

## Clinical Study

# Physical Activity Is Associated with Weight Loss and Increased Cardiorespiratory Fitness in Severely Obese Men and Women Undergoing Lifestyle Treatment

Eivind Aadland<sup>1</sup> and Lesley Robertson<sup>2</sup>

<sup>1</sup> Faculty of Health Studies, Sogn og Fjordane University College, P.O. Box 523, 6803 Førde, Norway

<sup>2</sup> Red Cross Haugland Rehabilitation Center, 6968 Flekke, Norway

Correspondence should be addressed to Eivind Aadland, eivind.aadland@hisf.no

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We aimed to examine the relationship between physical activity (PA) and change in body weight and cardiorespiratory fitness (CRF) in severely obese men and women. Thirty-five subjects (10 men, body mass index  $43.2 \pm 5.1$  kg/m<sup>2</sup>) who participated in a 10-month lifestyle treatment programme were included. The PA duration correlated only with weight change for men ( $r = -0.69$ ,  $P = .027$  versus  $r = -0.19$ ,  $P = .372$  for women). Conversely, the PA intensity correlated only with CRF for women ( $r = 0.61$ ,  $P = .003$  versus  $r = 0.39$ ,  $P = .340$  for men). PA explained 55.8 and 5.6% of weight change for men and women, respectively, whereas the corresponding explained variances for CRF were 15.6 and 36.7%. We conclude that PA was associated with change in body weight and CRF; however, there was a trend towards a gender specific effect between severely obese men and women.

## 1. Introduction

As physical activity (PA) is an important contributor to energy expenditure, it is a widely used weight reduction intervention. However, most studies find limited evidence for a decrease in body weight with physical activity alone (1–3 kg) [1–3] or in combination with dietary interventions (3.5–13 kg) [1–6]. A limitation when reporting such changes on a group level is the large interindividual variation in responses. Because there is a dose-response relationship between PA and weight reduction [7–9], this variation may arise from differences in PA level and other health behaviours. Variation could also be due to gender, as intervention studies suggest that PA may be more effective in reducing weight among men, than among women [10–12]. Because gender may be a moderator of response to PA interventions in obesity treatment, clinical studies in which results are analysed separately for men and women allow for better development of tailored lifestyle intervention programmes [4, 13].

Physical activity is shown to decrease weight in severely obese subjects over both the short term [14–18] and the long term [17, 19–25]. Although some studies suggest that greater

weight reduction may be related to a higher PA level [17, 20, 23], studies on the relationship between PA and weight change are scarce in this population. In addition to reducing weight, lifestyle interventions incorporating PA can increase cardiorespiratory fitness (CRF), which is an important risk factor for cardiovascular disease (CVD) and mortality [26]. As far as we know, the relationship between PA and change in CRF has not been studied in severely obese subjects.

Therefore, the objective of this study was to explore the effect of PA on changes in weight and CRF in severely obese men and women participating in a lifestyle intervention programme. We argue that because distinct gender-related differences might exist in response to PA, analysis should be performed separately for men and women. Such an analysis will facilitate the tailoring of treatment interventions that ultimately improve success rates.

## 2. Materials and Methods

**2.1. Participants.** Seventy-one severely obese patients who chose lifestyle treatment over bariatric surgery were enrolled

at the Red Cross Haugland Rehabilitation Centre (RCHRC) in Norway between August 2006 and May 2009. The inclusion criteria for participation in the programme were age between 18 and 60 years old and body mass index (BMI) > 40 kg/m<sup>2</sup> without comorbidity, or a BMI > 35 with comorbidity. The exclusion criteria were pregnancy, heart disease, drug or alcohol abuse, previous bariatric surgery and mental disorders and physical impairment that could reduce the ability to comply with the programme. Written informed consent was obtained from each study participant before inclusion in the study. The study meets the standards of the Declaration of Helsinki and was approved by the Regional Committee for Medical Research Ethics.

**2.2. Study Protocol.** The programme consisted of intermittent inpatient periods of six weeks, four weeks, and three periods of two weeks over a two-year period, separated by three to five months. The present study presents data from the first to the third inpatient period (i.e., 10 months of followup).

An interdisciplinary team of health professionals (dietician, nurse, medical doctor, physiotherapist, and exercise specialist) were responsible for the programme, which consisted of three main components: diet, PA, and cognitive behaviour therapy. Both theoretical and practical sessions were incorporated. With respect to diet, each subject followed a high-fibre, low-fat, reduced-energy meal plan based on the Nordic Nutrition Recommendations [27] that included three main meals and 2-3 snacks each day. Regarding PA, subjects participated in a supervised and structured exercise programme consisting of 20–30 minutes of brisk walking before breakfast and two 45–60 minute exercise sessions (e.g., swimming, aerobics, ball games, hiking, strength training) five days per week. No specific target regarding intensity was applied. Throughout the stay at RCHRC, this programme amounted to between 110 and 150 minutes of PA per day. Together with a team member, each subject developed an individualised plan for PA at home. The main objective of this plan was to increase PA level and strengthen each patient's mastery of everyday life. As such, the plan was based on opportunities at home and subject preferences.

**2.3. Measurements.** The patient's body weight, waist circumference (WC), height, and CRF were measured at the beginning of the first and third inpatient period. Subjects were weighed to the nearest 0.1 kg in light clothing before breakfast, using a digital scale (BWB-800, Tanita Corp., Tokyo, Japan). Height was measured to the nearest 0.5 cm using a wall-mounted stadiometer. Waist circumference was measured to the nearest 0.5 cm at the level of the iliac crest at the end of a normal expiration using a nonstretchable tape measure. Cardiorespiratory fitness was estimated using the Åstrand/Ryhming test according to suggested guidelines [28, 29]. Each subject's heart rate was measured between minute five and six at one submaximal work load on a bicycle ergometer (Ergometrics 900, Jaeger GmbH, Wursburg, Germany) while pedalling at a constant rate of 50 rpm. The measured heart rate was used to estimate maximal oxygen consumption (VO<sub>2max</sub>), with a correction factor for age. Because we used an indirect measure of VO<sub>2max</sub> that has not

been validated in severely obese subjects, validity and reliability were examined in a subsample of our subjects ( $n = 13$ ). The subjects performed a maximal treadmill test using a modified Balke-protocol on day one and performed three Åstrand/Ryhming tests thereafter (on day three, four and five, resp.). Åstrand/Ryhming test number one was used as a learning trial, test number two was used for validation, and test two and three were used for assessing reliability. Oxygen consumption on the treadmill test was measured using the Metamax I and the Metasoft v. 1.11.05 software (Cortex Biophysic, Leipzig, Germany). A one-point gas calibration using ambient air and a volume calibration using a three-liter syringe (SensorMedics Corporation, CA, USA) were performed between each test. The results were comparable to results in normal-weight subjects [30, 31]. There was no systematic bias compared to direct measurement of VO<sub>2max</sub> (−0.20 mL/kg/min difference,  $P = .900$ ). For test-retest reliability, we found a Pearson correlation coefficient of  $r = 0.92$  ( $P < .001$ ) and a standard error of measurement (calculated as suggested by Hopkins [32]) of 1.13 mL/kg/min. These results show that the Åstrand/Ryhming test has acceptable precision in detecting changes in CRF over time in our subjects.

Subjects self-monitored PA using simple training diaries. The mode, duration, and PA intensity were recorded. Intensity was reported as rate of perceived exertion (RPE) on the Borg 6–20 scale [33], which has acceptable validity [34]. Because of the overwhelming amount of data in these diaries, the first week in each month was extracted for analysis. The duration of PA per week as well as the duration for specific modes of PA was calculated. Intensity was calculated as the mean RPE for all training sessions per week. Both measures were averaged over the number of valid months. Because most diaries contained information only about modes of PA, such as strength training, bicycling and walking, activities such as housework and gardening were excluded from the analysis on the assumption that these activities would be performed by most subjects and therefore would be equally distributed. Inclusion criteria for the analysis were valid data on both the duration and PA intensity for at least seven out of the ten months of followup. The energy expenditure (EE) was calculated using reported duration and PA intensity, age, baseline BMI and CRF and the regression equation suggested by Jakicic et al. [35].

**2.4. Statistical Analyses.** Data are presented as mean  $\pm$  standard deviation (SD). Differences between groups were analysed with a one-way ANOVA and the Bonferroni post-hoc test. Where the assumptions of normality or homogeneity of variances were violated, differences were tested using the Kruskal-Wallis test with the Mann-Whitney test and Bonferroni adjustment for multiple comparisons. Differences over time were tested using a one-sample  $t$ -test and tested against a value of 0. Correlation between pairs of variables was analysed using Pearson's correlation coefficients as variables were found to approximate normality. Ninety-five percent confidence intervals (CIs) for correlations were obtained using 10 000 bootstrap samples. Regression analysis was performed using the partial-least-squares- (PLS-) method allowing for

TABLE 1: Baseline characteristics and change values for the group with valid training diaries. (Mean  $\pm$  SD  $n$ ; when different from the total in each group). WC: waist circumference; BMI: body mass index; VO<sub>2max</sub>: estimated maximal oxygen consumption; EE: energy expenditure.

	Valid training diaries	Men	Women	<i>P</i> between sexes
<b>Baseline</b>				
<i>N</i>	35	10	25	
Age	47.9 $\pm$ 8.8	48.8 $\pm$ 8.6	47.5 $\pm$ 9.0	.694
Height (cm)	168.8 $\pm$ 9.5	178.8 $\pm$ 8.1	164.8 $\pm$ 6.8	.000
Weight (kg)	123.4 $\pm$ 20.9	134.9 $\pm$ 22.3	118.7 $\pm$ 18.8	.036
WC (cm)	125.8 $\pm$ 13.4 [ $n$ = 30]	134.6 $\pm$ 17.1 [ $n$ = 8]	122.6 $\pm$ 10.5 [ $n$ = 22]	.056
BMI (kg/m <sup>2</sup> )	43.2 $\pm$ 5.1	42.0 $\pm$ 4.5	43.6 $\pm$ 5.3	.400
VO <sub>2max</sub> (L/min)	2.37 $\pm$ 0.57	2.81 $\pm$ 0.68	2.18 $\pm$ 0.41	.004
VO <sub>2max</sub> (mL/kg/min)	19.5 $\pm$ 5.0	21.5 $\pm$ 5.8	18.7 $\pm$ 4.6	.171
<b>Change to 10 months</b>				
Weight	-10.73 $\pm$ 7.05	-10.67 $\pm$ 7.52	-10.76 $\pm$ 7.01	.975
WC	-9.22 $\pm$ 7.18 [ $n$ = 28]	-7.71 $\pm$ 7.29 [ $n$ = 7]	-9.72 $\pm$ 7.25 [ $n$ = 21]	.531
VO <sub>2max</sub> (L/min)	0.17 $\pm$ 0.48 [ $n$ = 30]	0.20 $\pm$ 0.62 [ $n$ = 8]	0.16 $\pm$ 0.44 [ $n$ = 22]	.855
VO <sub>2max</sub> (mL/kg/min)	3.54 $\pm$ 4.54 [ $n$ = 30]	3.54 $\pm$ 4.54 [ $n$ = 8]	3.41 $\pm$ 4.52 [ $n$ = 22]	.800
<b>Physical activity</b>				
Duration (min/week)	403 $\pm$ 171	506 $\pm$ 198	361 $\pm$ 143	.022
Intensity (RPE)	13.9 $\pm$ 1.4	13.8 $\pm$ 0.9	13.9 $\pm$ 1.6	.855
EE (kcal/week)	3751 $\pm$ 1928	5313 $\pm$ 2191	3183 $\pm$ 1506	.005
<b>Mode of activity</b>				
Walking (%)	57.7 $\pm$ 23.2	59.7 $\pm$ 28.5	57.0 $\pm$ 21.3	.759
Bicycling (%)	11.7 $\pm$ 19.2	19.1 $\pm$ 26.9	8.7 $\pm$ 14.8	.483
Swimming (%)	13.2 $\pm$ 9.8	10.9 $\pm$ 8.6	14.1 $\pm$ 10.3	.398
Strength training (%)	12.2 $\pm$ 11.3	8.7 $\pm$ 7.1	13.6 $\pm$ 12.4	.250
Other (%)	5.3 $\pm$ 6.9	1.7 $\pm$ 2.8	6.7 $\pm$ 7.5	.031

multivariate modeling in small samples. Changes in weight and CRF were used as dependent variables. Four models were established for each dependent variable for men and women separately. Variables to be included were selected on the basis of the bivariate associations with the dependent variables. In model 1, age, baseline BMI, and baseline CRF were used as independent variables. Model 2 included the bivariate relationship between the PA duration and weight change as well as the bivariate relationship between PA intensity and the change in CRF. In model 3, PA duration and intensity were included. Model 4 contained the variables from models 2 and 3. In all PLS analyses, independent variables were standardised to variance because several different units of measurement were used. In order to assess the robustness of the findings, all models were cross-validated excluding every fourth subject. PLS analysis and the cross-validation were performed using Sirius v. 8.0 (Pattern Recognition Systems, Bergen, Norway), while all other analyses were performed using SPSS v. 17.0 (SPSS Inc., Chicago, USA). A two-sided  $P < .05$  indicated significant differences.

### 3. Results

**3.1. Analysis of Attrition.** A total of 71 subjects were included in the lifestyle treatment programme. Of these, nine subjects did not consent to take part in this study and six quit during the course of the programme: one to undergo bariatric

surgery, one having reached his weight goal, and four for unknown reasons. This left 56 subjects for analysis, among whom 35 subjects (10 men) had valid training diaries. Subjects without valid training diaries were younger than subjects with valid training diaries ( $39.3 \pm 11.1$  versus  $47.9 \pm 8.8$  years,  $P = .005$ ). Dropouts were taller than subjects with valid training diaries ( $179.8 \pm 8.4$  versus  $168.8 \pm 9.5$  cm,  $P = .029$ ). All other baseline- and change values were similar between groups. Further results are based on the group with valid training diaries.

#### 3.2. Baseline Characteristics and Outcomes at the Group Level.

Table 1 show that the men were taller, heavier and had better CRF (L/min) than the women at baseline. Changes in weight, WC, and CRF were similar between genders. Results regarding changes over time are therefore collapsed. All variables changed significantly over time ( $P < .001$ ), except for CRF expressed as an absolute value (L/min) ( $P = .061$ ). The weight and WC changes were  $-8.7 \pm 5.8\%$  (95% CI  $-10.7$  to  $-6.7\%$ ) and  $-7.2 \pm 5.5\%$  (CI  $-9.3$  to  $-5.1\%$ ), respectively. VO<sub>2max</sub> increased  $9.7 \pm 21.1\%$  (CI 1.8 to 17.5%) and  $21.1 \pm 25.8\%$  (CI 11.4 to 30.7%) when expressed as absolute and relative values, respectively. Taken together, subjects spent about 58 minutes on PA per day during the intervention, which corresponds to an EE of about 536 kcal/day. The duration and volume of PA were significantly higher for men than for women, whereas the intensity was similar between

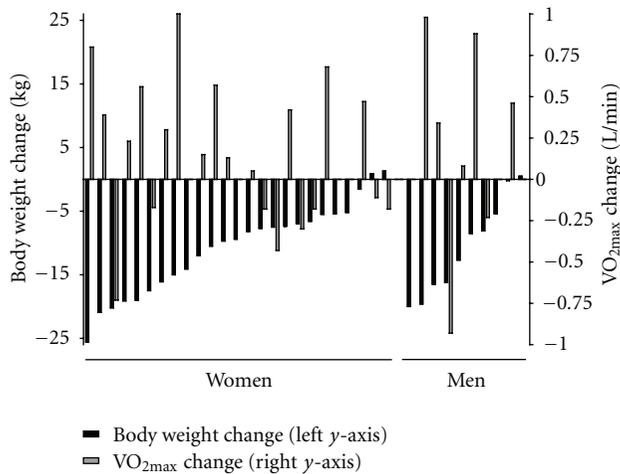


FIGURE 1: Individual changes in body weight and cardiorespiratory fitness ( $n = 22$  for women;  $n = 8$  for men). Subjects are sorted within gender with respect to body weight change.

genders. With regard to the mode of PA, the pattern was similar between men and women, except for “other activities,” which was reported more often by women.

**3.3. Relationships between PA and Change in Weight and CRF.** Figure 1 shows individual changes in weight and CRF. The figure clearly shows large individual variation in both outcome variables. Most subjects lost weight and displayed increases in CRF; however, the opposite was also seen. Changes in the two outcomes were not related ( $r = -0.16$ ,  $P = .401$ ,  $n = 30$ ).

Correlation between the PA duration and weight change was  $r = -0.33$  ( $P = .050$ ); the correlation between the PA intensity and weight change was  $r = -0.17$  ( $P = .336$ ). The correlation between the PA duration and the change in CRF was  $r = -0.04$  ( $P = .853$ ,  $n = 30$ ); the correlation between the PA intensity and the change in CRF was  $r = 0.51$  ( $P = .004$ ,  $n = 30$ ). The relationship between the PA duration and weight change was much stronger for men than for women ( $r = -0.69$ , CI  $-0.88$  to  $-0.41$ ,  $P = .027$  versus  $r = -0.19$ , CI  $-0.60$  to  $0.26$ ,  $P = .372$ ). Conversely, the relationship between the PA intensity and change in CRF was stronger for women than for men ( $r = 0.61$ , CI  $0.10$  to  $0.85$ ,  $P = .003$  ( $n = 22$ ) versus  $r = 0.39$ , CI  $-0.29$  to  $0.86$ ,  $P = .340$  ( $n = 8$ )). Scatterplots of PA duration versus change in weight and PA intensity versus change in CRF are shown in Figures 2(a) and 2(b), respectively. There were no relationship between PA duration and WC ( $r = -0.10$ ,  $P = .624$ ,  $n = 28$ ), nor between PA intensity and WC ( $r = -0.01$ ,  $P = .967$ ,  $n = 28$ ).

**3.4. Regression Analysis.** Tables 2(a) and 2(b) show the PLS regression analysis with respect to changes in weight and CRF, respectively. A correlation matrix including independent and dependent variables is shown in Table 3. For weight change, model 1 (baseline variables) was quite similar for both genders, explaining about 20% of the variance. Model 2 (PA duration) yielded remarkably different results between

genders, explaining 47.8% of the variance for men compared to 4% for women. The PA variables together (model 3) explained 55.8% of the weight change for men, whereas 5.6% of the weight change was explained for women. Together, baseline characteristics and PA (model 4) explained about two-thirds of the weight change for men, whereas only one-third of the change for women was explained.

Regarding the change in CRF, model 1 explained 40.4 and 34.2% of the variance for men and women, respectively. The corresponding variances explained by model 2 were 14.5 and 37.5%. For women, the PA variables together (model 3) explained one-third of the change in CRF, whereas 15.6% was explained for men. Taken together, the baseline variables and PA variables explained 81.6% of the change in CRF for men and 60.6% for women (model 4). However, the SEEs for men were generally almost twice as high as for women, reflecting considerable uncertainty in the predictions.

## 4. Discussion

This study found that severely obese subjects undergoing a 10-month lifestyle intervention showed great individual variation in the change in weight and CRF. Physical activity was related differently to change in weight and CRF in men and women. Duration and intensity of PA explained 55.8% of the weight change in men and only 5.6% in women. For CRF the opposite pattern was seen. While PA explained only 15.6% of the change for men, it explained 36.7% of the change for women.

**4.1. Weight Change.** We found a decrease in weight of  $-10.7$  kg ( $-8.7\%$ ) over 10 months in both genders. This is in line with other studies investigating lifestyle treatment for severely obese subjects [17, 24, 25]. However, other studies have shown more beneficial results after similar programmes [21] and larger weight losses have been achieved with more severe lifestyle interventions using low-energy or very low-energy diets [22, 23]. Weight losses in the present study seem consistent with results seen in overweight and moderately obese subjects undergoing lifestyle interventions [3–5]. Thus, regarding weight loss, lifestyle treatment programmes seem to work equally well in severely obese and less obese persons.

Few previously published studies of severely obese subjects have reported PA levels. Interestingly, Hofsø et al. [24] reported a median physical activity level of approximately the same magnitude as in the present study (65 minutes per day); the weight losses were also nearly identical. Unfortunately, Goodpaster et al. [25], who recently published the first randomised controlled trial in the field of lifestyle intervention for severely obese subjects, did not report total minutes spent in moderate to vigorous physical activity or EE, although PA was measured both objectively and through training diaries. Comparing the present study results with the results of Maffiuletti et al. [17] is also difficult because PA levels were determined using a scoring system that, while allowing for acceptable internal validity, limits its external validity.

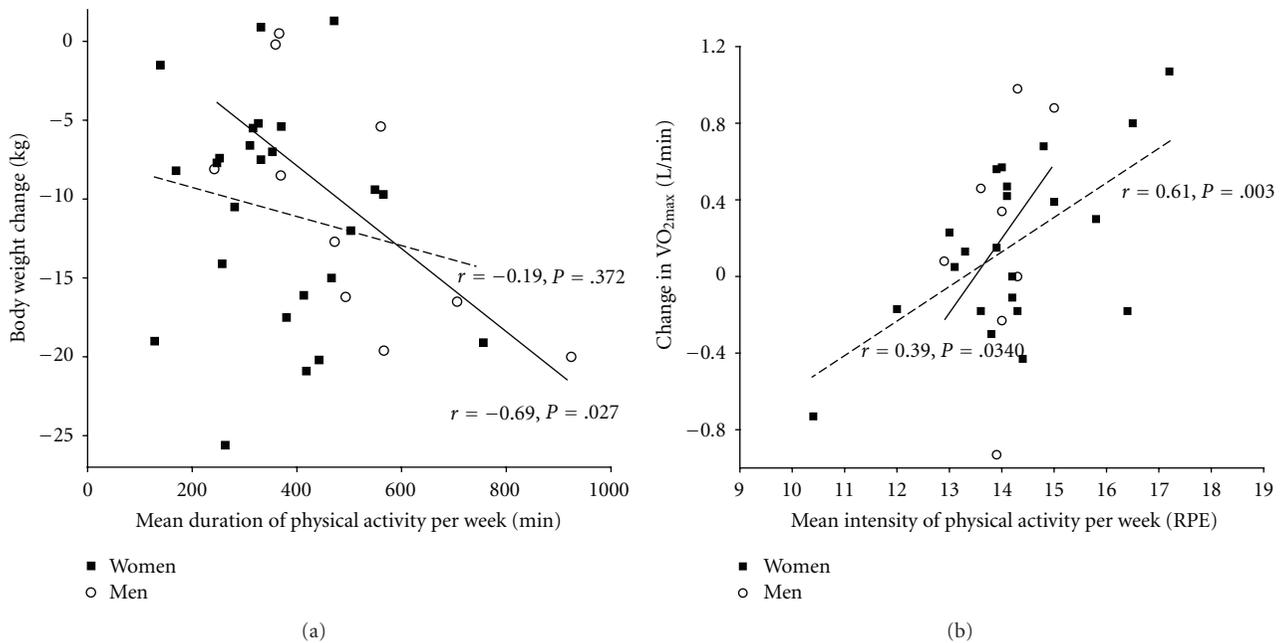


FIGURE 2: (a) Scatterplot showing weight change versus duration of physical activity for men (full regression line) and women (dotted regression line). (b) Scatterplot showing change in cardiorespiratory fitness versus intensity of PA for men (full regression line) and women (dotted regression line).

Although reports on dose-response relationships between PA and weight change in severely obese subjects are scarce, some studies have shown convincing results in less obese subjects [7–9]. The most recent study by Wadden et al. [7] showed a consistent increase in one-year weight loss of 4.4, 7.1, 9.0, and 11.9% for increasing quartiles of mean weekly minutes of physical activity (25.9, 84.8, 148.7, and 287.1 min) in 2570 subjects with a baseline BMI of about 36, randomised to lifestyle intervention.

Overall, a correlation of  $r = 0.41$  was found, yielding a 16.1% explained variance in weight change. This relationship is of approximately the same strength as in the present study when the male and female groups are collapsed ( $r = 0.33$ ). However, we found a marked difference between genders. In men, a moderate-to-high correlation was found ( $r = -0.69$ ), whereas in women, a nonsignificant association with weight change was found ( $r = -0.19$ ). Although it should be noted that the CIs overlapped between genders, there was a clear difference in the strength of the relationships. Although our results must be interpreted carefully due to the small samples, the results are in line with previous intervention studies suggesting larger weight losses due to physical activity for men than for women [10–12].

**4.2. Change in Cardiorespiratory Fitness.** An overall mean increase in CRF of 3.5 mL/kg/min (21.1%) was achieved in the present study. This change parallels other study results for both severely obese and less obese subjects undergoing lifestyle interventions incorporating PA [17, 18, 36]. Such an increase in CRF may reduce the risk of all-cause mortality and the incidence of cardiovascular disease in healthy men

and women by 13 and 15%, respectively [26]. As studies consistently show an especially large risk reduction with an increase in CRF beyond some minimal threshold [26, 37], any increase would be beneficial to health for most severely obese subjects, whose CRF is generally low [17, 18, 38, 39]. Moreover, low baseline CRF was a significant predictor for increased CRF in both genders in the present study, showing that subjects with the highest intervention potential benefitted the most. The increase in CRF may also benefit the subjects by allowing them to increase their PA level and thereby lose more weight [4]. This is indicated by the inverse relationship between baseline CRF and PA duration found in the present study ( $r = 0.40, P = .024$ , results not shown).

Duration of PA was not correlated with change in CRF in the present study, whereas PA intensity was significantly correlated with increases in CRF in the group as a whole, as well as for women. For men, this relationship was nonsignificant. The importance of PA intensity to increase CRF is well established [40]. The variation in change in CRF explained by PA for women (36.7%) is consistent with nine studies reviewed by Williams [37] in which PA explained 35% of the variation in CRF. The weaker explanation of the variation among men in the present study (15.6%) may be a result of men being a relatively small homogenous group, which resulted in a minimal range in PA intensities.

**4.3. Interpretation of the Results.** We found that regression models based on both baseline measures and PA variables explained 69.4 and 36.8% of the change in weight for men and women, respectively, with corresponding values for the change in CRF of 81.6 and 60.6%. These values are quite

TABLE 2: (a) Regression equations, standard errors, and explained variance in change in weight. All models are cross-validated excluding every fourth subject. Independent variables that have a significant contribution ( $P < .05$ ) to the model are labeled<sup>†</sup>. SEE: standard error of the estimate; SECV: standard error of the cross-validation. (b) Regression equations, standard errors, and explained variance in change in cardiorespiratory fitness. All models are cross-validated excluding every fourth subject. Independent variables that have a significant contribution ( $P < .05$ ) to the model are labeled<sup>†</sup>. SEE: standard error of the estimate; SECV: standard error of the cross-validation.

(a)							
	Regression equation (standardized)	Regression equation (actual)	SEE	SECV	R <sup>2</sup>	Adj R <sup>2</sup>	
<i>Men</i>							
Model 1	21.60 – 1.17* Age – 2.28 * Baseline BMI – 1.10 * Baseline VO <sub>2max</sub>	21.60 – 0.14* Age – 0.50 * Baseline BMI – 1.62 * Baseline VO <sub>2max</sub>	7.17	8.68	0.193	0.092	
Model 2		2.620 – 0.03* Duration	5.76	5.62	0.478	0.412	
Model 3	41.30 – 4.15* Duration <sup>†</sup> – 2.82 * Intensity <sup>†</sup>	41.30 – 0.02* Duration – 3.00 * Intensity	5.30	5.45	0.558	0.502	
Model 4	68.40 – 1.18* Age <sup>†</sup> – 2.29 * Baseline BMI <sup>†</sup> – 1.11 * Baseline VO <sub>2max</sub> – 3.72 * Duration <sup>†</sup> – 2.53 * Intensity <sup>†</sup>	68.40 – 0.14* Age – 0.50 * Baseline BMI – 1.62 * Baseline VO <sub>2max</sub> – 0.02 * Duration – 2.69 * Intensity	4.41	5.86	0.694	0.656	
<i>Women</i>							
Model 1	10.60 – 0.11* Age – 3.19 * Baseline BMI <sup>†</sup> + 0.99 * Baseline VO <sub>2max</sub>	10.60 – 0.01* Age – 0.60 * Baseline BMI + 2.40 * Baseline VO <sub>2max</sub>	6.38	7.85	0.208	0.173	
Model 2		–7.43 – 0.01* Duration	6.88	7.04	0.040	0.000	
Model 3	0.95 – 1.57* Duration <sup>†</sup> – 0.89 * Intensity	0.95 – 0.01* Duration – 0.56 * Intensity	6.96	7.38	0.056	0.015	
Model 4	33.40 – 0.96* Age – 3.97 * Baseline BMI <sup>†</sup> + 2.00 * Baseline VO <sub>2max</sub> – 2.84 * Duration <sup>†</sup> – 1.17 * Intensity	33.40 – 0.11* Age – 0.74 * Baseline BMI + 4.84 * Baseline VO <sub>2max</sub> – 0.02 * Duration – 0.72* Intensity	5.83	8.19	0.368	0.310	
(b)							
	Regression equation (standardized)	Regression equation (actual)	SEE	SECV	R <sup>2</sup>	Adj R <sup>2</sup>	
<i>Men</i>							
Model 1	0.88 + 0.56* Age <sup>†</sup> – 0.14 * Baseline BMI – 0.55 * Baseline VO <sub>2max</sub> <sup>†</sup>	0.55 + 0.04* Age – 0.02 * Baseline BMI – 0.49 * Baseline VO <sub>2max</sub>	0.56	0.58	0.404	0.165	
Model 2		–5.24 + 0.39* Intensity	0.56	0.62	0.145	0.002	
Model 3	–8.85 + 0.10* Duration + 0.38 * Intensity <sup>†</sup>	–5.47 + 0.00* Duration + 0.39 * Intensity	0.61	0.59	0.156	0.015	
Model 4	–19.00 + 0.73* Age <sup>†</sup> + 0.33 * Baseline BMI <sup>†</sup> – 1.01 * Baseline VO <sub>2max</sub> <sup>†</sup> + 0.09 * Duration + 0.71 * Intensity <sup>†</sup>	–11.7 + 0.05* Age + 0.04 * Baseline BMI – 0.90 * Baseline VO <sub>2max</sub> + 0.00 * Duration + 0.72 * Intensity	0.35	0.62	0.816	0.677	
<i>Women</i>							
Model 1	3.46 – 0.15* Age <sup>†</sup> + 0.14 * Baseline BMI – 0.63 * Baseline VO <sub>2max</sub> <sup>†</sup>	1.51 – 0.01* Age + 0.01 * Baseline BMI – 0.66 * Baseline VO <sub>2max</sub>	0.36	0.41	0.342	0.310	
Model 2		–2.39 + 0.18* Intensity	0.35	0.34	0.375	0.344	
Model 3	–4.86 – 0.12* Duration + 0.58 * Intensity <sup>†</sup>	–2.12 – 0.00* Duration + 0.17 * Intensity	0.36	0.36	0.367	0.336	
Model 4	–3.93 – 0.15* Age + 0.25 * Baseline BMI <sup>†</sup> – 0.47 * Baseline VO <sub>2max</sub> <sup>†</sup> + 0.12 * Duration + 0.56 * Intensity <sup>†</sup>	–1.71 – 0.01* Age + 0.02 * Baseline BMI – 0.50 * Baseline VO <sub>2max</sub> + 0.00 * Duration + 0.16 * Intensity	0.29	0.32	0.606	0.564	

high compared to other prospective studies, where explained variances in weight change are in the range of 12 to 38% [10, 41, 42]. However, the residuals are substantial in all models for both genders, indicated by the SEEs of ~6 kg for weight and 0.3–0.6 L/min for VO<sub>2max</sub>. Therefore, care should be taken to ensure the ethical use of such models in clinical settings. Although selection strategies may ensure more effective use of limited resources [43], we believe individuals in need of essential healthcare who are found to

have a low probability of success should not be given less attention and followup based on such predictions.

If the dissimilar responses to PA between genders are accurate, tailoring the content and focus of lifestyle treatment programmes to men and women may improve the rate of treatment success. It can be argued that men and women in our sample used different strategies to lose weight because PA explains 55.8 versus 5.6% of the changes in body weight for men and women, respectively, whereas both genders lose

TABLE 3: Correlation matrix between independent and dependent variables in the regression analyses for men ( $n = 8-10$ ) in the lower left corner and women ( $n = 22-25$ ) in the upper right corner (Pearson  $r$  ( $P$  value)). BMI: body mass index;  $VO_{2max}$ : estimated maximal oxygen consumption.

	Age	Baseline BMI	Baseline $VO_{2max}$	PA duration	PA intensity	Change in weight	Change in $VO_{2max}$
Age	1	-0.15 (.467)	-0.40 (.064)	-0.08 (.696)	-0.48 (.014)	-0.01 (.947)	-0.12 (.605)
Baseline BMI	0.11 (.755)	1	0.14 (.549)	-0.20 (.349)	-0.02 (.945)	-0.42 (.039)	0.11 (.632)
Baseline $VO_{2max}$	0.45 (.224)	0.35 (.350)	1	0.29 (.189)	-0.18 (.416)	0.14 (.526)	-0.49 (.019)
PA duration	0.32 (.372)	0.13 (.725)	0.33 (.384)	1	-0.19 (.362)	-0.19 (.372)	-0.12 (.584)
PA intensity	-0.22 (.541)	-0.15 (.671)	-0.21 (.589)	0.26 (.471)	1	-0.11 (.605)	0.61 (.003)
Change in weight	-0.22 (.545)	-0.43 (.218)	-0.24 (.532)	-0.69 (.027)	-0.45 (.195)	1	-0.24 (.274)
Change in $VO_{2max}$	0.26 (.527)	-0.21 (.613)	-0.41 (.313)	0.10 (.809)	0.39 (.340)	0.03 (.951)	1

the same amount of weight. In other words, factors other than PA may cause the weight reduction in women and might not benefit men equally. Although we have no measure of the diet component of this lifestyle intervention, we can speculate that women relied more on changes in eating to regulate energy balance, than men did. As the literature suggests [44, 45], women may have a closer regulation of appetite than men in short periods of increased energy expenditure, which leads to a partial compensation for the negative energy balance. This would influence weight change in our study and may imply that women should increase their PA level together with having a strict diet. This finding is also in line with results showing an interaction between PA and diet for women such that PA was only beneficial when performed together with changes in diet [10]. Hence, women should be advised to increase their PA level and to make dietary changes. Moreover, PA intensity is important to increase CRF. Thus, we recommend that PA should be an important part of lifestyle treatment programmes for severely obese subjects of both genders.

**4.4. Strengths, Limitations, and Suggestions for Further Research.** The present study has several limitations. First, as the sample was small, relationships may be made spurious by low representativeness or by increasing the influence of specific cases or outliers in the data. However, all regression models were cross-validated, with minor changes made to the standard errors. Second, as weight regain following weight loss is very common, the 10-month followup in the present study may not have been long enough to determine the clinical importance of our results. However, PA is consistently seen as a predictor of weight maintenance [46, 47], so its effect could become more important over time. Third, as precise measures are important to reveal true relationships, the measures used could undermine our conclusions. In particular, body weight has low sensitivity to changes in fatness after PA interventions. Because PA stimulates muscle hypertrophy, decreases in fat mass may be masked [48, 49]. Furthermore, self-report measures show large deviations compared to objective measures of PA [50]. However, as no gold standard exists, PA measurement remains a topic for debate. There is no evidence, as far as we know, that these measures have less reliability in obese subjects than in other subjects.

While our use of training diaries may be a limitation as discussed above, it may also be a strength. We calculated PA duration and intensity as the mean for at least seven of the ten months of followup, thereby avoiding variation in PA from week to week and during seasons as a source of error. This variation could be a serious threat to studies where PA levels are measured for single points in time, as illustrated by correlations ranging between  $r = -0.43$  and  $0.00$  between PA duration for each of the ten months and total weight change in the present study. Finally, the lack of diet as a research measure, one of the two main components determining energy balance, constitutes a limitation for the prediction of changes in weight.

Due to the methodological weaknesses described above, our results are preliminary. Further research examining PA and CRF in severely obese subjects undergoing lifestyle treatment should include objective measures to determine PA level and direct measurements of CRF (i.e., by measuring oxygen consumption and/or by performance tests). Furthermore, results should be reported for men and women separately. Finally, comprehensive studies including both objective and subjective measures of health should be conducted, and relationships with PA and CRF should be determined.

## 5. Conclusion

This study showed beneficial changes in weight and CRF for severely obese subjects undergoing lifestyle treatment. Individual variation in outcomes was large, and PA was related differently to changes in weight and CRF between men and women. Further research is needed to determine the effects of PA in severely obese subjects. Until then, it is reasonable to state that more PA is better.

## Conflict of Interests

The authors declared that they have no conflict of interests.

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