracture [72].

The physiologic impairments described above reduce the ventilatory reserve or the difference between the maximal available ventilation and the ventilation measured at the end of exercise [73] and contribute to low CR fitness levels in the stroke population. At peak exercise performance, people after stroke have significantly lower minute ventilation and tidal volume, but not respiratory rate, compared with control participants [74]. Reductions in lung volumes and chest wall movements can lead not only to decreased exercise endurance, shortness of breath, and risk of sedentary behavior but also increased risk of recurrent stroke [75]. Therefore, exercise interventions designed to improve respiratory muscle strength and pulmonary function should be encouraged.

2.3. Exercise-Induced Adaptations in CR Fitness and Associated Aspects of General Health after Stroke. Exercise is a potent physiological stimulus which could induce a wide range of adaptations. These adaptations include improved CR fitness, changes in vascular function and vascular morphology, reduced respiratory effort, and enhanced glucose metabolism and insulin sensitivity.

The capacity of the stroke population to make cardiorespiratory adaptations to aerobic exercise has been demonstrated in numerous training studies. Table 1 summarizes trials individuals in the subacute (<6 months after stroke) and chronic (>6 months post-stroke) stages of recovery. In these studies, the magnitude of change in peak VO_2 (mean gain of ~12.5%) was comparable to the 10% to 30% improvements (reported for healthy, sedentary adults) [76, 77] and the 13% to 15% gains observed for participants in cardiac rehabilitation [78, 79]. Even the relatively modest gains in CR fitness reported in some stroke exercise studies (e.g., 8% [80], 6% and [81]) may be sufficient to raise the anaerobic threshold, thereby, extending the time during which muscle contractions can be sustained with oxidative metabolism. Interventions which result in even small changes in aerobic capacity may be of clinical significance on the basis of where stroke survivors stand relative to the range of VO_2 required for general ADLs [10, 37]. Considering the degree to which VO_2 peak levels have been compromised after stroke, even modest changes in CR fitness will have a greater impact on activities of daily living for stroke survivors than to their age-matched healthy peers.

The considerable interindividual differences noted in most training studies are attributable to many factors, including severity of stroke, time since onset, variations in intensity and mode of training, and level of compliance with the exercise regimen [11, 21, 22, 90]. In studies of people with stable coronary disease, considerable interindividual differences have been observed, of which only a small portion (about 11%) have been attributed to recognized covariates such as initial fitness status and an even smaller percentage (about 5%) to measurement errors [91, 92]. The most rapid improvements in exercise capacity tend to occur in previously sedentary people [93]. Further, it has long been acknowledged that the highest overall relative gains are usually seen in individuals with the lowest initial values of VO_2 peak [94].

2.4. Exercise-Induced Muscular Adaptations after Stroke

2.4.1. General Adaptations. Several important studies reported that strength training, provided it is progressive and of adequate intensity, can be effective in combating the losses in muscle mass [95], muscle quality [96], and function [97] which typically occur with advancing age. Strength training results in significant muscle hypertrophy in both healthy elderly and frail elderly populations [95, 98]. Several studies also showed that strength training can affect adaptation in skeletal muscle fibers [99–101]. Strength training with high repetitions and a strong endurance component results in higher proportions of Type IIa (fast oxidative) [102, 103], and Type I [101, 104] myosin heavy chain muscle fiber types and is an effective stimulus for fiber hypertrophy in Type I, Type IIa, and Type IIx muscle fibers [101, 105, 106]. High repetition strength training also results in improved muscle capillarization in peripheral arterial disease patients [99] and in healthy populations [107]. Finally, there is evidence that TNF-α levels are successfully reduced with strength training in frail elderly humans [31].

2.4.2. Post-Stroke. Patients after stroke have been studied far less in the context of strength training. Of the few trials undertaken none have assessed the capacity of strength training to cause skeletal muscular adaptations. However, the results of a recently completed nonrandomized pilot study in chronic stroke [23] has showed that skeletal muscle hypertrophy accompanied by molecular adaptations occurred in both the paretic and nonparetic limbs. Pilot work suggested that functionally and metabolically relevant skeletal muscle tissue adaptations are possible in this population. There is now a randomized study underway to further test the impact of strength training on paretic limb skeletal muscle after stroke (Ivey, PI).

Metabolic Adaptations with Exercise in Stroke Survivors. Over the last decade, major advances have been made in the understanding of the effectiveness of exercise and lifestyle interventions to improve cardiometabolic health and prevent progression to diabetes in high-risk nonstroke populations. The Diabetes Prevention Program showed that lifestyle interventions based upon low-intensity exercise and weight loss were more effective than metformin (58% versus 31%) to prevent progression to diabetes in high-risk individuals, which occurs in ~10% of controls annually by natural history [53]. Preliminary findings in chronic stroke survivors demonstrated that moderate intensity treadmill training reverses impaired glucose tolerance and type 2 diabetes status in 58% of cases [18]. The study investigated the effects of 6-month moderate intensity treadmill training ($N = 26$) versus stretching exercises ($N = 21$) on insulin response during an OGTT and found significant reductions with treadmill training in fasting insulin areas compared to controls (−23% versus +9%, $P < 0.05$). Changes in insulin area were inversely related to changes in CR fitness by VO_2 peak in the two groups combined ($r = -0.34$, $P < 0.05$), but not to body weight or fat mass [18]. This suggested that greater improvements in VO_2 peak, as with higher intensity training, may

Table 1: Cardiorespiratory adaptations to aerobic training after stroke.

Mode	No. of subjects	Program duration weeks	Frequency x/week	Session duration minutes	Intensity	Change in peak VO_2%
Subacute stroke (<6 months after stroke)						
Cycle ergo meter [82]	E: 44 C: 48	12	3	20–30	40 rpm	E: +9 C: +0.5
Treadmill [83]	E: 6 C: 6	26	5	20	NR	E: +35 C: +1
Cycle ergo meter [21]	E: 23 C: 22	3-4	3	30	50–75% peak VO_2	E: +13 C: +8
Chronic stroke (>6 months after stroke)						
Cycleergometer [84]	E: 37 C: 24	26	3	10–20	40–50% HRR	E: +18 C: −3
Cycleergometer [85]	E: 24 C: 24	8	2	20	50–60% HRR	E: +13 C: −3
Treadmill [18]	E: 26 C: 20	26	3	40	60–70% HRR	E: +15 C: −3
E1: Mod intensity [86] E2: Low intensity	E1: 18 E2: 19 C: 18	14	3	30–60	E1: 50–69% HRR E2: <50% HRR	E1: +4 E2: +6 C: −3
Treadmill + strengthening [87]	E: 14	12	5	90	80% HR max	E: +19
Treadmill [81]	E: 20*	4	2–5	NR	80–85% HR max or RPE 17	Immediate: +6 Delayed: +6
Cycle ergometer [85]	E: 19 C: 23	10	3	30	50–70 rpm	E: +13 C: +1
Aerobic exercise [80]	E: 29	12	3	30	HR at RER of 1.0	E: +8
Treadmill [13]	E: 23	26	3	20	<60% HRR	E: +10
Aerobic exercise [88]	E: 32 C: 31	19	3	60	<80% HRR	E: +9 C: +1
Water based [89]	E: 7 C: 5	8	3	30	<80% HRR	E: +23 C: +3

E: Experimental; C: control; rpm: revolutions per minute; HRR: heart rate reserve; *crossover design; NR: not reported; RPE: rating of perceived exertion; RER: respiratory exchange quotient.

produce even greater improvements in insulin sensitivity. These preliminary findings have implications for diabetes prevention after stroke and warrant further investigation in the larger context of improving general health and function in this population.

Vascular Adaptations with Exercise after Stroke. During exercise, the arterial wall is chronically exposed to increased blood flow, and the vessel diameter expands to accommodate a larger volume of flow [55, 56]. However, as with the above outcome categories, vascular adaptations to exercise after exercise stroke remain only partially understood, with initial experiments providing encouraging preliminary results. First, the group observed vascular changes after a unilateral training program that focused on exercising only the paretic leg. Beyond demonstrating increased functional performance and strength in the paretic limb with this intervention, there were also substantial vascular changes on the paretic side with the potential for altering regional and systemic physiological health [3]. Specifically, four weeks of unilateral leg training improved femoral artery blood flow and diameter [3]. More recently, treadmill training over six months has resulted in significantly improved resting and hyperemic blood flow in the paretic and the non-paretic lower extremities, when compared to elements of conventional stroke rehabilitation [8]. Briefly, treadmill training increased both resting and reactive hyperemic blood flow in the paretic limb by 25% compared to decreases in the control group ($P < 0.001$, between groups). Similarly, non-paretic leg blood flow was significantly improved with tread mill training compared to controls ($P < 0.001$). CR fitness (VO_2 peak) improved by 18% with tread mill training and decreased by 4% in control ($P < 0.01$, between groups), and there was a significant relationship between blood flow change and peak fitness change for the group as a whole ($r = 0.30$, $P < 0.05$). There has been also recently published evidence showing that treadmill exercise training can have a positive impact on cerebral vasomotor function in both hemispheres, particularly in those not taking statin medication [62]. These data provided the first evidence of exercise-induced cerebral vasomotor reactivity

improvements in stroke survivors, implying a protective mechanism against recurrent stroke and other brain-related disorders.

Respiratory Adaptations. Although reduced respiratory function has been reported after stroke, therapeutic interventions aimed at improving respiratory muscle strength and function are extremely limited. Two recent randomized controlled trials have examined the effects of inspiratory muscle training (IMT) in people after stroke. One trial examined whether six weeks of inspiratory muscle training would produce significant improvements in cardiopulmonary function when compared to a 6-week intervention consisting of breathing techniques and also a control group [63]. The authors concluded that IMT produced significant improvements in pulmonary function variables and cardiopulmonary outcomes during peak exercise testing. These improvements translated into functional gains as observed by the Barthel Index and functional ambulation scores.

Britto et al. published findings from a double-blind randomized controlled trial in chronic stroke survivors [108]. Individuals were randomized to an 8-week home-based exercise training program using either (1) an inspiratory muscle trainer (IMT) with progressive increases in resistance or (2) an IMT without resistance. Results demonstrated significant improvements in respiratory function (maximal inspiratory pressure and inspiratory muscular endurance) for the experimental group but not the control group. Although the experimental group (IMT with resistance) was able to exercise at a higher workload for the functional performance test, these differences were not significantly different. More work is needed in this area to identify other biologic factors which precipitate respiratory decline, identify therapeutic interventions to improve breathing mechanics, and improve pulmonary function in those individuals post-stroke.

2.5. Adaptations in Memory and Cognition after Exercise and Stroke

2.5.1. Animal Models. Given the central importance of cognitive health to all aspects of functional and physiological health after stroke [109], researchers are now accumulating evidence related to how exercise impacts this outcome category. Over the past 15 years, progress has been made in understanding the influences of exercise on central nervous system functions (see reviews Kramer, 2007; Devine, 2009). Animal studies have demonstrated favorable effects of aerobic training on neural function through modulation of synaptic plasticity underlying neuroprotective and neuroadaptive processes [110]. For example, learning and memory were enhanced in rats after one week of voluntary wheel running [111], possibly through the upregulation of brain-derived neurotrophic factor (BDNF) [112, 113] or other growth factors, such as vascular endothelial growth factor [114]. In a rodent stroke model, treadmill exercise enhanced gene expression for BDNF and a corresponding reduction in brain infarct volume [115]. Similarly, exercise attenuated the effects of traumatic brain injury, again in a rodent model, through a BDNF-mediated mechanism [116]. These neuroplastic responses appear to be dose dependent [117].

2.5.2. Human Models. Human studies have begun to reinforce the findings of the earlier animal work. Evidence of a causal relationship between exercise training and improved cognition has been reported in older adults without known cognitive impairment [118, 119] and in people with cardiovascular disease [120]. Quaney and colleagues [121] provided the first preliminary evidence on the effects of exercise training on cognitive executive function and motor learning in chronic stroke survivors. After an 8-week cycle ergometry exercise program, significant improvements were found in measures of information processing and complex motor learning tasks [121].

3. Conclusions

Reduced CR fitness after stroke is well documented with clinically relevant physiologic consequences. Although the precise mechanisms and the consequences of the severe reduction in CR fitness have not been fully elucidated, preliminary evidence points to several noteworthy biological correlates. For example, maladaptive changes to the tissues of the paretic side may both contribute to and be compounded by reductions in CR fitness. These include negative unilateral changes in muscle mass, intramuscular fat, muscle fiber type distribution, hemodynamic function, capillary density, and inflammatory markers. Further, there are systemic disturbances to metabolism and respiration which are exacerbated due to the presence of sedentary living and accompanying CR fitness decline. The evidence in the literature suggests that maladaptive physiologic changes have been observed in the paretic lower limb and these may contribute to the low CR fitness found in people post-stroke.

Exercise training has been shown to be a potent stimulus for improving CR fitness and associated physiological outcomes in both stroke and nonstroke aging populations. Changes in VO_2 peak, muscle tissue quantity, muscle biology, tissue inflammation, pulmonary function, systemic metabolism, and cognition have all been reported in various elderly and disabled subgroups. Although the body of evidence for exercise-induced adaptation in stroke is limited, great progress has been made over the last decade to show that stroke survivors maintain their capacity to adapt and are capable of performing exercise at levels not previously thought possible. Further work is needed to determine the effects of exercise on attenuating inflammatory responses and improving tissue composition after stroke. While a limited number of exercise training studies have increased pulmonary performance after stroke, it is evident that continued work in this area is needed to improve functional and cardiorespiratory outcomes. Finally, larger randomized research studies aimed at effective exercise prescription and informing best practice in stroke rehabilitation are essential to the advancement of stroke recovery.

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Research Article

Exercise Preferences Are Different after Stroke

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Objective. To explore exercise preferences in stroke survivors and controls. *Methods*. A novel scale—the Exercise Preference Questionnaire—was developed for this study. This questionnaire, together with established assessments of physical activities, mood, and quality of life, was completed in a single assessment session. *Results*. Twenty-three adult stroke survivors (mean age 63, 65% male) and 41 healthy controls (mean age 61, 66% male) participated. The groups differed on 4 of the 5 *a priori* exercise preference factors: relative to controls, stroke survivors preferred exercise to be more structured, in a group, at a gym or fitness centre, and for exercises to be demonstrated. Factor analysis yielded 6 data-driven factors, and these factors also differentiated stroke and control groups. There was evidence that group differences were diminished when activity levels and psychological wellbeing were accounted for. Individual variability in exercise preferences and reported barriers to exercise are outlined. *Conclusion*. Stroke survivors have different exercise preferences, and a better understanding of these preferences can be used to inform rehabilitation programs and increase adherence.

1. Introduction

Stroke is a leading cause of disability, affecting around 60,000 people every year in Australia [1]. Exercise, defined as planned and repetitive bodily movements with the aim to improve or maintain physical fitness and mobility [2], is essential to poststroke recovery. Exercise not only assists people to regain function lost after stroke through repetition of specific actions, it is also believed to help prevent further stroke. Yet despite the importance of exercise, many stroke survivors are not very physically active [3]. Lack of adherence to physical activity programs is a common problem across different populations, with many people withdrawing from exercise before any personal health benefits are realized [4]. Attrition rates of 50% in the first six months of commencing an exercise program have been reported [5]. Identifying a way to increase exercise participation and adherence would have major personal and health system benefits [4].

Understanding and incorporating an individual's exercise preferences into a program can help to increase motivation to exercise [6]. Exercise preferences reported by healthy older adults include: having a good quality instructor, being located close to home, low costs, participating with others of similar age, including music, and having a friend to exercise with [6]. Walking and exercising at a fitness class were the most preferred methods while those who wished to exercise at home were happier to exercise more often [6]. These preferences were different to those expressed by breast cancer survivors, who preferred to exercise at home, alone and in a flexible program [7, 8]. Exercise preferences for stroke survivors have not been examined previously. As exercise preferences have been shown to vary across different health and life situations [9], it is important to specifically examine the preferences of stroke survivors to determine the most effective exercise program for this population.

Long-term engagement of stroke survivors in exercise programs may reduce further stroke and enhance recovery [3]. Better understanding of the exercise preferences of stroke survivors could help improve their participation in exercise. The aim of this study was to explore exercise preferences in stroke survivors and age- and sex-matched community dwelling controls.

The lack of previous research in this area made it difficult to formulate hypotheses. We predicted that stroke patients

will have different exercise preferences to controls, given the wide range of physical and emotional impacts of stroke. For the same reason, we hypothesised that variability in exercise preferences will be higher within the stroke group than the control group. Finally, we hypothesised that exercise preferences will be associated with current activity levels, quality of life, and psychological wellbeing.

2. Methods

2.1. Participants. Stroke survivors and healthy older people living in the community were eligible for recruitment, providing they were at least 18 years old and were able to communicate in English. Stroke participants must have had a completed stroke (not TIA) not less than 6 months and not more than 4 years previously. Participants for the stroke group were recruited through the Stroke Association of Victoria and affiliated Stroke Support Groups and the National Stroke Research Institute register of people interested in participating in further research. Controls included partners of participating stroke survivors, people from community groups across Victoria, and colleagues' family members and friends.

2.2. Procedure. Potential participants were contacted by the researcher (G. Banks) or a stroke network coordinator and briefed about the study. All participants gave written informed consent prior to participation. Procedure was the same for stroke survivors and controls. The assessment tools were completed in 1 of 3 ways: (a) mailed out to the participant with attached instructions, (b) completed by the participant in the presence of the researcher, or (c) read to the participant with their verbal responses recorded verbatim by the researcher. Participants were instructed to fill in the questionnaires as honestly and accurately as possible and assistance was only given to clarify questions. All study procedures and assessment tools were approved by the La Trobe University Faculty of Health Sciences Ethics Committee.

2.3. Assessment Tools. The primary outcome for this study was exercise preference, as indicated by the Exercise Preference Questionnaire (EPQ). Secondary outcome measures, detailed below, included the Human Activity Profile (HAP), the Assessment of Quality of Life (AQoL) scale, and the Irritability, Depression, and Anxiety (IDA) scale. Background information on age, gender, marital status, living arrangements, and type of stroke and side affected (if applicable) was also collected.

2.4. Exercise Preference Questionnaire (EPQ). The questionnaires used to probe exercise preference in older adults [6], breast cancer [7, 8], and cardiac rehabilitation [9] were considered for this study, but they did not adequately capture the experience or challenges associated with stroke. The Exercise Preference Questionnaire (EPQ) was therefore created specifically for this study in consultation with a statistician and an expert clinician (see Appendix). It consisted of 33 questions divided into three sections designed to capture exercise preferences and current exercise habits. Section 1 was comprised of three questions to identify current exercise frequency and mode. Section 2 had 22 questions, with three additional stroke-related questions for stroke participants only ("I like to exercise with other people who have had a stroke," "I think exercise will help prevent further stroke," and "I worry exercise might cause another stroke"). Participants were asked how much they agreed with each statement regarding different exercise preferences on a scale from 0–100%. The questions predominantly explored five factors: (1) exercise with others, (2) degree of structure of exercise programme, (3) independence, (4) exercise location, and (5) exertion (see Table 1). These factors are referred to as *a priori* factors, as they were subjectively determined before data were collected. The three general questions in Section 2 that were not related to the five factors of most interest were as follows: "I like to exercise," "I feel I am able to participate in an exercise program," and "I prefer to exercise in the morning."

Section 3 had three open questions enabling the participant to specify what they liked and disliked about exercise, and what stopped them from exercising. The last two questions asked participants to identify favoured types of exercise, first by listing three favourites (with no prompts) and then selecting most to least favourite of 10 exercise options (walking, water aerobics, golf, swimming, weight training, bowls, yoga, pilates, cycling, and gym).

2.5. Human Activity Profile. The HAP is a measure of activity that includes 94 activity items that require increasing energy expenditure [10]. For each item the participant indicates if they are still doing the activity, have stopped doing the activity, or if they never did the activity. Their highest level activity that they are still doing on the scale is noted and represents their maximum activity score (MAS). Their adjusted activity score (AAS) is calculated by subtracting the total number of activities the individual has stopped doing from those they are still doing. Higher scores represent greater activity. As the AAS is a more stable estimate of daily activities, it was the activity score used in this study. The HAP has been shown to be reliable [10] and valid in the stroke population [11].

2.6. Irritability, Depression, and Anxiety Scale. The IDA includes four subscales, but was primarily used to assess anxiety and depression levels. Of the 18 self-report items, five assess depression, five assess anxiety, and the other eight assess irritability. Higher scores represent greater mood disorder. The IDA has been validated [12] and used in previous stroke research [13].

2.7. Assessment of Quality of Life. The AQoL is a utility-based scale that assesses health-related quality of life across five dimensions: independent living, social relationships, illness, physical senses, and psychological wellbeing [14]. A score is calculated for each dimension, and then weighted to range from death (0) to full health (1). The overall score combines

Table 1: *A priori* exercise preference factors.

Factor 1 "group"	I like to exercise alone
	I like to exercise with family or friends
	I like to exercise with other people of similar age
	I like to exercise in a community group
Factor 2 "structure"	I like to do the same activity each time I exercise
	I like my exercise sessions to be planned (e.g., water aerobics class)
	I like to have written instructions for my exercises
	I like to make exercise part of my daily activities (e.g., walk to shops)
Factor 3 "independence"	I like someone showing me what to do when I exercise
	I like someone else to organise my exercise sessions
	I like the flexibility of organising my own exercise sessions
Factor 4 "location"	I like to exercise at a gym
	I like to exercise at a community fitness centre
	I like to exercise at a rehabilitation centre
	I like to exercise at home
	I like to exercise outdoors
Factor 5 "exertion"	I like to feel tired after an exercise session
	I like to do gentle exercise
	I like to work hard in an exercise session

all dimensions except "illness" and can range from −0.04 (worst possible quality of life) to 0 (equivalent to death) to 1 (best possible quality of life). The AQoL has been shown to be valid in both the general [14] and stroke populations [13].

2.8. Data Processing: Exercise Preference Questionnaire.

Section 2 A Priori Factors. To analyse differences in exercise preference between stroke survivors and controls on these factors, we first removed the 3 stroke-specific items. Second, in cases where questions reflected opposing views, for example, "I like to exercise alone" and "I like to exercise in a group," the anchor for the score of one question was reversed (from zero to 100). So if a score of 30 was recorded by the participant on this question, the final score for analysis was 70. This allowed us to determine an average agreement score for each factor, which was the sum of all scores for each question related to that factor divided by the number of questions within the factor. This was the score used for analysis for each factor. A single overall exercise preference score was also generated, termed a "vector," by combining all five factors together.

Section 2 Data-Driven Factors. Although we proposed the five *a priori* factors as a logical grouping, we also wished to let the data drive the development of item groupings and emergent themes. A factor analysis was therefore planned to explore factors emerging from the EPQ data. The three stroke-specific items were again removed. Data from the remaining Section 2 items were then entered into factor analysis (without reversal of negative questions).

Section 3. A coding tree was created for responses to the three open-ended questions (liked and disliked aspects of exercise and limitations to exercise). All responses were then coded independently by two reviewers (G. Banks and J. Bernhardt), and responses were tallied for each group.

2.9. Statistical Analysis.

Section 2 A Priori Factors. For each of the five *a priori* EPQ factors, Shapiro-Wilk tests were conducted to ascertain whether the data were normally distributed. As the majority were normally distributed, t-tests were used to determine whether there was a group difference on each factor. Multivariate regression was then conducted to assess the effect of group on the five factors, adjusted for anxiety, depression, and activity levels. An additional adjusted multivariate regression was used to assess the effect of group on the total exercise preference score (vector).

Section 2 Data-Driven Factors. For the data-driven approach, the first step was a factor analysis of data from all relevant items in Section 2 of the EPQ. A principal components analysis was computed, using the Oblimin rotation method (Promax with Kaiser Normalisation) for producing the pattern and structure matrices. Using an exact weighting scheme, each participant's estimated factor score on each factor was calculated as a weighted sum of the products of scoring coefficients and the participant's standardised scores on the original variables [15]. Once these weighted factor scores had been derived, the data analysis was the same as that described above for the *a priori* factors to determine between-group differences.

Table 2: Participant characteristics.

Characteristic	Stroke (N = 23)	Control (N = 41)
Male	15 (65)	27 (66)
Age—*mean (SD), range*	63.4 (14.7), 36–86	60.7 (13.5), 34–87
Married	15 (65)	34 (83)
Living arrangements		
Home alone	6 (26)	4 (10)
Home with others	16 (70)	37 (90)
Hostel	1 (4)	0 (0)
Side affected by stroke		
Left	16 (69)	n/a
Right	5 (22)	n/a
Other	2 (9)	n/a
Months since stroke—*mean (SD), range*	22.1 (13.6), 6–47	n/a

* N(%) unless otherwise specified.

Section 2 Variability. To determine the variability in preferences across the two groups, standard deviations for each *a priori* factor and also each individual item in Section 2 were calculated.

Other Analyses. Pearson correlations were computed to establish whether there were associations between exercise preferences, current activity levels, quality of life and anxiety, and depression. Descriptive statistics were used to summarise responses to the open questions in Section 3 of the EPQ. All data were analysed with SPSS (version 17) and STATA (version 9).

3. Results

The demographic characteristics of the 23 stroke survivors and 41 controls are outlined in Table 2.

3.1. EPQ Section 2 A Priori Factors. Stroke survivors had different exercise preferences to controls on 4 of the 5 factors (Figure 1). Stroke survivors had greater preference for exercising in a group ($t(62) = -2.0$, $P = 0.048$), greater preference for exercising in a structured manner ($t(62) = -3.6$, $P = < 0.001$), greater preference for being dependent in exercise ($t(62) = -2.5$, $P = 0.016$), and greater preference for exercising in a facility ($t(61) = -3.2$, $P = 0.002$). There was no difference between groups for factor 5, indicating both groups liked similar levels of exertion ($t(62) = -0.2$, $P = 0.804$). When psychological wellbeing (total IDA score) and activity level (HAP AAS score) were accounted for in multivariate regression, the group differences in exercise preference were diminished and only one—location—remained significant ("group," $P = .134$; "structure," $P = .082$; "independence," $P = .265$; "location," $P = .018$).

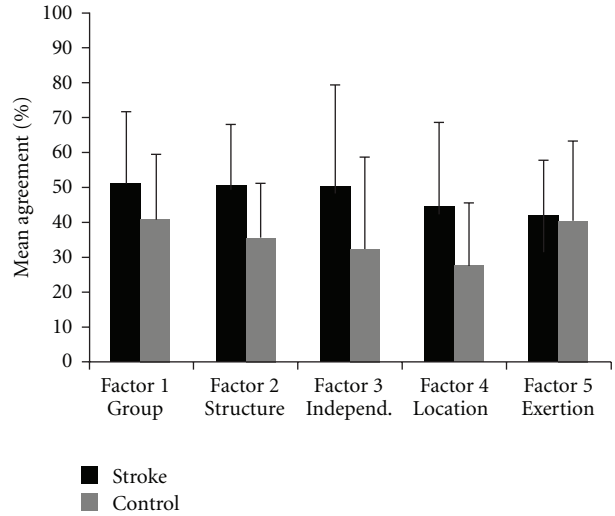

Figure 1: Mean scores for stroke and control groups on each of the 5 *a priori* EPQ factors (standard deviations are shown).

With the factors combined into a single vector, the stroke and control groups were significantly different on the total combined score ($P = 0.011$).

3.2. EPQ Section 2 Data-Driven Factors. Principal components analysis yielded 6 factors with eigenvalues >1, and these factors together accounted for 67% of the variance. Factor 1 alone accounted for 24%, factor 2 for 12%, and factor 3 for 11%. Cronbach's alpha was 0.75, indicating good internal consistency of the scale. The pattern matrix is presented in Table 3, using 0.5 as a cutoff for factor loading, and the labels that we coined to sum up each factor are shown in Table 4.

When the two groups were compared on the weighted factor scores, it was found that stroke survivors had different exercise preferences to controls on 2 of the 6 factors. Stroke survivors had greater preference for routine/"unadventurous" exercise ($t(61) = -2.9$, $P = 0.005$) and exercise at a gym or fitness centre ($t(61) = -4.1$, $P = < 0.001$) than controls, but there were no significant group differences among the other 4 factors. When psychological wellbeing (total IDA score) and activity level (HAP AAS score) were accounted for in multivariate regression, the group difference in exercise preference was diminished for the routine/"unadventurous" factor ($P = .179$) but remained for the gym/fitness centre factor ($P = .005$). These first 2 factors matched reasonably well with our *a priori* factors: 3 of the 7 routine/"unadventurous" factor items were from our "structure" factor, and another ("I like someone showing me what to do when I exercise") was from our "independence" factor; 3 of the 4 gym/fitness centre factor items were from our "location" factor.

3.3. Individual Variability in Exercise Preference. The error bars in Figure 1 show the variability (standard deviations) across the *a priori* factors for the two groups. Analysis of individual items indicated higher variability in the stroke group, where standard deviations were higher than for controls

Table 3: Factor analysis loadings used to derive the 6 data-driven factors.

	1	2	3	4	5	6
I prefer to exercise in the morning	.699					
I like to have written instructions for my exercise	.624					
I like to do the same activity each time I exercise	.609					
I like to do gentle exercise	.600					
I like to exercise at home	.530					
I like someone showing me what to do when I exercise	.506					
I like my exercise sessions to be planned	.506					
I like to exercise at a rehabilitation centre		.821				
I like to exercise at a gym		.727				
I like to exercise at a community fitness centre		.587				
I like the flexibility of organising my own exercise sessions			−.835			
I like to exercise in a community group			.663			
I like someone else to organise my exercise session			.562			
I like to exercise outdoors				.808		
I like to make exercise part of my daily activities				.780		
I like to exercise with other people of similar age				.526		
I like to exercise alone		−.506		.517		
I feel I am able to participate in an exercise program					.800	
I like to exercise					.644	
I like to work hard in an exercise session					.643	
I like to feel tired after an exercise session						.819
I like to exercise with family or friends						.508

Table 4: Data-driven factor labels.

Factor	Label	Exercise preferences
1	Routine, unadventurous	Planned, instructed, gentle, at home, prefer AM
2	Gym-goer	Rehab centre, gym, fitness centre, not alone
3	Follower	Not organising, community group, someone else to organise
4	Flexible	Outdoors, part of daily life, with similar-aged people, alone
5	Active	Able to exercise, like to exercise, like to work hard
6	Strenuous, social	Like to feel tired, with family of friends

on 16 of the 22 Section 2 items. Average item standard deviation was 33.0 in stroke compared to 29.4 in controls, and this difference was significant ($t(42) = 2.76$, $P = .009$). In the stroke group, the largest variability was for individual questions concerning location ("I like to exercise at a community fitness centre" (SD = 39.7, mean = 52.0), "I like to exercise at home" (SD = 39.5, mean = 57.2), "I like to exercise at a gym" (SD = 38.6, mean = 53.7)) and independence ("I like someone else to organise my exercise sessions" (SD = 38.8, mean = 50.2), "I like the flexibility of organising my own exercise sessions" (SD = 38.1, mean = 66.5)]. All had ranges of 0–100. The smallest variability was for individual questions concerning exertion ("I like to do gentle exercise" (SD = 26.9, mean = 65.0, range 20–100), "I like to feel tired after an exercise session" (SD = 27.9, mean = 71.5, range 0–100), "I like to work hard in an exercise session" (SD = 28.0, mean = 68.0, range 30–100)) and a question on structure ("I like to do the same activity each time I exercise" (SD = 26.5, mean = 72.6, range 25–100)).

3.4. Associations between Exercise Preferences and Other Variables. Using the 5 *a priori* factors, we identified significant negative correlations between: "structure" and activity levels ($r = -.49$, $P < .001$) and quality of life ($r = -.26$, $P = .035$), "independence" and activity levels ($r = -.37$, $P = .003$), and "location" and quality of life ($r = -.28$, $P = .027$). No associations with depression or anxiety were revealed.

3.5. Other Exercise Preference Data. More stroke survivors than controls were currently participating in an organised exercise program (48% versus 29%). Stroke survivors and controls were similar in the aspects of exercise they reported liking, focusing on the health benefits, improvements to fitness and strength, and how good it makes one feel. There were group differences in dislikes and barriers, however, with stroke survivors reporting pain and tiredness whereas controls reported issues with not having enough time and motivation (see Table 5). Fear that exercise might cause

Table 5: Likes, dislikes, and limitations to exercise for stroke survivors and controls.

	Stroke	*N* (%)	Control	*N* (%)
Top 5 likes	1- Improves mobility	5 (22)	1- Improves fitness and strength	19 (46)
	2- Is healthy	4 (17)	2- Makes you feel better	17 (41)
	3- Improves fitness and strength	4 (17)	3- Is healthy	5 (12)
	4- Makes you feel better	4 (17)	4- Makes you flexible	3 (7)
	5- Improves the effects of stroke	4 (17)	5- Makes you feel happy	3 (7)
Top 3 dislikes	1- Nothing	9 (39)	1- Nothing	11 (27)
	2- Tiredness	5 (22)	2- Time it takes	7 (17)
	3- Pain	3 (13)	3- Hard to fit in	4 (10)
Top 5 limitations	1- Nothing	5 (22)	1- No time	11 (27)
	2- Being tired	4 (17)	2- Motivation	6 (15)
	3- Laziness	3 (13)	3- Nothing	5 (12)
	4- Weather	2 (9)	4- Injuries	5 (12)
	5- Illness	2 (9)	5- Laziness	4 (10)

NB: most participants gave multiple responses.

another stroke was not a major factor for most stroke survivors, although there were 4 survivors who expressed a moderate level of agreement (40–60%) with this statement. Only 2 stroke survivors expressed less than 50% agreement with the statement that exercise can help prevent stroke.

4. Discussion

The notable finding from this study was that stroke survivors have different exercise preferences to people of the same age who have not had stroke. These preference differences were evident irrespective of whether the EPQ's factor structure was defined *a priori* or generated from the raw data. In particular, stroke survivors reported a greater preference for structured exercise, exercise at a gym or fitness centre, and exercise in groups compared to controls. Many of these group differences diminished when current activity levels and psychological wellbeing were accounted for, indicating that these factors are important influences on exercise preference. Individual variability in preferences of stroke survivors was higher than controls for questions on exercise location but lower than controls for questions on exertion. The two groups also diverged on exercise dislikes and barriers, with stroke survivors focusing on pain and tiredness whereas controls focused on not having enough time and motivation.

First we will discuss group differences on the 5 *a priori* exercise preference factors. Stroke survivors had greater preference for group exercise rather than exercise alone. Exercising in a group provides a social interface as well as an exercise opportunity, and isolation can be a major issue following stroke [16]. Stroke survivors showed a strong preference to exercise with people of similar age compared with controls. This may reflect a desire to be around people with similar life experiences or a better understanding of their individual situation. The stroke group also had greater preference for structure and routine in exercise. Considering the limitations to one's own abilities following a stroke, a familiar environment and regular activities can be reassuring. Stroke survivors reported a greater preference for exercises to be demonstrated to them. Observation is an important part of learning, and an exercise demonstration can aid correct technique and help reduce potential injuries. Decreased confidence is common after stroke [17] and can limit a person's willingness to try the unknown without assistance. Stroke survivors also expressed greater preference for exercising in a facility. Exercising in a gym or community fitness centre is a known entity; amenities are generally easy to find and access and professionals are usually on hand if assistance is required.

A similar picture emerged from data-driven factor analysis. Factor 1 ("routine-unadventurous") corresponded with the *a priori* "structure" factor and factor 2 ("gym-goer") closely matched the *a priori* "location" factor. Stroke survivors and controls expressed significantly different exercise preferences on both these factors. Thus, the lines of evidence converge to indicate that stroke survivors prefer exercising in a structured manner at a specific facility compared to controls. In both *a priori* and data-driven analyses; however, the inclusion of current activity levels and psychological wellbeing in a multivariate model weakened the effect of group on exercise preference. The effect of group remained significant only for the *a priori* "location" factor and data-driven "gym-goer" factor, and these factors both centred around exercise in an established facility. This indicates that the preference for structured exercise expressed by stroke survivors is partly attributable to their lower activity levels and poorer psychological wellbeing.

Our findings in stroke do have similarities to those identified in cardiac patients, who were found to place more importance on being part of group exercise and having individualised attention from professionals than controls [7, 9]. The tendency for stroke survivors to prefer structured exercise and an established exercise facility, however, contrasts with the preferences of a group of slightly younger

breast cancer patients [7, 9]. Only 22% of these patients liked to exercise in an established facility, and the majority wanted exercise to be flexible and unsupervised. While it is important to demonstrate that different populations have different exercise preferences as a first step, the greatest clinical impact will come with understanding more about the preferences of individuals. Tools such as the EPQ can be used to understand the exercise preferences of individual stroke survivors and programs can be tailored accordingly. In line with our second hypothesis, stroke survivors had greater individual variability in exercise preferences than controls on 4 of the 5 *a priori* factors, although the differences were not marked. The main pattern to emerge was the relatively high variability among stroke survivors in whether they liked certain locations for exercise and whether they wanted to be independent. This suggests that planners of exercise programs for stroke survivors should take careful note of individual differences in preferences regarding location and independence. The stroke group had relatively low variability in whether they liked to exert themselves when exercising, indicating fewer individual differences on this parameter.

Correlational analyses using the *a priori* factors indicated that lower current activity levels were associated with a higher preference for structure and lower preference for independence. Lower quality of life was associated with a higher preference for structure and a higher preference for exercising at a facility. Stroke survivors reported poorer quality of life and lower activity levels than controls, and these factors are likely to be major underlying reasons for the difference in exercise preferences after stroke.

Responses to the open questions were informative. Both stroke and control groups liked exercise because it is healthy, improves fitness and strength, makes one feel good, and keeps the mind active. The two groups diverged, however, when it came to dislikes. Stroke survivors indicated that they did not like exercise because it can cause them pain and make them tired. A susceptibility to fatigue and tiredness is common after stroke, making previously routine activities tiring [18]. Stroke can also result in decreased strength and stability, increasing vulnerability to injury and pain. The poststroke sequelae of fatigue and pain should be considered, with modifications to session length and content as required, when planning exercise programs. In contrast, control participants indicated they disliked exercise because it takes a lot of time and is hard to fit in.

5. Conclusions

Understanding exercise preferences is important when organising an exercise or rehabilitation program. This preliminary study gives an insight into the exercise preferences of stroke survivors and their interaction with current activity levels, psychological wellbeing and quality of life. The next step will be to refine the Exercise Preference Questionnaire, adding or removing items where necessary, to ensure that it captures the most relevant information without becoming unwieldy.

Appendix

Exerices Preference Questionnaire$_{(\text{stroke})}$

- This questionnaire is about what kinds of exercise you like and don't like.
- Your answers will help us understand more about the best kinds of exercise programs for people after a stroke.
- Please answer honestly—all information collected is confidential.
- The questionnaire shouldn't take more than 10 minutes—thank you for your time.

(1) Do you currently participate in an organised exercise program?

Yes ☐ No ☐ (If "no", please proceed to question 4)

(2) How long have you participated in this program for?

Less than 1 month ☐ 1–6 months ☐

More than 6 months ☐

(3) What does this program include? Tick all that apply.

Walking ☐ Aerobics ☐ Weight training ☐

Swimming ☐ Yoga ☐ Cycling ☐

Other ☐ (please specify)...

Please indicate how much you agree with each of the following statements:

Don't agree at all (0%)—Totally agree (100%)

(4) I like to exercise ☐%

(5) I feel I am able to participate in an exercise program ☐%

(6) I prefer to exercise in the morning ☐%

(7) I like to exercise at a gym ☐%

(8) I like to exercise alone ☐%

(9) I like to do the same activity each time I exercise ☐%

(10) I like someone showing me what to do when I exercise ☐%

(11) I like to exercise at a community fitness centre ☐%

(12) I like to feel tired after an exercise session ☐%

(13) I like to exercise with family or friends ☐%

(14) I like my exercise sessions to be planned (e.g., water aerobics class) ☐%

(15) I like someone else to organise my exercise sessions ☐%

(16) I like to exercise at a rehabilitation centre ☐%

(17) I like to do gentle exercise ☐%

(18) I like to exercise with other people of similar age ☐%

(19) I like to have written instructions for my exercise ☐%

(20) I like the flexibility of organising my own exercise sessions ☐%

(21) I like to exercise at home ☐%

(22) I think exercise will help prevent further stroke ☐%

(23) I like to work hard in an exercise session ☐%

(24) I like to exercise with other people who have had a stroke ☐%

(25) I like to make exercise part of my daily activities (e.g., walk to shops) ☐%

(26) I like to exercise outdoors ☐%

(27) I like to exercise in a community group ☐%

(28) I worry that exercise might cause another stroke ☐%

(26) What do you like about exercise?

.....

(27) What don't you like about exercise?

.....

(28) What stops you from exercising?

.....

(29) List your three favourite types of exercise

.....

(30) Number the following forms of exercise from 1–10 with 1 being your favourite and 10 being your least favourite form of exercise:

Walking ☐ Water aerobics ☐ Golf ☐

Swimming ☐ Weight training ☐ Bowls ☐

Yoga ☐ Pilates ☐ Cycling ☐ Gym ☐

THE END—Thank you very much.

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Research Article

Fatigue after Stroke: The Patient's Perspective

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Background. Fatigue after stroke is common and distressing to patients. *Aims*. Our aims were to explore patients' perceptions of post-stroke fatigue, including the causes of fatigue and the factors that alleviate fatigue, in a mixed methods study. *Results*. We interviewed 15 patients who had had a stroke and were inpatients on stroke rehabilitation wards. A substantial proportion of patients reported that their fatigue started at the time of their stroke. Various different factors were reported to improve fatigue, including exercise, good sleep, rehabilitation and rest. Fatigue influences patients' sense of "control" after their stroke. *Conclusion*. Our results are consistent with the possibility that poststroke fatigue might be triggered by factors that occur at the time of the stroke (e.g., the stroke lesion itself, or admission to hospital) and then exacerbated by poor sleep and boredom. These factors should be considered when developing complex interventions to improve post-stroke fatigue.

1. Introduction

Fatigue is defined as a feeling of lack of energy, weariness, and aversion to effort [1]. Fatigue is common after stroke [2] with a prevalence ranging from 16% to 72% [2–7] depending on the population studied and whether patients with mood disorders are included or excluded. One recent large study demonstrated that fatigue after stroke was associated with lower self-reported mood, was more common in women, and increased with age, but together these factors explain only about 30% of the variance in fatigue [8]. Other small studies have demonstrated associations with systemic inflammation [9], reduced physical fitness [10], and "a locus of control directed towards powerful others" [11]. In a population-based study of minor ischaemic stroke and TIA, fatigue was more common in stroke than TIA [12]. Because the stroke patients had little or no motor deficit, the authors suggested that their excess of fatigue compared with TIA patients might be attributable to central mechanisms, rather than the result of increased physical effort required after stroke [12]. Early work suggested an association with brain stem strokes [2], though this has not been confirmed by more recent studies. Recently, a very small study suggested that "central" fatigue might be associated with mood disorders and that "exertional" fatigue is associated with impaired physical fitness [13].

Many stroke survivors do not make a complete recovery from their stroke and are left with residual neurological problems and other long-term consequences such as depression, reduced physical fitness, impaired cognition, and an increased risk of falls. Given the plethora of after stroke symptoms, an important question is whether fatigue actually matters to patients. The available literature suggests that fatigue is perceived as a major problem after stroke. For example, in a postal survey of 88 stroke survivors, 68% reported that they had fatigue, and 40% reported that fatigue was their worst or one of their worst symptoms [4]. Fatigue affected functioning in physical and psychological domains [4]. In another study of 90 stroke survivors at least one year post-stroke, 50% of participants indicated that fatigue was their main complaint [14]. Furthermore, fatigue in stroke patients has been linked to shorter survival and a higher risk of institutionalization [5].

Given the large burden of fatigue after stroke and its possible adverse impact on survival, further research is crucial to better understand its aetiology, in order to develop new treatments. The patient's perspective is essential given the subjective nature of fatigue, and qualitative research

Table 1: Characteristics of participants.

Characteristic	Participants (n = 15)
Age (mean ± SD)	72.3 ± 11.5
Gender (% Female)	11 (73%)
Stroke Severity (NIHSS) (mean ± SD)	3.9 ± 3.5
Fatigue Assessment score (mean ± SD)	24.8 ± 6.5
Time since stroke in weeks (mean ± SD)	13.4 ± 9.4
Localization (%)	
Right hemisphere	7 (47%)
Left hemisphere	6 (40%)
Other	2 (13%)
OCSP syndrome type (%)	
Posterior circulation	3 (20%)
Total anterior circulation	5 (33%)
Partial anterior circulation	6 (40%)
Lacunar syndrome	1 (7%)
Pathological subtype	
Ischaemic	14 (93%)
Haemorrhagic	1 (7%)
Comorbid conditions (%)	
Hypertension	9 (60%)
Diabetes	3 (20%)
Previous stroke	1 (7%)
Arthritis	1 (7%)
Thyroid disease	2 (13%)
Medications (%)	
β-blockers	3 (20%)
Antiplatelets	10 (67%)
Statins	12 (80%)
Antihypertensives	9 (60%)
Mobility (%)	
Walking	73
Nonwalking	26

methods are ideal for in-depth exploration of the patient's perspectives. One small qualitative study recruiting 19 stroke survivors to three focus groups explored stroke survivors' views of fatigue after stroke [15]. This study reported that stroke survivors felt unprepared for the fatigue phenomenon and struggled to adapt, with fatigue having a debilitating influence upon daily occupational performance and roles, including social participation, return to work, driving, reading, and sleeping. The participants indicated that exercise (such as walking and water aerobics) and use of assistive technology were helpful strategies in reducing fatigue [15].

Our aim was to explore, using mixed qualitative and quantitative methods, patients' perceptions of post-stroke fatigue, including its aetiology, and its exacerbating, and relieving factors, with a view to developing new treatments.

2. Methods

The study was approved by Lothian Research Ethics Committee. We performed a mixed-qualitative and quantitative interview study recruiting patients from inpatient stroke rehabilitation wards in Edinburgh (July–September 2009). To be approached by the researcher for inclusion into the study, patients had to have suffered a stroke at least one month prior to interview, and the nurses had to report that they were suffering from fatigue (based on their observations of the patient and patients' own reports of fatigue). Those with severe dysphasia, confusion and those who were medically unstable due to another medical condition were not eligible. Eligible patients were given a patient information sheet and those who consented were included in the study.

The researcher (VB) administered the National Institute of Stroke Scale (NIHSS) [16], diagnostic criteria for post-stroke fatigue [17], and the Fatigue Assessment Scale (FAS) [18] to assess fatigue severity. To fulfil diagnostic criteria for post-stroke fatigue, patients had to have fatigue for more than 50% of waking hours, and the fatigue had to be clinically significant, that is, interfere with activities of daily living [17]. The researcher then performed a semistructured interview, with both "closed" and "open" questions, to explore patients' beliefs about the aetiology of their fatigue, and its exacerbating and relieving factors (see Figure 4). Patient responses were explored in more detail by the researcher, and emerging concepts were identified. The researcher recorded patient responses on paper data collection forms, and then used a five-step thematic framework approach [19] to analyse the qualitative data. The first step involved familiarisation with the data to list key themes that arose. The second step involves drawing out all the main concepts, themes, and issues in relation to aims of the study and patient responses. In step 3 all the data were reviewed and the thematic framework applied; codes were assigned to the relevant themes. In step 4, the data were then rearranged according to various themes. Finally, step 5 involves mapping and interpreting the data, and finding links between themes keeping in mind the aims of the study.

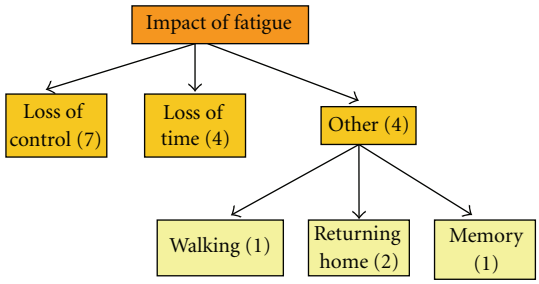
3. Results

All patients were recruited during their hospital admission because of their stroke. Twenty-three patients were identified by nursing staff as having fatigue. One could not hear well enough to participate and four patients felt too tired to speak to researcher. After reading the study information sheet, a further three patients did not think the study applied to them as they were not experiencing fatigue, leaving fifteen patients who participated in the study.

The characteristics of the 15 participants are shown in Table 1. All 15 met our case definition for post-stroke fatigue. The mean FAS score was 25 [SD 6.5].

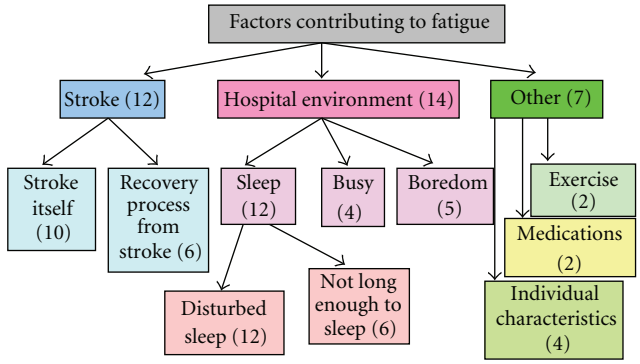
3.1. Nature of Fatigue after Stroke. Six (40%) patients reported feeling fatigued before the stroke but all six patients said that their fatigue after their stroke was a different type of fatigue from the fatigue that they had experienced prior to their stroke.

Patients described their post-stroke fatigue to be "a tiredness in the muscles" (9/15, 60%), "a general feeling of tiredness" (10/15, 67%), or "mental tiredness" (5/15, 33%).



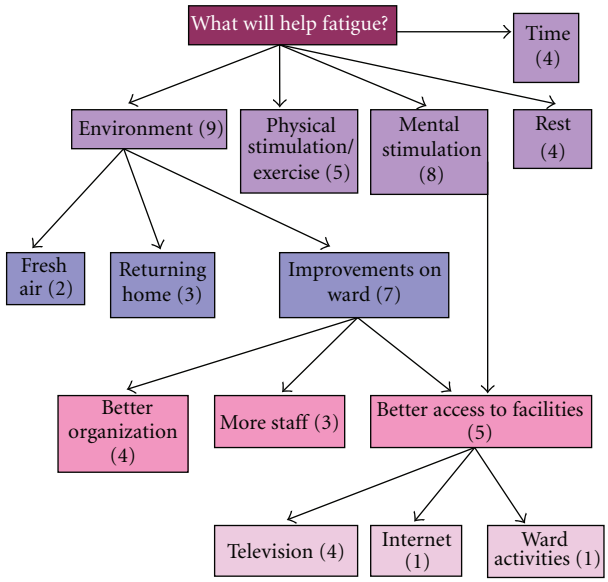
The numbers in brackets are the number of patients who had the boxed opinion

Figure 1: Impact of fatigue.



The numbers in brackets are the number of patients who had the boxed opinion

Figure 2: Factors contributing to and exacerbating fatigue.



The numbers in brackets are the number of patients who had the boxed opinion

Figure 3: Factors that might help fatigue.

3.2. Aetiology of Fatigue, Exacerbating, and Relieving Factors. Twelve (80%) patients felt the fatigue was caused by the stroke itself or brain recovery, 14 (93%) patients felt hospital environment contributed, and 5 (33%) felt that boredom was a contributor. Twelve (80%) had been woken at least once during the night as a result of disturbance on the ward and 6 (40%) complained that not being given long enough to sleep in general (being woken very early for washing and breakfast) also contributed to fatigue.

Only three patients (20%) reported that meal times made their fatigue worse and five (33%) patients felt that medications made their fatigue worse. There was no particular time of day that patients felt most fatigued: five (33%) patients reported that they were most severely affected in the morning, six (40%) noticed fatigue being worst in afternoon, three (20%) reported that their fatigue was constant throughout the day, and one (7%) patient said that the fatigue was worst in the evening. Five (33%) reported visiting times as aggravating their fatigue, nine (60%) patients felt that exercise and rehabilitation helped fatigue, and 14 (93%) found sleep beneficial.

Qualitative analysis identified several themes and subthemes. The main impact of fatigue was a sense of loss of control (7 patients), loss of time (4 patients), adverse effect on walking (one patient), returning home (2 patients), and memory (one patient) (Figure 1). Contributing factors to fatigue include the stroke as a central process as well as recovery and hospital environment (in particular sleep) (Figure 2). Interventions that patients felt would help included mental stimulation, exercise, sleep, and more activities on the ward (Figure 3). Environmental suggestions for improving fatigue included fresh air, returning home, more staff, and better access to facilities such as television, internet, and ward activities. Four (27%) patients felt that better organisation on the ward would help their fatigue; subthemes included more staff, a more relaxed environment, and increased staff availability to carry out activities. Another subtheme suggested by one patient was arranging bays so that patients with less severe dysphasia were grouped together so that they could converse with one another.

4. Discussion

There is very little information in the literature about patient's perception of the causes of fatigue after stroke, or about the factors that might exacerbate or improve fatigue. Intriguingly, a substantial proportion of patients felt that their fatigue started at the time of their stroke, and that post-stroke fatigue was different in phenomenology than any prestroke fatigue that they had experienced. This observation would be consistent with the idea of a "central" neurological cause of post-stroke fatigue [12]. Some patients also felt that fatigue was part of the normal recovery process from stroke. Exercise was reported by some patients to improve fatigue, confirming the findings of a previous small qualitative study, but some patients reported that rest improved fatigue [15]. Most patients reported that sleep improved fatigue, and so it is concerning that the majority of the patients reported disturbed sleep in hospital. The majority of patients felt that the ward environment was a major contributor to fatigue and recommended simple ward changes such as better access to television, internet, and activities.

Fatigue before stroke.

Did you feel fatigued before your stroke?

If so, what was it like? Is fatigue NOW similar or different to what you had before?

Characteristics of fatigue now.

Is it a □ tiredness in your muscles (*patient can choose* >1)

□ general feeling of tiredness

□ mental fatigue

Is there any time of day you feel more fatigued?

If YES: Is it morning, afternoon or evening?

How long does your fatigue last in a 24 hr period? _____ hrs

Change in fatigue over time: Is it getting better, staying the same, or getting worse?

Sleep

On average, how many hours of sleep do you get a night?

On average, how many times a night do you get woken by disturbance on the ward?

Is there anything else that wakes you?

Do you nap during the day? If so, how many hours for?

Precipitating and relieving factors (take note of any relevant comments made by patients)

Using scale:

Strongly agree — Agree — Neutral — Disagree — Strongly disagree

Do you find that exercise makes you feel less fatigued?

Do you find that doing rehabilitation makes you feel less fatigued?

(*explain to patient what is meant by rehabilitation*)

Do you find that sleeping makes you feel less fatigued?

Do you feel that medication makes you feel less fatigued?

Do you feel that your fatigue is worse at or after meal times?

Do you feel more fatigued at or after visiting times?

Do you have visitors:

○ more than once a day

○ once a day,

○ every few days,

○ not very often.

Do you think the staff do enough to help you?

- is there anything else they could do to help?

Do you find that resting makes the fatigue better, worse or no change?

Open questions

What do you think has caused your fatigue?

What have you found hardest regarding your fatigue?

What do you think is likely to make it better?

Figure 4: Interview schedule.

The main limitation was the small number of patients recruited, though for a qualitative study, this is not particularly small. Several patients refused to take part as they were too tired or did not think they were tired enough to be involved in study. Furthermore, we had to rely on nurses' initial screen of whether or not patients were fatigued before the researcher could approach them; this meant that we may have missed patients with fatigue.

We deliberately included patients at least one month after stroke, in order to explore the longer term impact of fatigue. We did not screen for depression, so it is possible that some of the participants' fatigue might have been explained, at least in part, by depression, though the ward staff screened for, and treated, depression as a routine aspect of the management of patients after stroke.

Previous work has shown that fatigue is still present for several years after the stroke [5]. Many of the factors that patients reported as being relevant to fatigue were specific to a ward environment, for example, boredom, noise, and ward regime with fixed times for meals and bedtimes. Thus, a similar mixed methods study needs to be performed in community-dwelling stroke survivors.

What are the directions for future research? The observation that fatigue seemed to start at the time of the stroke, and that post-stroke fatigue was different in phenomenology than prestroke fatigue is consistent with the concept that the brain lesion itself might trigger fatigue [12]. Thus, neuroimaging studies would be warranted to explore in more detail associations between fatigue and the site and size of the brain lesion. There are also other factors occurring at the time of the stroke that might trigger fatigue, for example, admission to hospital. The reported association between fatigue and poor sleep justifies larger observational studies seeking an association between fatigue and poor sleep. Given that sleep apnoea is sometimes a complication of stroke, studies to determine whether fatigue is associated with sleep apnoea would also be of interest. The reported association between exercise and improvements in fatigue is consistent with the findings of a previous qualitative study [15] and previous quantitative studies showing associations between fatigue and indices of reduced physical fitness [10, 13]. Graded exercise is effective for chronic fatigue syndrome [20] and might well be effective for post-stroke fatigue: this is an area where further research is needed.

Implications for Clinical Practice. Clinicians need to be aware that poor sleep and boredom are common problems for stroke survivors undergoing rehabilitation in hospital. Every effort should be made by ward staff to facilitate better sleep on stroke rehabilitation units and to provide activities to alleviate boredom.

5. Conclusions

This mixed methods interview study suggests that poststroke fatigue might be triggered by the stroke lesion itself or other events occurring at the time of stroke, for example, admission to hospital, and perhaps exacerbated by poor sleep and boredom. A complex intervention targeting these factors, and perhaps incorporating exercise, might plausibly improve fatigue after stroke, and should now be developed and tested.

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