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ORIGINAL RESEARCH ARTICLE

Whole-Body Strength Training Using a Huber Motion Lab in Coronary Heart Disease Patients: Safety, Tolerance, Fuel Selection, and Energy Expenditure Aspects and Optimization

ABSTRACT

Guiraud T, Labrunée M, Pillard F, Granger R, Bousquet M, Richard L, Boned A, Pathak A, Gayda M, Gremeaux V: Whole-body strength training using a huber motion lab in coronary heart disease patients: safety, tolerance, fuel selection, and energy expenditure aspects and optimization. Am J Phys Med Rehabil 2014;00:00–00.

Objective: The aim of this study was to investigate safety, tolerance, relative exercise intensity, and muscle substrate oxidation during sessions performed on a Huber Motion Lab in coronary heart disease patients.

Design: After an assessment of $\dot{V}O_2$ peak, 20 coronary heart disease patients participated in two different exercises performed in random order at 40% and 70% (W40 and W70) of the maximal isometric voluntary contraction. AQ3

Results: No significant arrhythmia or abnormal blood pressure responses occurred during either session, and no muscle soreness was reported within 48 hrs posttest. The authors found a difference between W40 and W70 sessions for mean (standard deviation) ventilation (25.1% [8%] and 32.1% [9%] of maximal ventilation, respectively; $P = 0.04$) and a small difference for mean (standard deviation) heart rate (73 [7] and 79 [8] beats/min, respectively; $P < 0.01$). When compared with the W40, the W70 was associated with higher active energy expenditure (2.4 [0.6] and 3.1 [0.9] Kcal/min, respectively; $P < 0.0001$) and a similar mean (standard deviation) oxygen uptake (5.5 [1] and 6.6 [1] ml/min per kilogram, respectively; $P = 0.07$). The qualitative percentages of carbohydrates and lipids oxidized were 71% and 29%, respectively, at W40 and 91% and 9%, respectively, at W70.

Conclusions: Both protocols, which consisted of repeating 6-sec phases of contractions with 10 secs of passive recovery on the Huber Motion Lab, seemed to be well tolerated, safe, and feasible in this group of coronary heart disease patients.

Key Words: Physiologic Responses, Oxygen Uptake, Substrate Oxidation, Coronary Heart Disease

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Physical activity is recognized as an effective nonpharmacologic intervention recommended for both primary and secondary prevention of coronary heart disease (CHD).[1] Resistance training, combined with aerobic endurance exercises, has been an integral part of international recommendations for the prevention and rehabilitation of patients with CHD for the last 30 yrs[2–5] and is now recognized by the medical community as an essential part of exercise programs. It is well known that muscle mass and muscle strength decrease by approximately 30% between the third and sixth decades of life.[6] With aging, the total number of muscle fibers decreases, especially fast-twitch muscle fibers, which are recruited in force development. In CHD patients, increasing muscle strength and function can lead to significant improvements in health parameters such as insulin resistance, endothelial function, and quality-of-life.[7] It has also been shown that resistance exercise positively influences proprioceptive abilities, leading to a gradual improvement in coordination and gait control, which reduces the risk for falls.[7–9]

The range of techniques or devices available to increase the efficacy of cardiac rehabilitation unfortunately remains limited.[10] Among new devices, the Huber Motion Lab (HML), a motorized rotating platform, seems to present the qualities needed in a cardiac rehabilitation program, because it allows patients to do exercises that simultaneously involve balance, coordination, and strength training. However, data from scientific literature on the safety of HML and physiologic responses and tolerance to HML training remain sparse. Couillandre et al.[11] (2008) showed that the use of the HML involved muscles in an isometric mode (especially the upper limbs) leading to the predominant stimulation of anaerobic metabolism and the adaptive mechanisms associated with this type of contraction. Overall, it has been shown that the effects of training on the HML are positive in two main functional areas, that is, strength and balance. In addition, a recently published study showed that 8 wks of training on the HML had a positive impact on body composition (reduced percentage of body fat), anthropometric data (reduction of waist circumference), muscle performance (strength), and walking economy in healthy subjects.[12]

To date, neither the safety aspects of the HML nor tolerance and acute cardiopulmonary responses of CHD patients to whole-body strength training (WBST) have been studied. This information is required to determine whether WBST meets cardiovascular rehabilitation guidelines before it can be considered for use in cardiac rehabilitation programs. The objectives of the current study were therefore to (1) verify that no adverse events occur during and after acute sessions of two different intensities on the HML, (2) compare the acute cardiopulmonary responses between two different exercise intensities, and (3) assess the relative intensity of HML acute exercise sessions compared with maximal exercise capacity measured on cardiopulmonary exercise tests (CPETs) in patients with CHD.

MATERIALS AND METHODS

Participants

Twenty patients with CHD, who had provided written informed consent, were recruited at the Clinic of Saint-Orens, Cardiovascular Rehabilitation Center (Toulouse, France). Inclusion criteria were a history of greater than or equal to 70% of arterial diameter narrowing of at least one major coronary artery, documented previous myocardial infarction and/or percutaneous coronary intervention. Exclusion criteria were recent acute coronary syndrome (<1 mo), significant resting ECG abnormality, severe arrhythmia, **AQ4** history of congestive heart failure, uncontrolled hypertension, recent bypass surgery of 3 mos or less, recent percutaneous coronary intervention of 1 mo or less, left ventricular ejection fraction of 45% or less, pacemaker, recent modification of medication of less than 2 wks, and musculoskeletal conditions making exercise on a cycle ergometer difficult or contraindicated. Demographic and baseline characteristics are presented in Table 1. The research protocol was approved by the Committee for the Protection of Human Subjects (Toulouse University Hospital, France). T1

Experimental Design

All patients were asked to attend the cardiac rehabilitation center three times. On the first visit, patients underwent a complete medical evaluation, which included measurement of height, weight, body composition, and resting ECG and a maximal CPET on a cycle ergometer. During 2 subsequent wks, in random order, patients performed the two exercise sessions (40% *vs.* 70% of maximal isometric voluntary contraction [MVC]) under the supervision of an exercise physiologist to maintain the optimal exercise technique and a cardiologist. The choice of intensities was based on guidelines for resistance training in cardiac rehabilitation. These recommend exercise at between 30% and 60% of MVC.[13] As 60% of MVC seems to be moderate in the isometric mode, the authors choose to keep 70% of MVC as the upper limit. All tests were conducted on an electromechanically braked bicycle ergometer (Ergoline 800S, Bitz, Germany) for CPET and on a commercially

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TABLE 1 Baseline characteristics of patients with CHD

Anthropometrics, mean (SD)	
Age, yrs	53.1 (9.9)
Sex, male/female	19 (95)/1 (5)
BMI, kg/m^2	28.9 (2.9)
Waist circumference, cm	101.5 (8)
Risk factors, *n* (%)	
Hypertension	10 (50)
Currently smoking	7 (35)
Diabetes	4 (20)
Dyslipidemia	15 (75)
Pathology, *n* (%)	
Previous myocardial infarction	20 (100)
Coronary artery bypass grafting surgery	0 (0)
Percutaneous coronary intervention	20 (100)
Medications, *n* (%)	
Antiplatetet agents	20 (100)
β blockers	17 (85)
Calcium channel blockers	1 (5)
ACE inhibitors	12 (60)
Angiotensin receptor antagonist	17 (85)
Statins	1 (5)
Nitrates	0 (0)
Antidiabetic agents	4 (20)
Exercice tolerance, mean (SD)	
PPO, W	171 (37)
Maximal HR, beats/min	126.2 (16.4)
$\dot{V}O_2$max, ml/min per kilogram	20.6 (5.2)
Maximal ventilation, l/min	68.1 (16.6)
VT, ml/min per kilogram	12.4 (4.2)
Power at VT, W	104 (29)
Maximal SBP, mm Hg	171.7 (23.4)
Maximal DBP, mm Hg	79.9 (12.1)

BMI indicates body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; VT, ventilatory threshold.

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available device (HML, LPG Systems, France) for the WBST.

Maximal CPET

A 2-min warm-up at 20 W was performed before the test, and the power was increased by 10 W every minute depending on the functional capacity of the patient until exhaustion.[14] Verbal encouragement was given throughout the test. The criteria for stopping the exercise test were volitional exhaustion, significant ECG abnormalities (ST depression > 2 mm or ventricular arrhythmia), or an abnormal blood pressure response. Oxygen uptake ($\dot{V}O_2$) was determined continuously on a 10-sec basis using an automated cardiopulmonary exercise system (Ganshorn, Germany). Gas analysers were calibrated before each test, using a gas mixture of known concentration (15% of O_2 and 5% of CO_2) and ambient air. Participants breathed through a facemask connected to the turbine. The turbine was calibrated before each test using a 3-l syringe at several flow rates. Electrocardiographic activity was monitored continuously using a 12-lead ECG (GE-Healthcare Marquette), and blood pressure was measured manually every 2 mins using a sphygmomanometer. The highest oxygen consumption during a 10-sec period and the highest heart rate (HR) during a 5-sec period during the test were considered peak oxygen consumption ($\dot{V}O_2$peak, in ml/kg per minute) and peak HR (in beats/min), respectively. The power output of the last completed stage was considered the peak power output (PPO, in W). The inability to maintain the required pedal cadence (i.e., 60 revolutions/min) was considered as the criterion for competing the test.

Exercise Sessions

General Setting

Oxygen consumption using Powercube (Ganshorn, Germany) and electrocardiographic activity (GE-Healthcare Marquette) were monitored continuously during both sessions according to the same modalities as for the CPET. Blood pressure was measured manually every 2 mins with a sphygmomanometer. Perceived exertion and sensation of breathlessness were measured every 3 mins using the 20-point Borg scale and the 10-point visual analogic and self-assessment scale, respectively.[15] Muscle soreness within 48 hrs posttest was assessed using a visual, analogic, and self-assessment scale.

WBST and assessment of MVC

The HML (LPG Systems, France) consists of an oscillating platform and two large handles mounted on a movable column. Several feet and hand positions are marked on the platform and handles, respectively. WBST exercises consisted of adopting specific positions, defined as a combination of various foot and hand positions, and developing low-high force levels against the handles. These actions required the synergistic activation of various muscle groups of the lower limbs, trunk, and upper limbs. The handles are equipped with strain gauges, and feedback about the force developed was provided to the subjects. In addition, an interactive interface, shown as a target, informed the subject about their ability to maintain the required force level. This "gamelike" control panel is intended to stimulate the subject's motivation to practice and to adhere to the WBST training program.[12]

MVC was measured in the standardized positions before the change to each subsequent position. Subjects were asked to exert maximal isometric pushing and pulling forces (i.e., opposite actions with the two hands on the handles). For each position, pulling and pushing forces were recorded by the strain gauges on the handles. Subjects did two 6-sec

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MVCs at each position. A third trial was done if the difference between the first two trials was greater than 5%. Verbal encouragement and visual feedback about the force developed were provided to the subjects during each MVC. The highest mean force produced during the 6-sec period was retained as the MVC value for each action (i.e., pulling and pushing forces). The MVC value was expressed in decanewton.

WBST sessions

The velocity inclination of the plate (rotation) was set at 30/30 (see HML instructions manual). Both exercises consisted of six exercise blocks in different postures. Each block consisted of eight contractions of 6 secs alternating with 10 secs of passive recovery, and this was repeated twice. The total duration of the session, which included 3 mins of warm-up, 10 mins of MVC assessment, 27 mins of exercise, and 5 mins of recovery, was 45 mins. The sole difference between the two sessions (W40 and W70) was the intensity of isometric contraction, which was set at 40% and 70% of the MVC, respectively. The two sessions could have been matched for energy expenditure. However, the aim of this study was not to compare metabolic plasticity between two exercise intensities but rather to optimize the duration of rehabilitation exercise usually prescribed and allowed in routine practice. If accepted and tolerated, more is better. All of the patients had one complete session of familiarization in the days before the protocol. To validate both sessions, patients had to validate a coordination score corresponding to a minimum of 60%. This score corresponds to a percentage of the time spent in the target.

Data Analysis

Determination of Peak Oxygen Uptake ($\dot{V}O_2max$)

Mean values of $\dot{V}O_2$ were displayed every 10 secs during the test. The primary criterion for the attainment of $\dot{V}O_2max$ was a plateau in $\dot{V}O_2$ (change < 2.1 ml/min per kilogram) despite an increase in power output.[16] In the absence of a plateau, attainment of $\dot{V}O_2max$ was based upon the presence of a respiratory exchange ratio of 1.10 or greater or the inability to maintain the required pedal cadence (i.e., 60 revolutions/min).

Substrate Oxidation Calculation

Energy expenditure and substrate oxidation were calculated by indirect calorimetry using mean values corresponding to the entire sessions of exercise excluding warm-up and recovery. Energy expenditure was calculated using the Weir equation (EE kcal/min = $[(3.9 \times \dot{V}O_2 \text{ ml/min}) + (1.1 \times \dot{V}CO_2)] \times 1.44] / 1440$).[17] AQ6 Quantitative carbohydrates (CHO) and lipid oxidation (g/min) were calculated from $\dot{V}O_2$ and $\dot{V}CO_2$ using the Frayn equations, which have been validated for high-intensity exercise.[18–20] Protein oxidation was neglected.[21]

$$\text{CHO (g/min)} = 4.55 \times (\text{VCO}_2 \text{ l/min}) - 3.21 \times (\text{VO}_2 \text{ l/min})$$

$$\text{Lipid (g/min)} = 1.67 \times (\text{VO}_2 \text{ l/min}) - 1.67 \times (\text{VCO}_2 \text{ l/min})$$

Qualitative CHO and lipid oxidation (in percent) were calculated from RER values using a table AQ7 of nonprotein respiratory quotient.[22]

Determination of Time Spent at a Percentage of $\dot{V}O_2peak$

Mean values of $\dot{V}O_2$ were displayed every 10 secs during both sessions. The time spent greater than 20%, 30%, and 40% of $\dot{V}O_2max$ was computed by summing each 10-sec block that satisfied the criterion.[23]

Sample Size

The primary endpoint of this study was to investigate the safety during sessions performed on HML in CHD patients. On the basis of a previous study of CHD patients,[24] the expected probability of severe arrhythmias is 1% (the authors therefore expect to observe 99% of patients without severe arrhythmias). It considers that it would not be acceptable to continue the implementation and evaluation of this training if severe arrhythmias occur in more than 15% of cases (85% of patients without severe arrhythmias). By applying a scheme of phase II single-stage A'Hern with a power of 80% and an alpha risk of 5%, it is necessary to recruit 19 patients with no severe arrhythmias occuring in these 19 patients. This analysis was performed using SPSS 16 for Windows (SPSS, Inc, Chicago, IL). AQ8

Statistical Analysis

Means and standard deviations were reported for continuous variables, whereas frequencies and percentages were reported for categorical values (see Table 1). CHO and lipid oxidation during the two sessions were compared using a repeated measure ANOVA with time and group factors (see AQ9 Table 2). Statistical analyses were performed using T2 Statview software version 5.0 (SAS Institute, Inc). A $P < 0.05$ was considered as significant.

RESULTS

Results from the CPET are presented in Table 1. The primary criterion for the determination of $\dot{V}O_2max$ (i.e., the plateau) was satisfied for 80% of

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TABLE 2 Energy expenditure, CHO, and lipid oxidation measured during both exercise sessions in patients with CHD

	3-Min Rest	37-Min Training Session	5-Min Recovery	ANOVA, *P*
Quantitative parameters, mean (SD)				
Total EE, Kcal/min				
W40	1.42 (0.37)	2.46 (0.63)	2.58 (1)	*a* = 0.03
W70	1.20 (0.30)	3.11 (0.91)	3.53 (1.36)	*b* < 0.0001
				c < 0.0001
CHO, g/min				
W40	0.19 (0.08)	0.46 (0.16)	0.56 (0.26)	*a* < 0.001
W70	0.17 (0.05)	0.72 (0.22)	0.85 (0.35)	*b* < 0.0001
				c < 0.0001
Lipids, g/min				
W40	0.07 (0.03)	0.07 (0.03)	0.04 (0.02)	*a* = 0.0003
W70	0.05 (0.03)	0.02 (0.01)	0.01 (0.01)	*b* < 0.0001
				c = 0.0088
Qualitative parameters				
Respiratory quotient values				
W40	0.84	0.90	0.93	*a* = 0.0003
W70	0.87	0.96	0.97	*b* < 0.0001
				c = 0.69
CHO, mean (SD), %				
W40	49.37 (17.39)	71.17 (10.79)	80.63 (17.40)	*a* = 0.0003
W70	58.76 (12.79)	90.85 (8.91)	92.57 (11.21)	*b* < 0.0001
				c = 0.11
Lipids, mean (SD), %				
W40	50.62 (17.39)	28.82 (10.79)	19.36 (17.40)	*a* = 0.0003
W70	41.23 (16.59)	9.15 (8.91)	7.43 (11.21)	*b* < 0.0001
				c = 0.11

a indicates mode effect; *b*, time effect; *c*, interaction effect (mode × time).

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the participants, whereas 20% of the participants satisfied the secondary criteria (RER or the inability to maintain the required pedal cadence). Therefore, all of the participants satisfied at least one of the two criteria. All of the participants were able to complete both WBST sessions. The score for coordination reached 70% in all sessions. No significant ventricular arrhythmia or abnormal blood pressure response occurred during either exercise session, and no muscle soreness was reported within 48 hrs of testing.

When considering the entire sample, the authors found a difference in mean (standard deviation) ventilation between W40 and W70 sessions (16.5 [4] and 21.3 [5] l/min, respectively; $P < 0.01$), and the authors observed a small difference in mean (standard deviation) HR (73 [7] and 79 [8] beats/min, respectively; $P < 0.01$). When compared with the W40 session, the W70 session was associated with higher energy expenditure (2.4 [0.6] and 3.1 [0.9] Kcal/min, respectively; $P < 0.0001$) and higher oxygen uptake (5.4 [1] and 6.6 [1] ml/min per kilogram, respectively; T2 $P < 0.01$) (see Tables 2, 3). All of the participants preferred the W70 session, which was considered less difficult than the W40 session (Borg scale ratings of 11.5 [0.8] and 11.2 [1.5], respectively).

The PPO of the study participants, measured with CPET, was 171 (37) W. This study showed that available energy during a session at 40% and 70% of MVC on an HML is comparable with that in cycling (in energy expenditure) at 49 and 56 W, respectively. This corresponds to 29% (11%) and 32% (10%) of PPO, respectively.

On the basis of $\dot{V}O_2$ values obtained during a 35-min WBST session, the authors found, retrospectively, that repeated 6-sec phases of exercise at 70% of MVC interspersed by 10-sec phases of passive recovery corresponded to exercise at 33% of $\dot{V}O_2$peak. For W40 and W70, the times spent greater than 30% of $\dot{V}O_2$peak were 645 (807) and 1233 (775) secs ($P < 0.0001$), respectively, whereas those greater than 40% of $\dot{V}O_2$peak were 233 (549) and 541 (627) secs ($P < 0.0001$). The individual's responses are presented in Table 4. The proportions of CHO and T4 lipids oxidized were 71% and 29%, respectively, at W40 and 91% and 9%, respectively, at W70.

DISCUSSION

Despite its widespread use in physiotherapy clinics worldwide, the HML had never been studied in patients with cardiac diseases. The HML is an alternative form of exercise that is known to have a positive effect on both equilibration and strength in different populations but has never been tested in

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TABLE 3 Physiologic and metabolic responses during both WBST sessions

Parameters	3-Min Rest	37-Min Training Session	5-Min Recovery	ANOVA, *P*
Ventilation, l/min				
40%	10.36 (3.17)	16.58 (4.7)	17.68 (6.38)	*a* = 0.01
70%	9.20 (2.21)	21.38 (5.51)	24.35 (6.73)	*b* < 0.0001
				c < 0.0001
Ventilation, %max				
40%	15.75 (5.82)	25.13 (8.44)	26.74 (10.41)	*a* = 0.04
70%	14.10 (4.67)	32.18 (9.36)	36.83 (12.64)	*b* < 0.0001
				c < 0.0001
Total $\dot{V}O_2$, l				
40%	0.88 (0.25)	17.52 (4)	2.47 (0.79)	*a* = 0.01
70%	0.75 (0.20)	21.25 (5.20)	3.11 (0.81)	*b* < 0.0001
				c = 0.02
$\dot{V}O_2$, ml/min				
40%	294.66 (85.83)	473.70 (108.13)	494.88 (159.64)	*a* = 0.07
70%	252.69 (67.10)	574.52 (140.73)	622.35 (163.82)	*b* < 0.0001
				c < 0.0001
$\dot{V}O_2$, ml/min per kilogram				
40%	3.41 (1.08)	5.54 (1.36)	5.71 (1.75)	*a* = 0.07
70%	2.98 (0.85)	6.60 (1.55)	7.11 (1.58)	*b* < 0.0001
				c < 0.0001
$\dot{V}O_2$, % $\dot{V}O_2$max				
40%	17.28 (7.66)	27.80 (11.10)	28.74 (12.56)	*a* = 0.2
70%	14.82 (6.07)	32.75 (10.04)	35.28 (10.09)	*b* < 0.0001
				c < 0.0001
$\dot{V}O_2$, % $\dot{V}O_2$ at VT				
40%	26.46 (10.76)	58.48 (18.72)	63.03 (19.82)	*a* = 0.1
70%	29 (9.71)	47.9 (17.71)	50.39 (21.23)	*b* < 0.0001
				c = 0.0003
HR, bpm				
40%	68.56 (8.13)	73.48 (7.98)	77.21 (9.14)	*a* = 0.09
70%	67.41 (8.33)	79.56 (8.58)	85.50 (9.78)	*b* < 0.0001
				c < 0.0001
HR, %max				
40%	52.04 (9.45)	59.02 (9.93)	61.61 (11.20)	*a* = 0.33
70%	53.62 (8.83)	63.36 (10.14)	68.26 (12.51)	*b* < 0.0001
				c < 0.0001
PAS, mm Hg				
40%	114.25 (13.63)	124.85 (13.14)	113.50 (7.09)	*a* = 0.39
70%	114.50 (12.51)	132.85 (17.12)	113.20 (8.91)	*b* < 0.0001
Rate-pressure product, FC × PAS				*c* = 0.008
40%	7825.91 (1212.10)	9163.39 (1681.42)	8756.45 (1286.58)	*a* = 0.07
70%	7697.26 (1026.77)	10,624.32 (1783.75)	9719.89 (1361.15)	*b* < 0.0001
				c < 0.0001
Rate-pressure product, % RPP max				
40%	37.85 (11.10)	44.46 (14.08)	43.72 (13.09)	*a* = 0.43
70%	37.04 (9.95)	51.12 (14.23	47.19 (14.12)	*b* < 0.0001
				c = 0.007

a indicates mode effect; *b*, time effect; *c*, interaction effect (mode × time); VT, ventilatory threshold.

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CHD patients. In this study, the authors aimed to compare the acute physiologic responses of CHD patients to two different intensities (W40 and W70) of training sessions on an HML to assess safety and metabolic responses and to optimize exercise protocols. The main finding of this study indicates that both exercise sessions were safe and well tolerated but that W70 was preferred. Therefore, WBST at W70 on an HML could potentially be used to improve adherence of coronary patients to a cardiac rehabilitation program.

Safety and Tolerance Aspects

The uniqueness of this apparatus lies in that it combines several parameters (all in one) that inevitably raise questions regarding safety in CHD patients, notably the repetition of short and quite intense 6-sec phases of moderate (40% of MVC) to high-intensity (70% of MVC) contraction interspersed with short periods (10 secs) of passive recovery. In the W40 and W70 sessions, the authors found no evidence of myocardial ischemia, significant arrhythmia, abnormal blood pressure responses, and rate-pressure

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TABLE 4 Individual's data (seconds) from the time spent greater than 30%, 40%, 50%, and 60% of $\dot{V}O_2max$ during both exercise sessions

	W40, Secs				W70, Secs			
Patient	T > 30	T > 40	T > 50	T > 60	T > 30	T > 40	T > 50	T > 60
1	10	0	0	0	710	120	0	0
2	0	0	0	0	190	0	0	0
3	10	0	0	0	2120	1340	380	70
4	0	0	0	0	510	220	0	0
5	490	0	0	0	1160	370	20	0
6	0	0	0	0	240	0	0	0
7	190	0	0	0	880	100	0	0
8	510	90	0	0	2010	800	400	120
9	0	0	0	0	110	0	0	0
10	0	0	0	0	450	100	10	0
11	290	30	0	0	970	230	60	0
12	2130	1090	100	0	2200	1550	380	20
13	740	90	0	0	1320	50	0	0
14	1500	190	0	0	2350	1300	50	0
15	1920	200	0	0	1690	460	120	10
16	120	0	0	0	600	30	0	0
17	830	0	0	0	1720	690	80	0
18	150	0	0	0	980	140	0	0
19	2400	2240	1590	610	2300	2040	1420	810
20	1610	730	100	0	2160	1290	680	150

product reaching more than 60% of that measured at PPO. Both WBST sessions therefore seemed safe and very well tolerated for patients with CHD, who had benefited from angioplasty. Interestingly, all of the patients preferred the W70 session. This observation was not based on the objective measurements of parameters but on indirect indices such as perceived exertion ratings and the open question. A possible explanation for this result could be the same sensation of breathlessness in both sessions, even though the workload was higher in W70. The feeling of exerting a greater effort for muscle exercise without feeling more breathless could encourage patients to work at a sufficient level without discomfort. Knowing that breathlessness is a major reason for stopping exercise or reducing its intensity, this exercise protocol (i.e., W70) could be used to improve long-term adherence to cardiac rehabilitation programs because patients feel they are exerting more force.

Fuel Selection and Energy Expenditure

In the last decade, it has been shown that regular resistance training (in association with aerobic exercise and lifestyle changes) is an appropriate strategy to promote weight loss and to improve body composition (i.e., reduction of fat mass and increase in lean body mass) in healthy and CHD patients.[25] This study showed that (1) W70 exercise sessions promoted higher energy expenditure than W40 exercise sessions of the same duration and (2) CHO was by far the principal fuel for this exercise irrespective of the intensity. Under the quantitative scopus of energy expenditure at exercise, and to an original and very recently published meta-analysis conducted by Henderson et al.[26], exercise energy expenditure, but not exercise intensity, can be highlighted as the main determinant of resting lipid oxidation in response to a previous bout of endurance exercise among non-CHD patients. Because W70 exercise for a standardized duration is well tolerated, applicable as a usual rehabilitation protocol, and associated with higher energy expenditure and preferred by the CHD patients of the present study, it could thus be supposed that W70 exercise promotes fuel use among CHD patients. Under the qualitative scopus of energy expenditure at exercise, the authors could also argue that W70 exercise could promote CHO oxidation during exercise but also fatty acid oxidation during recovery. This hypothesis could be suggested by the review from Spriet.[27] Indeed, considering a paired energy expenditure level, Spriet reviewed the metabolic regulation of fat use during exercise and in recovery, suggesting that high-intensity endurance exercise bouts and then shorter exercise bouts compared with moderate-intensity endurance exercise bouts act in favor of fatty acid oxidation during the recovery period then lead to a nondifferent total fatty acid oxidation between both intensities.[27] The metabolic studies supporting this review were conducted to compare the effect of

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exercise intensity, with paired energy expenditure levels, on endurance, and none of these studies were conducted in CHD patients. Although Gayda et al.[21] confirmed this paradigm among patients with chronic heart failure, its extension to resistance exercising remains to be confirmed.

Insulin resistance and type II diabetes are
AQ12 highly prevalent in patients with CHD and CHF. The reduced use of glucose in skeletal and heart muscle is associated with reduced functional capacity and the diminished efficiency of cardiac and skeletal muscle metabolism.[28] Previous studies demonstrated that patients with CHD or CHF have reduced glucose oxidation at rest and that exercise training improves skeletal muscle glucose uptake among these patients.[29,30] The study findings showed that CHO was by far the principal fuel during exercise irrespective of intensity. This underlies the potential therapeutic role of this exercise modality to enhance CHO use and, thus, to improve skeletal muscle metabolism and functional capacity in these patients.

In 1998, DeGroot et al.[31,32] measured EE during different circuit weight training exercises in cardiac patients. The circuit consisted of repeat exercises at 40% or 60% of 1-RM on a bench press, lateral pull-down, shoulder press, hamstring curl, triceps extension, and quadriceps extension. The work time at each station was 30 secs interspersed with 30 secs–1 min of recovery. They found that EE ranged between 2.98 (0.62) and 3.81 (0.47) Kcal/min at 40% and 60% of 1-RM. These results are almost equivalent to the results of this study, which showed a range between 2.46 (0.63) and 3.11 (0.91) Kcal/min at W40 and W70, respectively. In addition, the authors found equivalent results in rate-pressure product, suggesting that cardiorespiratory requirements of the training protocols of this study on an HML are very close to those of the resistance circuit training protocols studied by DeGroot (1998). It seems that HML could be an effective alternative to circuit training, as it may reduce purchase costs and take up less space. Although the total active EE is relatively small, the results have to be considered cautiously because the metabolic responses are protocol dependent. In fact, the metabolic responses should be higher with very short periods of recovery. However, this could be too demanding for patients and not allow them to complete the 27 mins of exercise.

Does WBST Induce Significant Aerobic Activity?

The results showed that, irrespective of intensity (40% or 70% of MVC), the protocols of this study based on the repetition of 6 secs of contraction interspersed with 10 secs of recovery led to energy expenditure similar to that achieved by leg cycling at around 50 W. This suggests that the HML cannot replace walking or cycling if the main objective is aerobic endurance training. When considering metabolic expenditure, the stimulation of energy systems, and the time spent at moderate-intensity training (40%–60% of $\dot{V}O_2$max), the HML is not enough to reach the exercise volume target needed to lead to improvements in aerobic capacity. The all-in-one feature of HML is valuable for equilibration, coordination, neurocognitive, and strength training, but the sessions were not demanding enough to consider the HML as an endurance training option in this sample of patients. Therefore, the authors could assume that HML could be a good complement to traditional programs or could replace usual resistance training, especially in patients with comorbidities such as osteoarthritis or impaired balance, but it cannot replace aerobic exercise.

Even though training volume is important for cardiovascular risk factors such as dyslipidemia, resistance training combined with endurance training (especially interval training) also seems to be of great interest for the improvement of $\dot{V}O_2$peak, insulin sensitivity, and endothelial function in patients with CHD.[10,33] In modern rehabilitation, it is important to propose a cardiac rehabilitation training program based on different types of exercise, which promotes the improvement of fitness, strength, balance, the metabolic functions of muscles, and possibly, compliance. This study thus provides a rationale for further work on the potential effects of long-term HML training on endothelial function, $\dot{V}O_2$ peak, muscle metabolism, and quality-of-life in patients admitted to cardiac rehabilitation programs, including heart failure patients, who usually have structural and metabolic skeletal muscle abnormalities including fiber atrophy, decreased type I myosin, and heavy chain fiber as well as a reduced skeletal muscle glucose uptake associated with insulin resistance.[34]

The limitations of the current study include a small sample of predominantly young men with high exercise tolerance. However, the authors have no reason to believe that the results would have differed in women. In addition, the authors did not use assay
biomarkers, such as CPK, to detect muscle injury. AQ13

CONCLUSIONS

The findings of the present study suggest that WBST sessions using an HML and using very short periods of exercise (6 secs) interspersed by short periods of passive recovery are safe and well tolerated for selected stable coronary patients entering a

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cardiac rehabilitation program. Future studies that compare WBST sessions with classic resistance training sessions are required to better describe safety and efficacy in different cardiac diseases such as chronic heart failure. Ultimately, the HML could be included in phase II cardiac rehabilitation. Finally, HML can be used safely in other rehabilitation programs in patients with cardiac comorbidities.

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