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The effect of minimal exercise on fitness in elderly women after hip surgery

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SUMMARY

To determine the effect of minimal exercise on functional fitness following total hip replacement in elderly women, 20 women (13 exercisers, 7 controls) who had undergone unilateral or bilateral hip replacement surgery for primary osteoarthritis were studied. An exercise treadmill test with respiratory gas and blood lactate analyses, and a field test of walking speed on a measured course, were administered before and after a twice weekly exercise programme of three months' duration. Markers of cardiorespiratory fitness, including peak achieved oxygen uptake (VO_2) and ventilatory and lactate thresholds were measured. Maximum self-selected walking speed was also measured over a flat course.

Peak VO_2 increased in the exercise group when compared to baseline ($P < 0.05$) but did not differ from the control group. The exercise group significantly improved their walking speed by 10.1% compared with non-exercising controls (1.41 vs 1.20 m/sec, $P < 0.05$), and increased VO_2 at lactate threshold. The improvements occurred despite the twice weekly exercise sessions being below the recommended frequency of exercise for improving cardiorespiratory fitness. Minimal exercise in elderly women after hip surgery can substantially improve submaximal exercise capacity, as well as walking speed.

INTRODUCTION

The number of elderly women requiring hip surgery is increasing.[1] Several studies have indicated that total hip replacement can improve quality of life,[2] including important functional parameters such as walking speed.[3] However, low walking speeds observed a year after hip surgery suggest that present post-operative rehabilitation may not promote

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maximal recovery.[4] Failure to achieve maximal recovery following hip surgery, compounded by age associated reductions in functional capacity, may seriously jeopardise capability of independent living.[5] The consequence of such an avoidable loss of independence is important both for the individual and as a general public health issue relating to effective use of health resources.[6]

The American College of Sports Medicine (ACSM) recommends that in order to improve cardiorespiratory fitness appropriate exercise should take place at least 3 days per week for 20 minutes at an intensity of 60% of maximum heart rate or 50% of maximum oxygen uptake.[7] It is likely that such guidelines are inappropriate for elderly subjects after hip surgery. The nature of the training response in such older individuals is poorly understood and requires clarification if suitable exercise regimes are to be developed. This study sought to establish whether the cardiorespiratory fitness of elderly hip replacement patients could be improved using a minimal amount of exercise, below that recommended by ACSM.

SUBJECTS AND METHODS

Elderly female subjects, aged 61-80 years of age, who had previously undergone hip replacement surgery for primary osteoarthritis at least six months previously and who were living independently in the community without assistance in self-care, were recruited by telephone from hospital medical records. A six month interval between surgery and inclusion in the study was adopted to limit the confounding influence of surgery on changes in cardiorespiratory fitness. Subjects underwent a full physical examination, including resting ECG and spirometry, to exclude significant respiratory or cardiac disease. Subjects were excluded if evidence of these was found or if they were using medication likely to affect cardiorespiratory or neuromuscular efficiency, such as beta-blockade. All subjects gave informed written consent to the procedures which were approved by the Medical Ethical Committee, The Queen's University of Belfast. Subjects were assigned either to an exercise group who took part in a twice weekly exercise programme for three months, or a control group who continued their normal activities (Table 1).

Subjects were assigned to exercise and control groups randomly on the basis of geographic location. Subjects living within a taxi drive from the Royal Victoria hospital, where the exercise classes took place, were assigned to the exercise group. Control subjects did not receive either sham exercise or specific advice on exercise. Provision of transport was essential to ensure that good attendance rates were achieved. There were no significant concurrent illnesses or changes in medication throughout the test period.

EXERCISE PROGRAMME

The exercise programme was developed by chartered physiotherapists skilled in the care of the elderly and took place in the physiotherapy department of the Royal Victoria hospital over a three month period. The emphasis was on enjoyable weight bearing activities. After an initial warm up period of 5-10 minutes (supervised walking, flexibility) the intensity of exercise increased and subjects took part in aerobic-type dance routines accompanied by music (15-20 minutes). This was followed by a cool-down period which involved stretching and balance exercises (10 minutes). Between each routine a short relaxation period was permitted, the duration of which decreased as fitness improved.

In order to gauge exercise intensity, heart-rate responses to a typical exercise class were measured for all exercisers using a miniaturised heart-rate monitor (Sportstester 3000, Polar Electro, Finland).

TABLE I

Physical characteristics of subjects

	Exercisers *mean (range)*	*Controls* *Mean (range)*	*All* *mean (SD)*
	n = 13	n = 7	n = 20
Age (Years)	70.8 (61-80)	71.0 (63-80)	70.9 (5.3)
Time since surgery (months)	13.3 (8-17)	15.6 (9-20)	14.1 (3.5)
Height (cm)	155.4 (143-172)	163.6 (162-165)	158.2 (6.9)
Weight (kg)	61.1 (50-74)	75.6 (64-95) *	66.2 (10.8)
Body fat (%)	31.2 (25-38)	33.6 (28-38)	31.8 (3.9)

* Significant difference ($p < 0.05$)

EXERCISE TESTING

All subjects performed maximal treadmill tests on three occasions. The treadmill tests were conducted by investigators (A-M N, I S) who were blinded to the allocation of subjects to the exercise or control group. An initial familiarisation test, as previously described[8] was followed by two further tests to establish peak oxygen uptake (Peak VO_2) which were undertaken at the start and at the completion of the intervention period (Test 1 and Test 2). During testing, subjects walked on a standard motorised non-programmable treadmill (Power-Jog). They were asked to use the handrails only for balance and encouraged during the test to exercise for as long as possible. The modified Naughton protocol was used for the familiarisation test.[9] Those subjects who performed less than 14 minutes remained on this protocol for further tests, whereas those who exceeded 14 minutes were tested using the Bruce protocol modified by an initial 3 minute stage at 5% incline and 2.7 km per hour.[10]

Mixed expired air was collected at rest over a two minute period, and at three minute intervals during the exercise test, and for five minutes into recovery following exercise. At the end of each 3 minute stage of exercise, blood pressure, heart rate, ST segment displacement and end tidal CO_2 (via Engstrom Eliza CO_2 Analyser) were recorded. Minute ventilation was measured using a vane turbine placed on the inspiratory side of a non-rebreathing respiratory valve circuit (Hans-Rudolph, Kansas City, KS, USA) in conjunction with a ventilometer (P K Morgan, Chatham Kent, UK). Interruptions of a light beam by the vane were counted to measure inspired flow volume, which was then converted to expired ventilation by using the Haldane correction and standard formulae.[11]

Expired air was directed from the subject via a large-bore flexible tube to a mixing chamber. Expired air was sampled continuously from the chamber from a point well away from the outlet, and expired 0_2 and CO_2 concentrations were measured by paramagnetic and infrared analysers respectively (P K Morgan). The outputs from the ventilometer and gas analysers were fed via an analogue–to–digital converter to an Amstrad PC 1640 microcomputer for on-line calculation of VO_2, minute CO_2 production (VCO_2) and expired ventilation (VE). The results were recorded at 15 second intervals. Anaerobic threshold was defined by retrospective (blinded) visual analysis of the VE/VO_2 curves.[12] Heart rate was measured from an ECG signal (Delmar Avionics, Los Angeles, CA, USA) and was averaged for the period of stable respiration. Patients were invited to rate their perceived exertion on a non-linear scale of 10 points, known as the Borg scale.[13]

Prior to the test a teflon cannula was inserted into an antecubital vein and attached via a normal bore extension set (volume 1.5 ml) to a three-way tap for sampling. Samples of blood (2 mls) were taken at rest, at the end of each stage of exercise, at peak exercise and at three and six minutes into recovery after discarding the dead space volume. The samples were immediately deproteinised with 8% perchloric acid to inhibit glucose metabolism and stored for a short period in ice before being analysed for whole blood lactate concentrations. Lactate threshold was defined by visual inspection of the inflection point representing a non-linear rise of lactate concentration with reference to VO_2.

Walking speed was measured on commencing the exercise programme and again at completion. Subjects were instructed to walk at a comfortable walking speed and timed using a hand held stop watch. Stature was measured, without shoes, using a portable stadiometer and measurements were taken to the nearest centimetre. Body mass, measured to an accuracy of 0.1 kg was taken using portable scales (Seca, Germany). Shoes and heavy clothing were removed. Skinfolds were measured using Harpenden skinfold caliper (John Bull & Co, UK) at the biceps, triceps, subscapular and suprailiac sites on the right side of the body using Eurofit protocols.[14] Body fat was calculated according to Durnin and Rahaman.[15]

STATISTICAL METHODS

Within group changes were measured using paired t-tests. Independent sample t-tests were used to test between-group differences. Results are expressed as means with 95% confidence intervals, and values of $P < 0.05$ regarded as significant.

RESULTS

The physical characteristics of subjects are shown in Table 1. The mean body weight of the control group was significantly higher than the exercise group although there were no significant differences in age, height, body fat (%) or time since surgery.

The exercise programme lasted for 12 weeks and attendance rates were good (89%). During the aerobic section of the class, which lasted for 15-20 minutes, the mean heart rate ranged between 50% and 81% of age-predicted maximal heart rate [group mean 102 beats/min, or 67% of age predicted maximal heart rate (220-age)]. Expressed as a percentage of maximum achieved during the initial treadmill test, mean heart rates represented between 30% and 70% (group mean 52%).

All subjects completed Test 1 and Test 2 protocols successfully. Hip pain was cited as a reason for stopping in only one subject. Fatigue was the most common reason for stopping. Table II shows the peak VO_2, peak heart rate, respiratory exchange ratio, peak lactate, duration of exercise, anaerobic threshold, lactate threshold, walking speed, and Borg scores for the exercise and control groups in the pre- and post-intervention treadmill test. Thirteen of the 20 subjects reached a heart rate greater than or equal to their age-predicted maximum in Test 1 and test 2. Although a significant improvement in peak VO_2 occurred in the exercise group when compared to baseline ($P < 0.05$) with no change observed for the control group, the difference between exercise and control groups was not significant. A biphasic VE/VO_2 graph was recorded in 75% of patients enabling an anaerobic threshold to be identified (the point of increase in gradient of the VE/VO_2 graph). No significant difference was observed within or between active and control groups. No change occurred in perceived exertion (Borg Scale) between Tests 1 and 2.

The lactate threshold was identified in 17 subjects in Test 1 and 15 subjects in Test 2. Low concentrations of blood lactate during the last phase of the exercise test was the reason for non-identification of lactate threshold in some subjects. A significant improvement in lactate threshold was found in the exercise group. The lactate threshold occurred at 83% of peak oxygen uptake in Test 1 and 90% of peak oxygen uptake in Test 2 ($P < 0.05$). In contrast, no significant change was found for non-exercising controls. Changes in absolute heart rate at lactate threshold, or heart rates at lactate threshold expressed as a percentage of age-predicted maximum heart rate between Test 1 and Test 2 were not significant in either the exercise or control group. Improvements occurred in walking speed for exercisers (1.28 to 1.41 m/sec) but not in non-exercising controls and this post-training difference between exercise and control groups was significant ($P< 0.05$).

TABLE II

Values for physiological parameters measured during the initial treadmill test 1 and the post-intervention treadmill test 2 for exercisers and controls. Values are means (95% Confidence Intervals).

AT = Anaerobic Threshold LT = Lactate Threshold
RER = Respiratory Exchange Ratio VO_2 = Oxygen Uptake

	Exercisers n = 13		*Controls n = 7*	
	Test 1	*Test 2*	*Test 1*	*Test 2*
Peak VO_2 (ml/kg/min)	19.3 (17.0, 21.6)	21.9* (18.7, 25.1)	21.5 (17.4, 25.6)	21.4 (17.6, 25.2)
Peak heart rate (beats/min)	152 (143, 161)	153 (146, 160)	156 (138, 174)	154 (141, 167)
Peak RER	1.15+ (1.10, 1.20)	1.05 (0.98, 1.12)	1.08 (1.02, 1.14)	1.07 (1.02, 1.12)
Exercise duration (mins)	15.4 (13.3, 17.5)	16.5 (14.0, 19.0)	16.3 (13.5, 19.1)	16.7 (14.0, 19.4)
VO_2 at AT (ml/kg/min)	14.1 (12.1, 16.1)	15.5 (12.8, 18.2)	15.9 (11.4, 20.4)	15.8 (12.3, 19.3)
Peak Lactate (mmol/l)	4.2 (3.2, 5.2)	4.5 (3.5, 5.5)	4.7 (3.3, 6.1)	4.5 (3.1, 5.9)
VO2 at LT (ml/kg/min)	16.5 (14.6, 18.4)	20.7* + (18.4, 23.0)	17.0 (13.2, 20.8)	16.9 (14.0, 19.8)
Walking Speed (m/sec)	1.28 (1.18, 1.38)	1.41* + (1.31, 1.51)	1.25 (1.14, 1.36)	1.20 (1.04, 1.36)
Borg Score	3.9 (3.1, 4.7)	3.9 (3.4, 4.4)	3.1 (2.5, 3.7)	3.6 (2.8, 4.4)

* $P < 0.05$ compared to baseline
+ $P < 0.05$ compared to controls

DISCUSSION

This study found that lactate threshold and walking speed could be significantly improved with a minimal exercise programme in elderly women following hip replacement. The ACSM [7] recommend that training takes place 3-5 days per week, for 20-60 minutes, at an intensity of 60-90% of maximum heart rate or 50-85% of maximum oxygen uptake. The exercisers in this study spent a maximum of 20 minutes at a training intensity which was close to the minimum guidelines recommended by ACSM of 60% maximum heart rate (50% of maximum oxygen uptake). However exercise took place only twice per week. Using lactate threshold as an indicator of training intensity[16, 17] it is clear that the experimental group in this study exercised below their anaerobic threshold.

In agreement with Foster et al[18] this study also demonstrated that peak VO_2 can be readily measured in elderly women. Conventional criteria for the attainment of maximum oxygen uptake i.e. a plateau in oxygen consumption with increasing work, respiratory exchange ratio value of greater than 1.15 heart rate at age-predicted maximum, and a lactate concentration greater than or equal to 8 mmol/l cannot be achieved by older subjects, probably due to lack of motivation or unfamiliarity with intense exercise hence the use of the term 'peak' oxygen uptake in this investigation. In this study, subjects achieved a mean peak lactate of 4.2 and 4.5 mmol/l in the first and second treadmill tests respectively. A plateau in oxygen uptake was observed in Test 1 and Test 2 for 17 subjects, and the mean peak respiratory exchange ratio was 1.05 or higher in Test 1 and Test 2. Age-predicted maximum heart rate was achieved in 13 of the 20 subjects.

The value of peak VO_2 for the whole group measured at the start of the study (mean = 20.0 ml/kg/min) was slightly higher than the value of 18.7 ml/kg/min recorded previously for both sedentary 74 year old women[19] and women aged 60-75 years.[20] Post-operative mean peak VO_2 for 18 female and 7 male hip replacement patients was 18.1 ml/kg/min in another study.[2] Initial walking speed for the subjects in this study (1.27 m/sec) was higher than the mean speed of 1.16 m/sec of a group of elderly women living independently with a similar mean age of 72 years.[21] It was also higher than pre-training walking speed in a group of women following hip surgery in Belfast[4] (0.82 m/sec), but lower than post-training values in this group (1.49 m/sec). Hence the hypothesis that significant fitness gains were a function of low initial fitness can be discounted. The stringent criteria applied at the screening stage to ensure safety during the treadmill testing may be responsible for these high initial values and this group of subjects may not be typical of elderly women after hip replacement. Even less vigorous exercise regimes may be sufficient for improving fitness in hip replacement patients whose aerobic capacity is lower than the subjects tested here.

Previous studies have produced inconclusive results regarding the influence of exercise intensity on training adaptation in the elderly. Some have shown that high intensity training elicits greater increases in aerobic capacity than low intensity training [22] while others found that low intensity training provided comparable increases in maximum oxygen uptake and lactate threshold to high intensity training.[23]

The improvement in peak VO_2 in our subjects after training (13%) was smaller than that reported in some other studies.[22, 23] The short duration of the exercise programme (12 weeks) was deliberately chosen as a feasible rehabilitation time for hip surgery patients, and may contribute to the relatively small changes. The improvement in lactate threshold by our subjects (4.2 ml/kg/min) is however greater than improvements reported previously.[24] The upper limit for improvement in peak VO_2 as a result of training may be reached sooner than the upper limit for lactate threshold, which may explain the greater increase in lactate threshold relative to peak oxygen uptake. Studies in younger subjects have shown that the factors controlling the adaptation in oxygen consumption are different from those controlling the change in lactate threshold[25] and although the mechanisms are unclear, the central cardiovascular, peripheral circulation and local muscular adaptations have been cited as influences.

The principal limitations of this study included the small numbers and the lack of true randomisation to exercise and control groups which were determined by geographical location. However, the results obtained suggest that minimal exercise can improve functional fitness in elderly women who have undergone a hip replacement operation. The exercise group found the exercise programme manageable and enjoyable. Minimal exercise is thus a positive intervention following hip surgery for osteoarthritic patients.

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