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Clinical Study

Gait Performance and Lower-Limb Muscle Strength Improved in Both Upper-Limb and Lower-Limb Isokinetic Training Programs in Individuals with Chronic Stroke

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Background. Limited improvement in gait performance has been noted after training despite a significant increase in strength of the affected lower-limb muscles after stroke. A mismatch between the training program and the requirements of gait could explain this finding. *Objective*. To compare the impact of a training program, matching the requirements of the muscle groups involved in the energy generation of gait, to a control intervention, on gait performance and strength. *Methods*. 30 individuals with chronic stroke were randomly assigned into two groups ($n = 15$), each training three times/week for six weeks. The experimental group trained the affected plantarflexors, hip flexors, and extensors, while the control group trained the upper-limb muscles. Baseline and posttraining values of gait speed, positive power (muscles' concentric action during gait), and strength were retained and compared between groups. *Results*. After training, both groups showed a similar and significant increase in gait speed, positive power of the hip muscles, and plantarflexors strength. *Conclusion*. A training program targeting the lower-limb muscles involved in the energy generation of gait did not lead to a greater improvement in gait performance and strength than a training program of the upper-limb muscles. Attending the training sessions might have been a sufficient stimulus to generate gains in the control group.

1. Introduction

It is well recognized that residual muscle strength on the affected side secondary to a stroke has a great impact on activities of daily living, especially on gait performance. The self-selected and maximal gait speeds of individuals with stroke have been positively related to the residual strength of the affected plantarflexors [1–3], hip flexors [1–3], knee extensors, and flexors [1, 2]. Gait asymmetry has also been negatively related to the residual strength of various muscle groups including the plantarflexors and the knee extensors [1]. Knowing that muscle weakness can jeopardize the fulfillment of a functional gait in individuals with stroke, muscle strengthening of the affected lower-limb has become a recognized therapy in the field of rehabilitation.

Many studies have verified the impact of resistance-strengthening programs on the muscle strength of the affected lower extremity of chronic individuals who have had a stroke (>3 months after stroke). Static, dynamic or isokinetic training protocols applied for less than three months resulted in a mean strength increase ranging from 7% to 155% and, generally speaking, this increase was clinically significant, with an effect size greater than one [4–9]. The large discrepancy in the relative increase could be related to differences in the form and intensity of the training protocols as well as in the evaluation procedures, namely, body positioning, stabilization [10], or torque measurements (peak torque versus strength taken at a common angle), for example.

The impact of resistance-strengthening programs on functional performance has been reported in most of the previous studies. The mean change in the self-selected gait speed ranges from 0 to 0.22 m/s [7–9, 11] and, expressed as a relative gain, it represents 0% to 25% of the pretraining values. Thus, resistance-strengthening programs have had a lower impact on self-selected gait speed than on strength among individuals with stroke.

The discrepancy between strength gain and gait changes may be related to the fact that the strengthening protocols did not match the requirements of the functional task in terms of range of motion, velocity, position, and trained muscles [12]. As opposed to strength training, functional training, defined as the practice of a context-specific task, has the advantage of directly practicing a problematic functional activity (e.g., gait), rather than focusing on the impairments (e.g., strength) negatively influencing its performance [13]. Significant gains in several activities of daily living have been reported following various functional trainings (see [14]). However, functional training alone not only allows less control of the intensity of effort produced [15], but its impact on gait is as limited as the one of strengthening programs [16]. One practical way to promote a match between strength-training parameters and a functional task, as well as allow a better control for the intensity of effort, is to use isokinetic devices. In addition, these dynamometers can accommodate the individual's strength throughout the range of motion and allow weakened muscles to be trained using various speeds and types of contraction [10]. It seems that no studies have yet explored the impact of an isokinetic-strengthening program specifically designed to match muscle requirements during gait on the biomechanical gait parameters. Only one study, by Teixeira-Salmela et al. [17], has assessed the impact of a conditioning program on gait speed and related biomechanical parameters. However, their conditioning program was general (strength and aerobic exercises) and not intended to correspond to the specific prerequisites of gait. Furthermore, the biomechanical gait parameters were analyzed only descriptively, thus restraining interpretation of the data.

Considering that transfer of strength gain into an improvement in functional performance could be related to the training program itself, the aim of the current randomized controlled trial was to compare the effect of a task-specific isokinetic training program, corresponding to the requirements of the concentric action in gait of the affected plantarflexors, hip flexors, and extensors, on gait performance and muscle strength, to an isokinetic training program targeting the affected upper-limb muscles. Selection of the lower-limb muscles was based on their significant involvement in energy generation during gait [18] and on the fact that their reduced moment and power production following a stroke have a great impact on gait speed after stroke [3]. Based on these findings, the main hypothesis of the present study was that the task-specific training of the affected lower-limb muscles would produce greater changes in gait performance and strength than a control intervention not aiming at training these muscle groups.

2. Materials and Methods

2.1. Participants. To take part in the study, individuals with a stroke had to meet the following criteria: (1) have a chronic (six months or more) unilateral stroke, (2) be able to walk 10 meters independently with or without a cane, (3) present residual weakness at the affected lower-limb (strength deficit > 10% compared to the unaffected side), and (4) have an activity tolerance of at least two hours with a rest period. The exclusion criteria were as follows: (1) receptive aphasia, (2) incontinence, (3) unstable medical condition, (4) history of injury, and (5) anesthesia at the lower limbs. Authorization by the primary-care physician was obtained if needed. All potential participants signed an informed consent form prior to the assessment session and the study was in accord with the ethical standards of the institutional ethics committee concerned.

2.2. Evaluation Sessions. In the week prior to each training program, participants attended a clinical, strength and gait evaluations that were split into three half-day evaluation sessions. The strength, and gait evaluations were repeated at the end of each training program.

2.2.1. Clinical Evaluation. In order to complete the characterization of all the participants, a trained physical therapist, blinded to the group assignment, collected demographic data and various outcome measures. For the outcome measures, the lower-limb physical impairment at the leg and foot, the perception threshold of touch-pressure of the affected foot and the function and dexterity of the affected upper extremity were evaluated by means of the Chedoke-McMaster Stroke Assessment [19], the calibrated Semmes-Weinstein filaments, and the Action Research Arm Test (ARAT) [20], respectively. Spasticity at the ankle was measured by the Composite Spasticity Index [21]. This scale evaluated three components of spasticity: resistance to full-range passive ankle dorsiflexion (0 = normal and 8 = maximal opposition), Achilles tendon jerks (0 = normal and 4 = hyperreflexia), and the amount and duration of ankle clonus (1 = none and 4 = tireless). Summed scores ranging from 0 to 5, 6 to 9, 10 to 12, and 13 to 16 corresponded to normal muscle tone, mild spasticity, moderate spasticity, and severe spasticity at the ankle, respectively. Also, balance was assessed with the Berg Balance Scale [22] and self-selected and maximal clinical gait speeds were quantified by means of the 5-meter walk test [23]. Finally, to measure a participant's activity level and his/her perceived health status, the Human Activity Profile (HAP) questionnaire (adjusted score) [24] and the Short Form 36 Health Survey were used, respectively [25].

2.2.2. Strength Evaluation. The maximal voluntary concentric strength in plantarflexion, hip flexion, and extension of the affected muscles was measured with a Biodex dynamometric system (Biodex Medical Systems, NY, USA).

The positioning and testing of each muscle groups are described elsewhere [26]. Briefly, the joint position was selected to closely represent that found during the muscles' maximal concentric effort in gait. Therefore, for the testing of plantarflexors, participants were seated with their affected knee strapped in nearly full extension, whereas for the hip muscles, participants were in an horizontal position with their evaluated lower-limb positioned in a leg-rest device that maintained the knee at 25° of flexion [18]. Because individuals with stroke have difficulty generating maximal exertion throughout the entire range of movement at high velocity [8, 26], especially at the hip joint [26], a 30°/s testing velocity was chosen to evaluate the effectiveness of each training program. A rest period of 30 seconds was given between contractions, and a 2-minute rest period was allowed between directions of movement for the hip joint. For each testing condition, two trials were done for each muscle group and the trial showing the highest torque value was retained. Passive torque was also recorded for gravity correction at each angle of the movements assessed.

From the torque-angle curves of each joint, strength values were extracted at the first common angle (external range of motion) reached by all participants, which was 7° of dorsiflexion for the plantarflexors, 0° (hip in neutral position) for the hip flexors, and 40° of hip flexion for the hip extensors.

2.2.3. Gait Evaluation. Kinematic and kinetic data were recorded with an Optotrak system (Northern Digital Inc.) and three AMTI force platforms during five gait cycles at self-selected and maximal speeds, respectively. The ankle and hip joint positions were combined with the ground reaction forces to estimate the net muscular moment using an inverse dynamic approach. Positive power phases, meaning that a concentric action was performed by a muscle group, were identified when the angular velocity multiplied by the local net muscular moment at the ankle and hip joints presented the same polarity [18]. At the ankle joint, the concentric phase of the plantarflexors, A2, begins at about 40% of the gait cycle and ends at toe off (~60%), which corresponds to the push-off phase. At the hip joint, two concentric phases are observed: H1, corresponding to hip extensor activity at the beginning of the gait cycle, and H3, representing the pull-off phase by the hip flexors to swing the limb forward and upward (~50–80% of the gait cycle) [18]. Within these concentric phases, the peak positive power was retained for each muscle group at both speeds and the values were normalized to body mass to remove the influence of individual mass.

The stride characteristics of each gait cycle were computed with footswitches located on the sole of the shoe at the heel, the metatarsal heads, and midfoot. These signals and those from the vertical ground reaction force were used by in-house developed software to determine the gait cycles, which were normalized to 100%. Three trials out of five, showing the most similar values of speed and cadence, were averaged.

2.3. Randomization. A 4 × 2 blocked randomization allowed the main author (MHM) to allocate participants to an experimental group (EXP), that is, task-specific isokinetic strengthening program of the affected lower-limb muscles, or to a control group (CTL), that is, isokinetic-strengthening program of the affected upper-limb muscles. Randomization was based on the baseline results of the 5-meter walk test at self-selected speed and the ARAT. A speed value higher or lower than 0.4 m/s was used as a delimiter because this can be considered the cutoff speed for community walking [27] whereas for the ARAT, a score higher or lower than 10/57 was retained because it could represent the lower limit for a functional upper arm [28] (see Figure 1). Because participants were not blinded to the group assignment, they were instructed not to reveal their training group status to the physical therapist in charge of the clinical evaluation to avoid any bias.

Table 1: Strengthening program for both training groups and each muscle group.

Training parameters	Weeks of training					
	1	2	3	4	5	6
Intensity (% MSC*)	65	70	70	80	80	80
Repetitions	6	6	8	6	8	10
Series	2	2	2	2	2	2

*MSC: maximal static contraction.

2.4. Strengthening Program. The strengthening program was conducted three times a week for six weeks for a total of 18 sessions. Each session lasted between 60 and 90 minutes and started with a 5-min warm-up period followed by a cool-down period of about 15 minutes. For each group, a trained physical therapist, blinded to the experimental and clinical evaluations, supervised the session and was in charge of the progression of the training based on the established protocol. The protocol started with a maximal static contraction in the external range of motion of the trained joint. This contraction allowed the physical therapist to determine the maximal torque that could be reached right at the beginning of the movement. Based on the maximal torque obtained, the intensity of the training session was determined and a target line, corresponding to the requested intensity, provided the participants with a retroaction of the force level to be reached. The dynamometer was put in an isokinetic passive mode and participants were asked to produce repeated submaximal dynamic contractions in the desired direction of movement, maintaining their effort throughout the movement. Progression of the training was based on intensity and repetitions in accordance with the recommendations of the American College of Sports Medicine for a strengthening program [29] (see Table 1), and all training sessions missed were noted in the participant's chart.

For the EXP group, the plantarflexors, hip flexors, and extensors were trained concentrically with a Biodex dynamometer. Submaximal contractions were preceded by a static preloading to closely correspond to the muscle conditions during their concentric action in gait and participants trained at slow and moderate velocities of 30°/s and 90°/s, respectively. These velocities were chosen to cover the joint angular velocity observed during the power generation

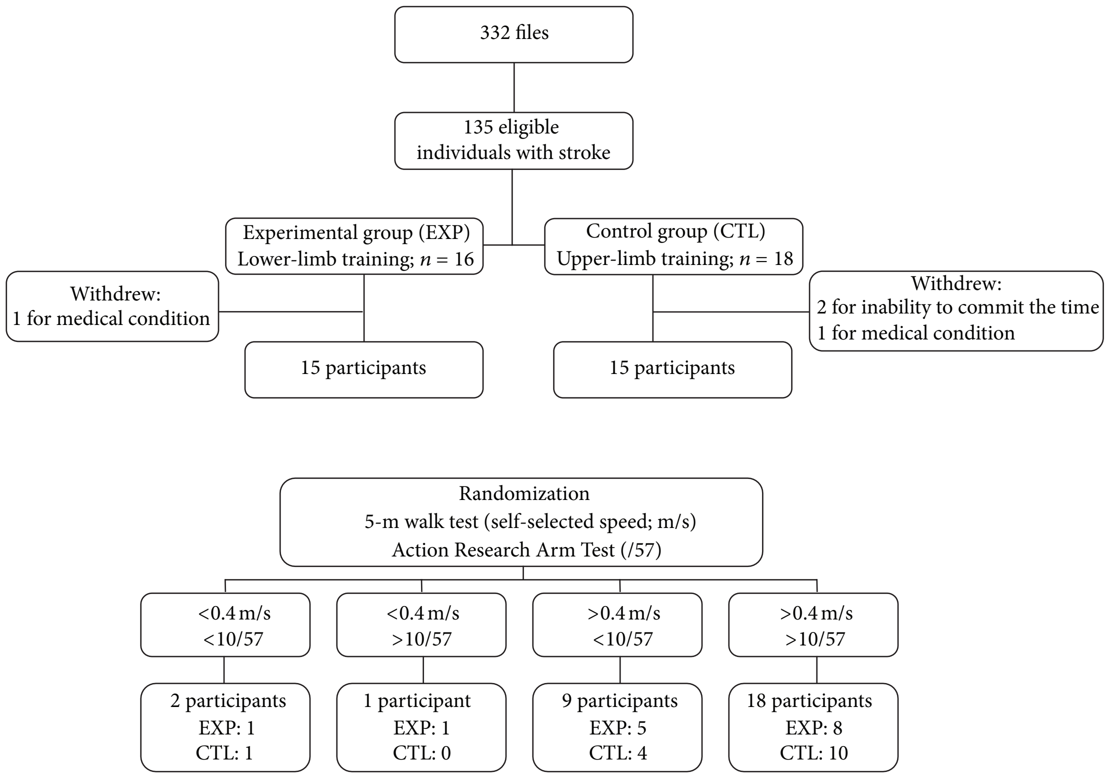

Figure 1: Chart of the recruitment and randomization procedures.

phase (concentric action) of gait when the maximal net moment is reached by the muscle group. Range of motion was individually adapted to each participant's gait kinematics. The positions of the adjacent joints were identical to those in the strengthening evaluation. For participants allocated to the CTL group, they took part in a training program targeting their upper-limb muscles. This was done to ensure that these participants had a training regimen as demanding and motivating as the EXP group, but without having any impact on the strength of the lower-limb muscles. Thus, participants trained concentrically their shoulder flexors, elbow flexors, and wrist extensors with a Cybex dynamometer (Cybex Medical, Ronkonkoma, USA) at slow and moderate velocities of 15°/s and 60°/s, respectively. The positioning and ranges of motion were in accordance with the Cybex manual. In addition, grip muscles were trained isotonically with a Martin vigorimeter (Chattanooga, United Kingdom). These muscles were chosen because they are related to the upper-limb function [30, 31]. The training programs of the EXP and CTL groups were conducted at the Institut de réadaptation Gingras-Lindsay-de Montréal pavilion Gingras and pavilion Lindsay, respectively. Therefore, both groups had to walk approximately the same distance to go to their training session.

2.5. Statistical Analysis. The main outcome measure was a change in gait speed and peak positive power following training. The secondary outcome measure was a change in strength at the plantarflexors, hip flexors, and extensors. Descriptive statistics (mean and SD) were calculated for the demographic and clinical data. The baseline comparison of the two training groups was assessed with the Wilcoxon's rank-sum test for the clinical evaluations and independent t-tests for the primary (gait speed and peak positive power) and secondary (strength values) outcomes. Also, two-way repeated measures ANOVA with a "group of subjects" between factors compared the main effect of time on gait performance and strength values for each gait speed and each muscle group, respectively. The P value was set at 0.05. All statistical analyses were performed using SPSS software Windows (version 18, Chicago, IL, USA).

3. Results

3.1. Participants. Out of 332 files scanned for potential candidates, 135 individuals with stroke met the study inclusion criteria and were sent a recruitment letter. Of these, 34 answered and agreed to participate. They were randomly divided into the EXP group ($n = 16$) and the CTL group ($n = 18$). After one week of training, one participant in the EXP group withdrew because of a medical condition and two others in the CTL group withdrew because they were unable to commit the time. Another participant in the CTL group dropped out after five weeks of training because of a medical condition. These participants were excluded from the analysis. Thus, a convenience sample of 30 chronic individuals with stroke, 15 in each training group, completed the study (see Figure 1). Overall, compared to healthy individuals evaluated from a previous study [32], participants showed a 34% decrease in their self-selected gait speed and presented strength deficits at the affected plantarflexors, hip flexors, and hip extensors of 64%, 40% and 34%, respectively. At baseline, both groups showed similar demographic characteristics, clinical, gait, and strength data ($P > 0.05$) (see Table 2).

3.2. Gait Changes. A significant increase in the self-selected ($F_{1,28} = 14.62$, $P = 0.001$) and maximal ($F_{1,28} = 5.6$, $P = 0.025$) gait speeds was noted after the 6-week strengthening program for both groups (between group $P > 0.1$). For the EXP group, this increase corresponded to a 9% (−13 to 42%) and 12% (−17 to 97%) mean change for the self-selected and maximal gait speeds, respectively. For the CTL group, the corresponding values were 19% (−11 to 48%) and 6% (−10 to 33%).

After training, a significant increase in the peak positive power bursts of the hip flexors at self-selected speed ($F_{1,28} = 5.34$, $P = 0.028$) and hip extensors at maximal speed ($F_{1,28} = 4.58$, $P = 0.042$) was noted for both groups (between group $P > 0.1$). For the hip flexors, the change in peak positive power corresponded to a mean increase of 31% (−33 to 122%) and 35% (−33 to 171%) for the EXP and CTL groups, respectively. For the hip extensors, the corresponding mean increase in the peak positive power was 43% (−78 to 151%) and 51% (−82 to 224%) (see Table 3). No change in the peak positive power of the plantarflexors was found for both groups and at both speeds. Note that for the plantarflexors, participants wearing an ankle support were excluded from the data analysis.

3.3. Strength Changes. No group difference was noted for the strength gains obtained at the plantarflexors, hip flexors, and extensors (between group $P > 0.2$). For both groups, a significant increase in the strength of the plantarflexors was found ($F_{1,28} = 11.21$, $P = 0.002$), representing a 51% (−31 to 180%) and 40% (−22 to 179%) mean strength gain for the EXP and CTL groups, respectively. A trend towards an increase in strength for the hip flexors ($F_{1,28} = 4.01$, $P = 0.055$) and hip extensors ($F_{1,28} = 3.82$, $P = 0.061$) was also noted (see Table 4).

4. Discussion

A 6-week task-specific isokinetic strengthening program, targeting the affected plantarflexors, hip flexors, and extensor muscles in the context of their concentric action during gait, did not produce greater gains in gait speed, peak positive power, and strength than a similar training targeting the affected upper-limb muscles. This finding suggests a generalized improvement in physical function rather than a training-specific effect of the isokinetic strengthening program. Therefore, it seems that the important point in rehabilitation of individuals in the chronic phase of their stroke is to promote physical activity regardless of the training they are provided with.

4.1. Effect of the Training Program on Gait Performance. The training of the EXP group was task-specific to the phase of gait substantially influencing walking speed, that is the energy generation phase of gait [18]. For that reason, the absence of a significant difference in the gains obtained in the gait parameters between the EXP and CTL groups is very surprising, especially since the CTL group did not train the lower-limb muscles. It is thought that attending the rehabilitation centres had a possible training effect for the CTL group. After stroke, very low levels of physical activity are reported [33] resulting in several negative health issues. In the current study, based on the baseline HAP score, most of the participants of the CTL group fell into the impaired to moderately active categories. Thus, attending a demanding training program 3 times a week for 6 weeks could be a sufficient stimulus to induce gains in gait performance in this subset of stroke survivors. Based on that, the intensity of training seems to be a key element in rehabilitation after stroke in order to enhance functional improvement.

Although our task-specific isokinetic training program matched the gait parameters found during the energy generation phase of gait, it could be thought that the training was not task-specific enough to the requirements of gait to translate into greater gains in gait and strength than the CTL group. Incorporating the practice of gait into the training program might have been more relevant to ensure a greater transfer between strength gain and gait speed [34]. However, it seems that functional training alone does not cause greater improvement in gait speed than resistance training, with a mean change as low as 0.04 m/s [16]. From the results of the current study and previous ones, it seems that the type of training (e.g., task-specific training or resistance training) does not seem to be the key element to generate improved gait performance since various training programs produced comparable gains in gait performance. This is in line with the review by Dickstein on rehabilitation of gait speed after stroke, where the author reported that other variables such as amount and intensity within a training program were common denominators of interventions that facilitated more improvement in function after stroke than the treatment mode [35].

For both groups, the improvement in self-selected and maximal gait speeds was modest and appeared to be mainly associated with an increase in hip power. This indicates that the hip compensatory strategy, typical of gait after stroke [3, 26, 36], is used even more after the training period. These results are in line with previous studies [17, 37] that assessed the impact of various training programs on gait speed and related biomechanical parameters. These studies reported marked changes in ankle and hip power after training, associated with significant improvement in gait speed.

4.2. Effects of the Training Program on Strength. No difference in strength gains was noted between both groups, for the plantarflexors, hip flexors, and extensors. This is not the first study to be plagued with a nonspecific effect of a training program as similar results were found by Flansbjer et al. [4], Ouellette et al. [7], and Kim et al. [8]. The lack of statistically

Table 2: Demographic and clinical characteristics of the experimental (lower-limb training) and control (upper-limb training) groups at pretraining.

Characteristics	Experimental group (n = 15)		Control group (n = 15)	
	Mean (SD)	n (%)	Mean (SD)	n (%)
Age (yr)	58.5 (14.9)		54.7 (14.6)	
Body mass (kg)	78.3 (11.3)		72.5 (13.4)	
Height (cm)	170.6 (7.3)		166.5 (9.5)	
Time since stroke (months)	56.9 (43.8)		85.5 (111.9)	
5-meter walk test: self-selected speed (m/s)	0.65 (0.24)		0.79 (0.29)	
5-meter walk test: maximal speed (m/s)	0.98 (0.38)		1.10 (0.50)	
Chedoke McMaster Stroke Assessment (/7)				
Leg	4.3 (1.2)		4.5 (1.4)	
Foot	3.5 (1.1)		3.9 (1.8)	
Action Research Arm Test (/57)	28.3 (25.2)		29.9 (24.9)	
Balance Scale (/56)	49.8 (5.3)		49.5 (5.8)	
Spasticity Index (/16)	7.4 (3.3)		6.7 (2.9)	
Human Activity Profile (adjusted score/94)	51.4 (14.3)		58.3 (16.5)	
SF-36 (%)				
Physical functioning	52.3 (24.9)		56.7 (23.2)	
Mental status	71.2 (16.4)		68.8 (23.4)	
Involved side				
Left		9 (60)		9 (60)
Right		6 (40)		6 (40)
Gender				
Female		6 (40)		6 (40)
Male		9 (60)		9 (60)
Ankle support		4 (26.6)		5 (33.3)
Hypoesthesia of the affected foot		2 (13.3)		2 (13.3)

significant difference between groups could be related to the variability of the response to the training programs. A phenomenon that is scarcely mentioned or explained in studies evaluating resistance training in individuals with chronic stroke is the fact that not all participants seem to benefit from the exercise protocol. Gains in strength are reported mainly as a mean for an entire group but the related standard deviation clearly indicates that strength gain is variable among participants. Variation in strength gain is not typical of individuals with stroke; earlier studies have acknowledged this phenomenon in the able-bodied [38, 39]. It is known that not all muscle groups have a similar rate of strength development and this, combined with the pretraining status of individuals [38, 39], could partly explain the variability in individual training responses.

In the current study, the plantarflexor strength showed the greatest change in both groups. This could be explained by the fact that because the plantarflexors showed a greater strength deficit at baseline than the hip flexors or extensors as compared to the unaffected side (data not presented), there was more possibility for an increase in strength than in the hip joint. This result concurs with the study of Kim et al. [8] who found that the plantarflexors showed a greater mean percentage change than the hip flexors and extensors. The fact that the plantarflexors of the CTL group presented a gain in strength allows the hypothesis that mechanisms other than the direct effect of the strengthening program itself are involved. One of these could be the presence of involuntary contractions of the lower-limb muscles associated with the training of the upper extremity. These contractions could be related to the necessity of the lower-limb muscles to stabilize the body to allow efficient maximal exertion of the tested upper-limb muscles. During training of the upper extremity, the feet of participants were positioned on a resting platform, possibly allowing them to use the platform as an anchor for the lower-limb muscles to provide stability for the body. As mentioned for the changes in gait performance, a more likely mechanism explaining the gain in strength of the plantarflexors of the CTL group could be the possible training effect caused by attending the rehabilitation centres for the training sessions. In fact, during gait, the affected plantarflexors are the most involved muscle group at self-selected speed, with a muscular level of effort (mean ± 1 SD) reaching 64% ± 19% of their maximal strength [26, 36]. This intensity of muscular effort during gait could act as an appropriate training stimulus especially for the plantarflexors, which were weaker than the hip muscles.

4.3. Discrepancy between Strength and Gait Changes. A disproportion between the increase (%) in the current muscle strength and the change in gait speeds was observed.

Table 3: Mean (SD), range, and 95% confidence interval (CI) for the laboratory self-selected and maximal gait speeds (m/s) and mean (SD) for the related peak positive power of the affected plantarflexors, hip flexors, and extensors for the experimental (lower-limb training—$n = 15$) and control (upper-limb training—$n = 15$) groups at pre- and posttraining.

Statistics	Self-selected speed (m/s)					Maximal speed (m/s)				
	Experimental		Control		P^b	Experimental		Control		P^b
	Pre	Post	Pre	Post		Pre	Post	Pre	Post	
Mean (SD)	0.56 (0.19)	0.59[a] (0.18)	0.68 (0.30)	0.78[a] (0.28)	0.1	0.92 (0.41)	0.98[a] (0.39)	1.08 (0.43)	1.13[a] (0.46)	0.3
Range:										
Min	0.29	0.35	0.30	0.38		0.29	0.35	0.30	0.40	
Max	0.93	0.95	1.39	1.24		1.65	1.74	1.71	1.89	
95% CI:										
Lower bound	0.45	0.49	0.51	0.63		0.69	0.77	0.84	0.88	
Upper bound	0.66	0.69	0.84	0.94		1.15	1.19	1.32	1.38	
Peak positive power (W/kg)										
Plantarflexors	0.63 (0.43)	0.74 (0.53)	1.19 (1.25)	1.32 (1.09)	0.2	1.14 (0.74)	1.39 (0.77)	1.86 (1.46)	1.62 (1.30)	0.3
Hip flexors	0.37 (0.17)	0.43[a] (0.14)	0.45 (0.37)	0.55[a] (0.41)	0.3	0.85 (0.67)	0.90 (0.47)	0.88 (0.64)	1.05 (0.61)	0.7
Hip extensors	0.12 (0.08)	0.14 (0.12)	0.19 (0.17)	0.29 (0.38)	0.1	0.43 (0.34)	0.48[a] (0.37)	0.61 (0.43)	0.91[a] (0.82)	0.1

[a] $P < 0.05$ (pretraining value versus posttraining value).
[b] P value is comparison between experimental and control groups.

This is not typical of this work and other studies evaluating the impact of various training programs for the affected lower-limb muscles have obtained similar results where greater effect size for muscle strength change was observed aftertraining in comparison to that for the self-selected gait speed [4, 5, 9, 34]. Unfortunately, there is a lack of explanation for this fact. One reason could be the specificity of the strength-training outcomes. For example, it was observed that static training at one specific angle produced mainly strength gains at this angle [40]. Specificity of training was also noted for velocity and type of contraction [41]. It seems that strength gains are not transferable to various testing conditions other than those used in the training protocol. Consequently, the transfer of strength gain to a functional task such as gait could be more problematic because the muscles have to function in conditions where velocity and type of contractions are constantly changing. In the current work, in addition to ensuring a correspondence between the trained muscle groups and those known to influence gait speed, careful attention was paid to the selection of the angle, velocity, and type of contraction to make them biomechanically comparable to the muscle conditions observed at their maximal concentric effort in gait. It was thought that creating predominantly a gain in strength during the above conditions would have benefited more gait speed. However, because the training program was performed in a sitting or horizontal position, the additional demand related to the role played by some muscle groups in maintaining balance during gait [18] was not required during training. It could be thought that dynamic balance control could also be an important determinant of the participants' capacity to increase gait speed rather than strength or power gains alone.

A second explanation for the divergence between strength and gait changes could come from the muscular levels of effort that need to be produced during gait. It was demonstrated that participants with stroke unconsciously used the gain in strength to reduce the muscular levels of effort during gait instead of substantially increasing their gait speed [42]. This concurrently helped them decrease the mechanical requirements of walking.

4.4. Limitations. It should be remembered that the present sample was small, consisting of chronic individuals with stroke. Considering the large failure in voluntary activation in the first months following a stroke, it could be thought that, in the subacute period of a stroke, intense overloading of the weakened muscles by resistance training would produce perhaps more significant results regarding strength and gait performance. Also, the rate of force development of the affected lower-limb muscles was not assessed and could have provided relevant explanations of the current results since it has a great impact on function after stroke [43]. Moreover, the activity that participants were doing outside the training was not monitored. Gathering of this information might have helped explain the absence of difference in the gains observed between groups. Overall, despite the low impact of strength gain on gait speed and power, the fact that the effort produced during gait could be decreased with an increase in strength [42] makes the necessity to increase strength following a stroke still highly relevant.

5. Conclusion

Although some individuals with stroke benefited from a task-specific isokinetic training program, the impact of the gains in strength on gait performance was limited, and no difference was observed between the EXP and CTL groups. Future research aiming at improving gait following a stroke should thoroughly determine the parameters of the strengthening program in order to maximize the transfer of strength gain to functional activities. The impact of a combination of upper- and lower-limb isokinetic training

Table 4: Mean (SD), range, and 95% confidence interval (CI) for the maximal torque (Nm) taken at a common angle of 7° of ankle dorsiflexion, 0° (hip in neutral position), and 40° of hip flexion for the plantarflexors, hip flexors, and extensors, respectively, for the experimental (lower-limb training—n = 15) and control (upper-limb training—n = 15) groups at pre- and posttraining.

	Plantarflexors					Hip flexors					Hip extensors				
Statistics	Experimental		Control		P^b	Experimental		Control		P^b	Experimental		Control		P^b
	Pre	Post	Pre	Post		Pre	Post	Pre	Post		Pre	Post	Pre	Post	
Mean (SD)	58.9 (42.0)	75.1[a] (37.1)	48.7 (36.3)	56.3[a] (35.1)	0.3	73.6 (29.7)	91.3 (36.9)	65.4 (33.9)	67.8 (31.3)	0.2	103.8 (40.7)	105.4 (34.4)	79.7 (47.7)	101.3 (60.5)	0.4
Range:															
Min	8.2	15.9	5.0	13.9		17.6	21.5	6.6	0		43.2	42.5	18.6	37.3	
Max	163.2	138.1	122.6	117.6		121.5	146.2	153.3	120.2		180.8	164.7	201.1	259.2	
95% CI:															
Lower bound	35.6	54.5	28.6	36.4		57.1	70.9	46.7	50.4		81.3	86.3	53.3	67.8	
Upper bound	82.2	95.6	68.8	75.7		90.0	111.8	84.2	85.1		126.3	124.4	106.1	134.8	

[a] $P < 0.05$ (pretraining value versus posttraining value).
[b] P value is comparison between experimental and control groups.

program on gait parameters should be further assessed since it might help maximize gait performance in stroke survivors. Because participants could have chosen to use the gain in strength to lower their lower-limb muscular levels of effort; as opposed to strongly increasing their gait speed, strengthening of the affected lower-limb muscles remains highly relevant following a stroke.

Conflict of Interests

The authors declare that there is no conflict of interests.

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