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RECOVERY AFTER TOTAL HIP JOINT ARTHROPLASTY IN ELDERLY PATIENTS WITH OSTEOARTHRITIS: POSITIVE EFFECT OF UPPER LIMB INTERVAL-TRAINING

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Objective: **To evaluate the influence of an interval training program for the upper limbs on cardiorespiratory fitness and walking ability in elderly patients after total hip joint arthroplasty.**
Design: **A randomized controlled trial. After surgery, control and training groups started general rehabilitation. Training group combined it with an arm-interval exercise program (3 sessions of 30 minutes per week, for 6 weeks).**
Subjects: **Patients were assigned randomly to control ($n = 7$) and training groups ($n = 7$).**
Methods: **Incremental exercise tests were carried out until exhaustion on an arm crank ergometer 1 month before and 2 months after surgery. A 6-minute walk test was also performed 2 months after surgery.**
Results: **$\dot{V}O_2$ peak increased significantly in the training group ($p = 0.0424$) and did not change in the control group. The difference in $\dot{V}O_2$ peak change between the groups was significant ($p = 0.0362$, +19.2% in the training group and −3.5% in the control group). In the walking test the training group covered a significantly longer distance than did the control group ($p = 0.0055$, 396.4 metres and 268.1 metres, respectively).**
Conclusion: **These results stress the importance of physical training in a rehabilitation program after total hip joint arthroplasty and this should be considered for improving the current practices in rehabilitation.**

Key words: exercise test, exercise training, elderly, total hip arthroplasty, osteoarthritis.

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INTRODUCTION

With population ageing, there is an increasing prevalence of osteoarthritis (OA) of the hip, which leads to an increase in the number of hip surgical interventions (1). Patients with OA have lower endurance and aerobic capacities than matched controls (2). These patients are physically deconditioned (with severe perturbations of cardiorespiratory fitness and exercise tolerance) (3). This symptom appears with a decline in functional activity, due mainly to pain and musculoskeletal restriction caused by OA (3). It has been reported that the severity of OA is associated with the severity of cardiorespiratory deconditioning (3). Therefore, patients with OA may also develop cardiovascular problems and those undergoing surgery have a higher risk of peri-operative complications (e.g. lower limb phlebitis, deep venous thrombosis, pulmonary embolism) (3).

Several studies have shown that exercise training in elderly people improves their physical fitness and protects them against a number of old age chronic diseases (4). Such training may also help elderly patients to maintain independent living. After both cardiac and thoracic surgeries effective reconditioning programs are proposed to geriatric patients (5). However, such strategies have not been studied and applied immediately after total hip arthroplasty (THA) (6).

We therefore investigated the influence of a training program in elderly patients on their recovery after THA. We used an interval-training program known to be an effective procedure to restore cardiopulmonary function (7). This program, named Square Wave Endurance Exercise Test (SWEET), is specific and individualized at the ventilatory threshold (8). Only an exercise program for the upper limbs was considered. Though patients would have been able to walk few days after surgery, they would not have been able to perform training that would be strenuous enough to promote an improvement in cardio-respiratory fitness. Moreover, due to pain and the patients' difficulties with movement, an exercise program for the lower limbs would have been very difficult to organize (and ethically questionable). We have stressed recently that although various protocols employing treadmill and bicycle exercise testing are available, they have limited use for individuals with vascular, neurological or orthopaedic conditions. Such situations preclude lower limb exercise (6).

The aim of our study was to evaluate the effects of a specific and individualized interval-training program for the upper limbs

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Table I. *Characteristics of the patients one month before surgery, median (extreme values)*

Variables	Training group $n = 7$	Control group $n = 7$
Number (female/male)	6/1	6/1
Age (years)	77.0 (67.0–80.5)	77.0 (67.0–82.0)
Weight (kg)	77.0 (45.2–97.0)	70.6 (53.2–86.4)
Height (cm)	157.0 (145.5–173.5)	158.5 (143.0–169.0)
BMI ($kg.m^{-2}$)	28.9 (21.3–34.3)	30.3 (21.7–32.5)
Danielsson's radiographic score	5.0 (2.0–9.0)	5.0 (3.0–7.0)

BMI = body mass index.

on aerobic capacity, ventilatory threshold (VT) and walking ability in elderly patients after THA.

METHODS

Subjects

Fourteen patients with OA (12 female and 2 male patients, median age 77.0 years) undergoing cemented and uncemented THA participated in the study. Patients' characteristics are shown in Table I. The training group (TG) and control group (CG) did not differ significantly in age, body mass, height, body mass index (BMI) or severity of hip OA. The study plan was accepted by the Local Ethical Committee and all patients signed an informed consent form. Only volunteers over the age of 65 years, whose main diagnosis was primary hip OA, were included. Patients were excluded if they were undergoing revision arthroplasties, were unable to sign the informed consent form or were taking medication that might have interfered with exercise testing and training. Exclusion criteria also included decompensated congestive heart failure, acute myocarditis, acute myocardial infarction, unstable angina pectoris, uncontrolled cardiac arrhythmias, severe aortic stenosis, severe hypertension, and untreated hypertrophic obstructive cardiomyopathy. Radiographs of the patient's hip were taken before surgery and evaluated by the surgeons. The radiographic scoring system was adapted from the method of Danielsson (9).

Design and procedure

Patients performed an incremental exercise test until exhaustion on an arm crank ergometer 1 month before (T_{-1}) and 2 months after surgery (T_2). They also performed a walking test at T_2. After surgery, patients were randomly assigned to 2 groups: TG ($n = 7$, 6 females and 1 male), and CG ($n = 7$, 6 females and 1 male) and stayed at the rehabilitation centre for 6 weeks.

Both groups undertook a traditional daily rehabilitation program, which consisted of exercises for muscular strength, range of motion, aquatics and walking for 2 hours per day. In addition, TG undertook an exercise training program with an arm ergometer.

Incremental exercise test with arm ergometer

All tests were performed under the supervision of a cardiologist. Patients performed an incremental exercise test on a mechanically braked arm crank ergometer (Monark Rehab Trainer, Model 881E, Monark Exercise, Sweden) in a fully-upright sitting position. This apparatus was calibrated before and after each test. The height of the crank axis was individually adjusted at heart level at a distance that caused a slight flexion of the elbow in the extended arm (10). All the tests on the arm crank ergometer began after 2 minutes of seated rest, followed by a 3-minute warm-up with no load, during which the subjects were familiarized with the working position. After a further 2 minutes of seated rest the exercise began at a power output of 10 W for 2 minutes, followed by a 10 W increment every 2 minutes using alternately an adapted increase in pedalling speed or friction resistance (11, 12). The pedalling speed was between 50 and 70 rotations per minute (rpm) (13). The load was increased until subjective exhaustion, when the subject could no longer maintain the pedalling rate (a decrease by more than 5 rpm) despite verbal encouragement. A 12-channel ECG (Nihon Kohden, type 2R-701.VK) was used continuously during exercise.

The 6-minute walk test (6-MWT)

At T_2, both TG and CG performed a functional test: a 6-minute walk test (6-MWT) (14, 15). The walking track was a 30-metre long empty hospital corridor (the surface was linoleum, hard and smooth). Patients were asked to walk back and forth along the 30-metre track and to cover the longest possible distance in 6 minutes. Every 30 seconds patients were encouraged in a standardized verbal way, and time was announced every 2 minutes. During walking, all patients used bilateral crutches.

Measurements during exercise testing and 6-MWT

During both of these tests, respiratory gas exchange was measured with a portable metabolic measurement system cart (Aerosport KB1-C, Aerosport Inc., USA) (16). During the 6-MWT, the cart was fixed around patient's waist. In addition, the patients had a mouthpiece and a noseclip. The ventilation volumes were measured by a pneumotachometer, and the concentrations of O_2 and CO_2 in the expired air are analysed by a galvanic fuel cell oxygen analyser (range 0–25%) and non-dispersive infrared carbon dioxide analyser (range 0–10%), respectively. The KB1-C was calibrated immediately prior to each test in the low-flow position according to the manufacturer's specifications using a 3-litre Hans-Rudolph calibrated syringe (Hans-Rudolph Inc., USA) (16). Expired gases were sampled and analysed every 20 seconds intervals. The respiratory and metabolic parameters were recorded including ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$) and CO_2 production ($\dot{V}CO_2$). Heart rate (HR) was continuously monitored and recorded during the test using a telemetric system (Sport Tester Polar Vantage N, Polar Electro, Finland) and standard electrocardiographic leads (only for the arm crank exercise test). In our study, the highest attained $\dot{V}O_2$ value is called as $\dot{V}O_2$ peak.

In addition, the duration of exercise and several mechanical parameters were followed during the incremental arm crank test, such as the maximal tolerated power (MTP = the highest power output in Watts which could be maintained with a constant pedalling speed for 1 minute). During 6-MWT, the distance, the stride length, and the cadence were followed. At the end of the arm crank test and the 6-MWT, perceived exertion and pain were assessed with Borg's standardized CR-10 scale (17). Prior to all tests the patients were provided with a typewritten set of standardized instructions for the use of CR-10 scale.

The VT using the V-slope method was determined from the data obtained during the arm crank test (18). The $\dot{V}E$, $\dot{V}O_2$, HR, and the workload at VT were then determined. VT was assessed from respiratory exchange ($\dot{V}E$, $\dot{V}CO_2$, $\dot{V}O_2$) by 3 observers. The mean of the 2 closest values was taken into account for calculating the VT. The VT is considered as an indicator of endurance capacity (8).

Training program with upper limbs

The training program started 1 week after surgery and was carried out in the rehabilitation centre. This program consisted of 3 sessions per week of the 30 minute SWEET proposed by Gimenez et al. (8), continued for 6 weeks. A session comprised 6 consecutive periods of 5-minutes including 4-minutes of "base" work followed by 1-minute of "peak" work. Initially, the base was set at the VT and the peak at the MTP that was determined during the progressive test using the corresponding target HR. In order to maintain a sufficient intensity during training (target HR, and CR-10) which aimed at reaching a peak HR at the end of

Table II. *Peak values obtained during the incremental arm exercise test before and after surgery, median (extreme values)*

Variables	Time[a]	Training group $n = 7$	Control group $n = 7$
Number (female/male)		6/1	6/1
Exercise duration (seconds)	T_{-1}	360.0 (180.0–445.0)	240.0 (140.0–330.0)
	T_2	374.0 (180.0–540.0)	200.0 (120.0–260.0)[a,b]
MTP (W)	T_{-1}	30.0 (20.0–40.0)	20.0 (10.0–30.0)
	T_2	30.0 (20.0–50.0)	20.0 (10.0–20.0)[a]
HRpeak (bpm)	T_{-1}	142.0 (122.0–146.0)	125.0 (109.0–158.0)
	T_2	138.0 (120.0–152.0)	127.0 (102.0–159.0)
% HRmax	T_{-1}	93.7 (82.4–104.7)	87.4 (73.6–107.5)
	T_2	95.9 (84.2–105.4)	83.7 (71.3–108.2)
$\dot{V}O_2$ peak (ml/[kg.minute])	T_{-1}	10.6 (4.9–12.8)	8.6 (7.1–10.3)
	T_2	11.8 (5.9–13.1)[b]	7.9 (6.4–9.9)
$\dot{V}E$ (l/minute)	T_{-1}	23.3 (13.5–32.1)	21.2 (15.5–27.4)
	T_2	22.1 (20.5–31.6)	20.3 (16.5–26.5)
CR-10			
Perceived exertion	T_{-1}	4.0 (2.5–6.5)	5.0 (3.0–10.0)
	T_2	5.0 (3.0–8.0)[b]	4.0 (3.0–6.0)
Pain	T_{-1}	0.0 (0.0–5.0)	0.0 (0.0–5.0)
	T_2	0.0 (0.0–5.0)	2.0 (0.0–4.0)

For multiple comparisons data were analysed with ANOVA followed by *post hoc* tests. [a] T_{-1} = 1 month before surgery; T_2 = 2 months after surgery; [b] $p < 0.01$, training group vs control group; [c] $p < 0.05$, before surgery vs after surgery.
MTP = maximal tolerated power; HR = heart rate; HRmax = age-predicted maximum heart rate (220 – age); $\dot{V}O_2$ = oxygen consumption; CR-10 = Category Ratio Scale of Borg's perceived exertion and pain scales.

sixth peak, the loads for the base and peak were increased alternately (+5 W) (8). This readjustment was made when the HR at the end of training session was lowered by 10–12 bpm compared with the previous session, or according to subjective feelings.

Statistics

The data are presented as median and extreme values. Training effects were evaluated using ANOVA followed by *post-hoc* test. For each group, results obtained before and after training were also compared using the paired *t*-test. Student *t*-test was used to compare the measurements of the 6-MWT between the groups. Relationships between variables were analysed with the Pearson correlation coefficient. The level of statistical significance was set at $p < 0.05$.

RESULTS

Peak values obtained during the incremental exercise test

All patients performed the test until exhaustion using the arm crank ergometer. The reasons for stopping the exercise were either generalized fatigue or dyspnoea (characterized as "cardiopulmonary") or joint pain, muscle pain, or muscle fatigue (designated as "musculoskeletal"). The results at T_{-1} and T_2 are summarized in Table II. Before surgery, both groups behaved similarly in all peak values measured. After surgery, exercise duration, and MTP were significantly higher in TG than in CG ($p = 0.0095$ and $p = 0.0074$, respectively). $\dot{V}O_2$ peak significantly increased in TG ($p = 0.0424$) and did not change in CG.

When comparing the changes from T_{-1} to T_2, the difference in change for exercise duration, MTP and $\dot{V}O_2$ peak between the groups were significant ($p = 0.0038$, $p = 0.0423$, and $p = 0.0362$, respectively) (Fig. 1).

Ventilatory threshold during the incremental exercise test

The results at T_{-1} and T_2 are summarized in Table III. Before surgery, no differences in VT (expressed as $\dot{V}O_2$) or in other variables measured at VT were found between the groups. After surgery, power output, $\dot{V}O_2$, and $\dot{V}E$ were significantly higher in TG than in CG ($p = 0.0016$, $p = 0.0107$ and $p = 0.0225$, respectively). Also, power output, $\dot{V}O_2$, and $\dot{V}E$ at VT significantly increased in TG ($p = 0.0010$, $p = 0.0208$ and $p = 0.0166$, respectively).

The overall pattern of changes at VT from T_{-1} to T_2 were similar to those observed during peak arm exercise. The differences in change for power output and $\dot{V}O_2$ peak between the groups were significant ($p = 0.0010$ and $p = 0.0162$, respectively) (Fig. 2). VT could not be assessed in 1 patient from CG.

The six-minute-walk test (6-MWT)

The results of the 6-MWT are summarized in Table IV. One patient from TG did not finish the 6-MWT, because she could not tolerate the mouthpiece any longer. After surgery, TG

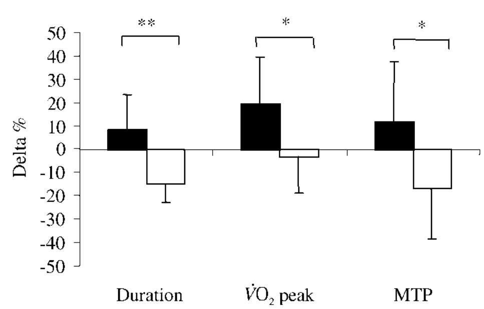

Fig. 1. Percentage changes in exercise duration, peak oxygen consumption ($\dot{V}O_2$ peak) and maximal tolerated power (MTP) in the incremental arm exercise test for the training group (■) and control group (□). Delta values were calculated as followed: $[(T_2–T_{-1}) / T_{-1}] \times 100$. Data were analysed with ANOVA followed by *post hoc* tests, * <0.05, ** <0.01.

Table III. *Ventilatory threshold ($\dot{V}O_2$) and related variables at ventilatory threshold obtained during the incremental exercise test before and after surgery, median (extreme values)*

Variables	Time[a]	Training group $n = 7$	Control group $n = 6$
Number (female/male)		6/1	5/1
Power output (W)	T_{-1}	10.0 (10.0–20.0)	10.0 (10.0–20.0)
	T_2	20.0 (10.0–30.0)[de]	10.0 (10.0–10.0)[b]
HR (bpm)	T_{-1}	105.0 (96.0–135.0)	106.5 (90.0–129.0)
	T_2	114.0 (105.0–132.0)	99.0 (84.0–126.0)
$\dot{V}O_2$ (ml/[kg.minute])	T_{-1}	7.5 (3.9–10.0)	6.9 (5.8–8.9)
	T_2	9.0 (5.3–11.1)[c]	5.6 (3.4–7.5)[a]
% $\dot{V}O_2$ peak	T_{-1}	77.6 (61.7–85.1)	89.0 (67.3–94.2)
	T_2	89.3 (71.3–95.7)	79.8 (36.6–92.4)
$\dot{V}E$ (l/minute)	T_{-1}	14.7 (7.6–21.9)	15.2 (9.2–19.1)
	T_2	18.2 (15.4–23.8)[c]	14.3 (8.2–19.0)[a]

For multiple comparisons data were analysed with ANOVA followed by *post hoc* tests. [a] T_{-1} = 1 month before surgery; T_2 = 2 months after surgery; [b] $p < 0.05$, [c] $p < 0.01$, training group vs control group, [d] $p < 0.05$, [e] $p < 0.001$, before vs after surgery HR = heart rate; $\dot{V}O_2$ = oxygen consumption; $\dot{V}E$ = ventilation.

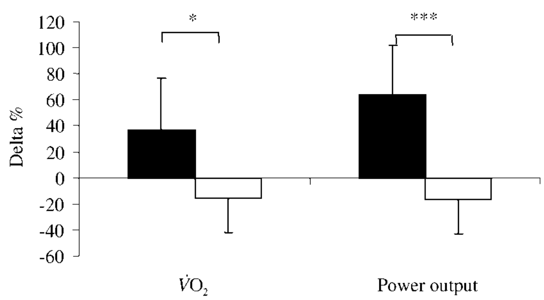

Fig. 2. Percentage changes in rate of oxygen consumption ($\dot{V}O_2$) and in power output at ventilatory threshold during incremental arm exercise test for the training group (■) and control group (□). Delta values were calculated as followed: $[(T_2–T_{-1}) / T_{-1}] \times 100$. Data were analysed with ANOVA followed by *post hoc* tests, * <0.05, *** <0.001.

walked a significantly longer distance than CG ($p = 0.0055$). During walking, stride length, cadence and $\dot{V}O_2$ significantly were higher in TG than in CG ($p = 0.0184$, $p = 0.0322$ and $p = 0.0326$, respectively). The average walking speed was higher in TG than in CG ($p = 0.0055$).

Two months after surgery, we found a significant correlation between the $\dot{V}O_2$ at the end of the 6-MWT and $\dot{V}O_2$ peak obtained during incremental maximal exercise test ($p = 0.0027$) (Fig. 3). A significant correlation between the distance covered and $\dot{V}O_2$ at the end of the 6-MWT was observed ($p = 0.0001$) (Fig. 4).

DISCUSSION

The principal finding of this study was that a relatively short, but intensive, arm exercise training period can produce significant increases in cardiorespiratory fitness and walking ability in elderly THA patients after surgery.

Clearly, the limitation of this study was the relatively small number of subjects. However, the differences between the groups were of such magnitude, especially in walking ability, that further studies are warranted in this area.

Before surgery, both TG and CG groups had similar $\dot{V}O_2$ peak during the incremental exercise test. During the 2-month period after surgery, the only difference in treatment between those 2 groups was the interval-training program with the upper limbs. After this period, the CG group experienced a decrease in $\dot{V}O_2$

Table IV. *Results of the 6-minute walk test 2 months after surgery, median (range values)*

Variables	Training group $n = 6$	Control group $n = 7$
Number (female/male)	5/1	6/1
Distance (metres)	404.5 (270.0–507.5)**	259.0 (218.0–301.7)
Speed (km/h)	4.0 (2.7–5.1)**	2.6 (2.2–3.3)
Stride length (m)	0.6 (0.5–0.8)*	0.5 (0.4–0.6)
Cadence (steps/minute)	105.4 (92.5–117.5)*	88.2 (81.3–104.0)
HR (bpm)	132.0 (113.0–150.0)	111.0 (99.0–138.0)
% HRmax	87.5 (76.4–107.5)	79.7 (66.9–93.9)
$\dot{V}O_2$ (ml/[kg.minute])	13.0 (7.5–15.9)*	9.8 (5.9–11.6)
$\dot{V}E$ (l/minute)	23.8 (18.1–36.2)	18.3 (13.2–32.3)
CR-10		
Perceived exertion	2.5 (1.5–5.0)	4.0 (0.5–7.0)
Pain	0.0 (0.0–2.0)	0.0 (0.0–2.0)

Data were analysed with Student's *t*-test. * <0.05, ** <0.01.
HR = heart rate; HRmax = age-predicted maximum heart rate (220 – age); $\dot{V}O_2$ = oxygen consumption; $\dot{V}E$ = ventilation.

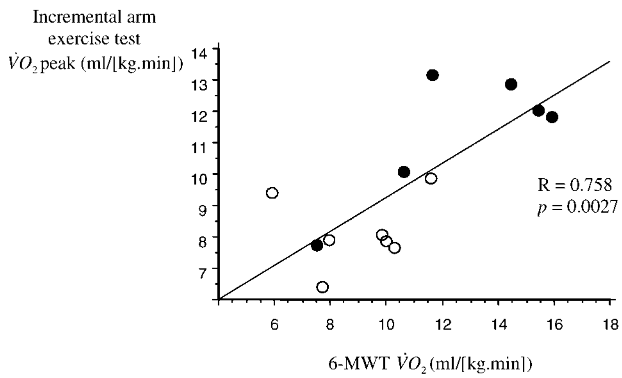

Fig. 3. Correlation between rate of oxygen consumption ($\dot{V}O_2$) peak (ml/[kg.minute]) obtained with the incremental exercise test and $\dot{V}O_2$ (ml/[kg.minute]) obtained during the 6-minute-walk test (6-MWT) 2 months after surgery for the training group (●) and control group (○).

peak, MTP and VT values, whereas significant increases in the same variables were observed in the TG group. The results obtained from the functional test (a 6-MWT) agreed with those from the incremental exercise test. The TG group (which had improved its $\dot{V}O_2$ peak) was able to cover a significantly longer distance in the walking test than was the CG group. During this test, the TG group presented a faster walking speed, a longer stride length and higher step frequency than the CG group. Therefore, besides an improvement in cardiorespiratory fitness, we can also speculate that the TG group has improved its gait efficiency.

The 6-MWT induced a similar increase in the heart rate to the one induced during the incremental arm exercise test after THA in both groups. Moreover, we observed a significant correlation between $\dot{V}O_2$ peak obtained during the incremental exercise test after the recovery period and $\dot{V}O_2$ obtained during the 6-MWT. Such a functional test seems to provide information concerning the exercise abilities of the patients.

No significant differences were observed between the TG and

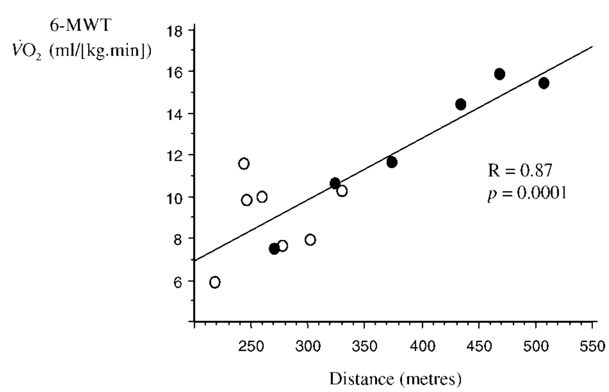

Fig. 4. Correlation between rate of oxygen consumption ($\dot{V}O_2$) (ml/[kg.minute]) and distance covered during the 6-minute-walk test (6-MWT) 2 months after surgery for the training group (●) and control group (○).

CG groups concerning perceived exertion and the $\dot{V}E$ in the 6-MWT despite higher walking speed in TG. This may indicate that our training also improved the physical fitness of our patients. This may have some importance in the reduction of the cardiorespiratory strain induced by physical tasks in daily life.

Altogether, our interval-training program was able to induce an improvement in upper body aerobic capacity and walking ability. The traditional rehabilitation program was able to maintain the fitness of the patients at the level they had before surgery. All of our patients in both programs finished the rehabilitation period without complications. However, despite the training program, all of our volunteers were deconditioned at the end of the recovery period.

It could be speculated that the improvements induced by our arm-exercise training could have stemmed from systemic cardiovascular and cardiorespiratory effects (central adaptations) rather than localized metabolic or haemodynamic changes. It has been reported that upper limb exercise induces stronger cardiovascular stimuli for a given level of submaximal work than does lower limb exercise (19). This may explain in part the observed improvements in the incremental exercise tests and in the walking test. However, due to the impressive improvement in the walking capacities of our trained patients compared with their matched controls it can be suggested that some transfer effects have occurred. Such effects have previously been reported in endurance training with lower limbs where some improvements in exercise capacity of the upper limbs (untrained muscle group) were observed and vice versa (20–22).

The present training program may help patients to recover faster after THA and may maintain them in a reasonable condition, enabling them to carry out activities of daily living more easily. Moreover, this training was suitable for OA geriatric patients and was clinically well tolerated (e.g. no injuries were reported). It is therefore recommended that physical training is incorporated in the rehabilitation practices after THA in order to enhance health and to prolong independent living in elderly patients (23). However, even though the TG showed improved cardiorespiratory fitness, the patients still remained deconditioned after the training. We suggest that arm exercise interval training could also be proposed to OA geriatric patients before THA.

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