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Original article

Whole-body strength training with Huber Motion Lab and traditional strength training in cardiac rehabilitation: A randomized controlled study

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ABSTRACT

Background: Isometric strengthening has been rarely studied in patients with coronary heart disease (CHD), mainly because of possible potential side effects and lack of appropriate and reliable devices.
Objective: We aimed to compare 2 different modes of resistance training, an isometric mode with the Huber Motion Lab (HML) and traditional strength training (TST), in CHD patients undergoing a cardiac rehabilitation program.
Design: We randomly assigned 50 patients to HML or TST. Patients underwent complete blinded evaluation before and after the rehabilitation program, including testing for cardiopulmonary exercise, maximal isometric voluntary contraction, endothelial function and body composition.
Results: After 4 weeks of training (16 sessions), the groups did not differ in body composition, anthropometric characteristics, or endothelial function. With HML, peak power output ($P = 0.035$), maximal heart rate ($P < 0.01$) and gain of force measured in the chest press position ($P < 0.02$) were greater after versus before training.
Conclusion: Both protocols appeared to be well tolerated, safe and feasible for these CHD patients. A training protocol involving 6 s phases of isometric contractions with 10 s of passive recovery on an HML device could be safely implemented in rehabilitation programs for patients with CHD and improve functional outcomes.

1. Introduction

Physical activity is considered an effective non-pharmacological intervention for both primary and secondary prevention of coronary heart disease (CHD) [1]. For the last 30 years, resistance training combined with aerobic endurance exercises has been an integral part of international recommendations for prevention and rehabilitation in patients with CHD [2–5] and is now considered by the medical community as an essential part of exercise programs. Muscle mass and muscle strength decrease by about 30% between the third and sixth decades of life [6]. With aging, the total number of muscle fibres decreases, especially fast-twitch muscle fibres, which are recruited during the development of force. In CHD patients, increasing muscle strength and function can help improve health features such as insulin resistance, endothelial function, and quality of life [7]. As well, resistance exercise positively affects proprioceptive abilities, thereby leading to a

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gradual improvement in coordination and gait control, which reduces the risk of falls [7–9].

Unfortunately, the range of techniques or devices available to increase the efficacy of cardiac rehabilitation (CR) remains limited [10]. Among new devices, the Huber Motion Lab (HML), a motorised rotating platform, seems to feature the qualities needed in such programs because it allows patients to perform exercises that simultaneously involve balance, coordination and strength training. In 2015, our team showed that exercise sessions with the HML, based on very short periods of exercise (6 s) at 70% of the maximal isometric voluntary contraction (MVC), interspersed with short periods of passive recovery were safe and well tolerated for selected patients with stable coronary disease [11]. Moreover, a recent study showed that 8 weeks of training on the HML had a positive impact on body composition (especially decreased body fat), anthropometric data (reduced waist circumference), muscle performance (strength) and walking economy in healthy people [12].

HML training and traditional strength training (TST) have never been compared for efficacy in patients with CHD. We aimed to compare a conventional rehabilitation program associating global aerobic reconditioning with dynamic/segmental aerobic muscle strengthening and a program combining aerobic training and isometric exercises predominantly based on the HML in such patients.

2. Materials and methods

2.1. Patients

We recruited 50 patients with CHD from the cardiovascular rehabilitation centre of Saint Orens (France). Inclusion criteria were $\geq$ 70% arterial diameter narrowing of at least one major coronary artery and/or documented previous myocardial infarction. Exclusion criteria were recent acute coronary syndrome ($\leq$ 1 month), significant resting electrocardiography (ECG) abnormality, severe arrhythmia, history of congestive heart failure, uncontrolled hypertension, bypass surgery $\leq$ 3 months, percutaneous coronary intervention $\leq$ 1 month, left ventricular ejection fraction $\leq$ 45%, pacemaker installation, modification of medication $<$ 2 weeks, and musculoskeletal conditions making exercise on a cycle ergometer difficult or contraindicated. Patients provided written informed consent. The research protocol was approved by the Committee for the Protection of Human Subjects (Toulouse, France).

2.2. Study design

All patients were enrolled in an outpatient CR program (CRP). On the first and last visit, patients underwent a complete medical evaluation that included measurement of height, weight, body composition, resting ECG variables, endothelial function, muscular function, quality of life, quality of sleep, and fitness based on a maximal cardiopulmonary exercise test (CPET) performed on a cycle ergometer. After the first visit, patients were randomly assigned to the HML or TST group. The sole difference between groups was the strength training activity (HML or resistance training machines). The CRP focused on optimizing the medical treatment, controlling cardiovascular risk factors, diet monitoring, therapeutic education sessions and psychological support when needed.

The exercise program lasted 3 hr/day, 4 days/week. The daily activity training included 1) a 45-min strength training activity using machines (TST) or HML (HML group) and 2) a 45-min walking session outside or 45-min of cycling at the target heart rate determined during the stress test (i.e., 60–80% of the heart rate reserve) [13,14]. Furthermore, the patients participated in relaxation sessions or aquatic relaxation sessions (45 min). Each session was monitored by a physiotherapist and was supervised by a cardiologist. In addition to the exercise protocol, patients were involved in therapeutic education sessions conducted by a multidisciplinary team with workshops and conferences on cardiovascular risk factors and treatment knowledge (~3–4 hr/week).

2.3. Exercise sessions

2.3.1. Whole-body strength training with HML and assessment of MVC

The Huber Motion Lab (LPG Systems, France) is an oscillating platform with 2 large handles mounted on a movable column. Several feet and hand positions are marked on the platform and handles, respectively (Fig. 1). HML exercises consist 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 require the synergistic activation of various

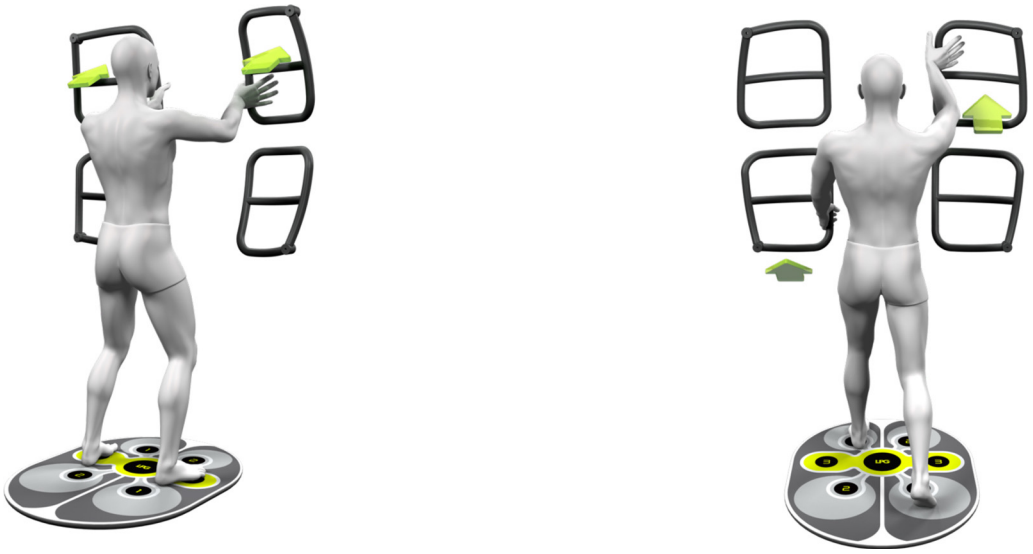

Fig. 1. The Huber Motion Lab, an oscillating platform with 2 large handles mounted on a movable column. Several feet and hand positions are marked on the platform and handles, respectively.

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muscle groups of the lower limbs, trunk and upper limbs. The handles are equipped with strain gauges, and feedback about the force developed is provided to users. Additionally, an interactive interface, shown as a target, informs the subject about their ability to maintain the required force level. This "game-like" control panel is intended to increase the user's motivation to practice and adhere to the HML training program [12].

MVC was measured in standardized positions before each subsequent position (Fig. 1). Patients were asked to exert maximal isometric pushing and pulling forces (i.e., opposite actions with the 2 hands on the handles). For each position, pulling and pushing forces were recorded by the strain gauges on the handles. Patients performed two 6 s MVCs for each position. A third trial was performed when the difference in results between the first 2 trials was > 5%. Verbal encouragement and visual feedback about the force developed were provided to patients during each MVC. The greatest mean force produced over the 6 s period was retained as the MVC value for each action (i.e., pulling and pushing force).

2.3.2. HML sessions

The velocity/inclination of the plate (rotation) was set at 30/30 (See HML instructions manual). Both exercises consisted of 6 exercise blocks in different postures. The positions are presented in Fig. 1. Each block consisted of 8 contractions of 6 s alternating with 10 s of passive recovery, repeated twice. The total duration of the session, which included a 3-min warm-up, 10 min of MVC assessment, 27 min of exercise and 5-min recovery, was 45 min. The intensity of isometric contraction was set at 70% of the MVC [11]. All patients performed a familiarization session in the days before the protocol. To validate and start the protocol, patients had to validate a coordination score corresponding to a minimum of 60% [11]. Because the MVC was calculated at each session, the exercise intensity was automatically adapted to enable progression.

2.3.3. TST sessions and assessment of MVC

TST sessions involved a circuit training including 6 different machines: leg press, chest press, vertical traction (shoulder press), low row (working back), pectoral (butterfly) and leg extension. Movements allowed for dynamically working the same muscle groups as with the HML. According to the guidelines for resistance training in cardiac rehabilitation, we set the intensity at 60% of MVC. At each position, patients were asked to repeat 3 series of 12 repetitions. With TST, the MVC was calculated by using the one-repetition maximum test (1-RM) on each machine at the beginning of each week during the program.

2.4. Measures

Measures were recorded twice by a cardiologist, a physiotherapist and a nurse the day after admission (pre) and the evening before hospital discharge (post).

2.4.1. Anthropometric variables and body composition

The formula used for calculating BMI was weight in kilograms (kg) divided by height in meters (m) squared. The waist circumference was determined by use of a measuring tape (e.g., K & E type) placed halfway between the lower part of the ribcage and the hipbone [31]. Body composition was measured by bioelectrical impedance by using the BODYSTAT 1500 (Bodystat Ltd., British Isles).

2.4.2. Endothelial function

Reactive hyperemia index (RHI), a measure of endothelial function, was assessed by using the EndoPAT 2000 device (Itamar Medical, Israel). This measurement was calculated by using a computerised automated algorithm provided with the accompanying software (v3.1.2) and performed according to the manufacturer's instructions. Briefly, patients were in a supine position for a minimum of 20 min before measurement in a quiet, temperature-controlled (21–24 °C) room with dimmed lights. Patients were asked to remain as still as possible and silent during the entire measurement period. Each recording consisted of 5 min baseline measurement, 5 min occlusion measurement, and 5 min post-occlusion measurement (hyperemic period). Occlusion of the brachial artery involved the nondominant upper arm. The occlusion pressure was at least 60 mmHg above the systolic blood pressure (BP) (minimally 200 mmHg, and maximally 300 mmHg). The natural logarithmic scaled RHI (L_RHI) was calculated from the ratio between the digital pulse volume during RH and at baseline [15].

2.4.3. MVC

Patients were seated on the extremity of a bench. The bench was raised to ensure that the feet did not contact the floor. The knee joint tested was set in the gravity-neutral position. The thigh was strapped to the bench. The MVC of the quadriceps was tested by using a strain gauge system, the Meas FN3148 Load cell with mechanical stops (Measurement Specialities, Aliso Viejo, CA). This strain gauge has an accuracy of 0.05% and range of 0–2000 N. It is quality certified. Extremities of the strain gauges were attached to steel cables by hooks. One of the steel cables was attached to a bench hook and the other end to the ankle by use of a strap. The strain gauge and strap were set perpendicular to the line of force. Analogic strain gauge readings were transferred to software on a computer via a sensor interface. Once installed in the apparatus, patients, with their arms crossed over their chest, were asked to extend their knee as strongly as possible against the resistance of the cable steel for a contraction period with a 1 s transition period and a 4- to 5 s plateau that is supposed to be sufficient to achieve maximal isometric contraction. The time force motion was numerically registered and visualized during extension. The peak force was identified on the curve according to the reliability of the decision by 2 assessors. Three trials separated by 1-min rest intervals were proposed. The best peak force between the trials was recorded as the maximal force contraction of the quadriceps for the study. The same method was used in the chest press position to measure the strength of the upper body.

2.4.4. Cardiopulmonary stress test

The peak power output (PPO) was determined by a test on an ergocycle with electromagnetic braking (Ergometrics 900, Ergoline, Germany). The PPO corresponds to the power reached at the last threshold of the test. The initial power was set to 30 W with an increment of 15 W/min. This progressive increase test was performed with continuous 12-lead ECG monitoring. Blood pressure was checked every 2 min during the stress test and during 6-min recovery (3-min active recovery and 3-min passive recovery). The Borg scale was used to evaluate the rate of perceived exertion from 6 to 20 [5]. The stress test was stopped when the patient was not able to maintain the required power or when the score of perceived exertion was 15–17/20, in case of severe angina pectoris (> 5/10), severe arrhythmia, decrease in BP >10 mmHg or ST-segment elevation > 2 mm [16]. Metabolic equivalents (METs) were calculated from the Watts obtained at PPO, considering that 1 litre of O_2 = 5.05 Kcal and 1 MET = 3.5 mL O_2/Kg body weight/min.

2.4.5. Quality of life

Health-related quality of life was measured by using the French version of the Medical Outcomes Study Short Form 36 (SF-36) [17]. The SF-36 includes 36 questions grouped into 8 categories

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corresponding to physical activity, limits due to the physical state, physical pain, self-perceived health, vitality, relationships with others, psychological health and limits related to the psychological state. For each category, the sum of the item scores was translated linearly to a scale from 0 (maximal exhaustion) to 100 (no exhaustion). Physical activity, physical pain and limits related to the physical state reflect the physical component score (PCS), and self-perceived health, vitality, psychological health, relationships to others and limits related to the psychological state reflect the mental component score (MCS). PCS and MCS were computed by using equations developed by Ware and Kosinski [18].

2.4.6. Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) assesses sleep quality during the previous month and differentiates "good" and "bad" sleepers [19]. Sleep quality is a complex phenomenon that implies several dimensions, each analysed by the PSQI. This questionnaire includes 19 self-assessment questions and 5 questions asked of the life partner, spouse or roommate (as appropriate). The questions correspond to 7 components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Only the self-assessment questions are included in the final score. Scores for the 7 components add to a final global score from 0 to 21 points, 0 meaning no sleep difficulty and 21 major difficulties. A global PSQI score > 5 suggests significant sleep disturbances.

3. Statistical analysis

Data are presented as mean ± SD. Shapiro-Wilk and Bartlett tests were used to assess normality and equality of variance among variables analysed, respectively. Chi-square test or Student *t* test was used to compare data between groups. ANOVA for repeated measures was used to compare times (pre vs post), with training groups (i.e., HML vs TST) entered as a co-factor. When a main effect was found, Fisher least significant difference post-hoc analysis was used to identify potential significant variables discriminating training procedure (HML vs TST). In a second step, we used logistic multiple regression with significant variables found on bivariate analysis as explanatory variables and improvement with training group (HML or TST) as a binary outcome variable. All statistical analyses involved use of SPSS 20.0 (SPSS, Inc., Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

4. Results

Baseline characteristics are presented in Table 1. All patients (94% men) underwent percutaneous angioplasty. The main cardiovascular risk factors were dyslipidemia (62%), smoking (48%), hypertension (44%) and type 2 diabetes (8%) and the treatment groups did not differ in risk factors. The program attendance was 100%. No adverse event was observed in either group.

Table 1
Baseline characteristics of patients undergoing isometric training with the Huber Motion Lab (HML) and traditional strength training (TST).

	Total ($n = 50$)	HML ($n = 25$)	TST ($n = 25$)
Baseline characteristics			
Age (years)	54.8 ± 10.1	51.2 ± 9.4	58.4 ± 9.5
Height (m)	1.74 ± 0.08	1.75 ± 0.06	1.73 ± 0.09
Weight (kg)	84.5 ± 13.2	85.6 ± 11.9	83.4 ± 14.6
Gender (male/female)	47 (94)/3 (6)	25 (100)/0 (0)	22 (88)/3 (12)
Hypertension	22 (44)	10 (40)	12 (48)
Currently smoking	24 (48)	15 (60)	9 (36)
Diabetes	4 (8)	2 (8)	2 (8)
Dyslipidemia	31 (62)	16 (64)	15 (60)
Disease, *n* (%)			
Coronary disease	50 (100)	50 (100)	50 (100)
Coronary bridging	0 (0)	0 (0)	0 (0)
Angioplasty	50 (100)	50 (100)	50 (100)
Medications, *n* (%)			
Antiplatetet agents	48 (96)	24 (96)	24 (96)
Beta-blockers	42 (84)	21 (84)	21 (84)
Calcium channel blockers	3 (6)	2 (8)	1 (4)
ACE inhibitors	40 (80)	21 (84)	19 (76)
Angiotensin receptor antagonist	1 (2)	0 (0)	1 (4)
Statins	48 (96)	24 (96)	24 (96)
Nitrates	0 (0)	0 (0)	0 (0)
Anti-diabetic agents	4 (8)	2 (8)	2 (8)

No significant differences at $P < 0.05$.

After 4 weeks of training (16 sessions), body composition and anthropometric characteristics were not modified, nor was endothelial function, in either group (Table 2). With HML, as compared with before training, training conferred improvement in PPO ($P = 0.035$), maximal heart rate ($P < 0.01$) and strength ($P < 0.02$) (Table 3). The CRP was beneficial in the entire group for both life and sleep quality, with no difference between groups (Table 4).

On logistic multiple regression analysis, improvement with HML versus TST was explained by 3 independent variables–variation in PPO and METs and strength measured in the chest press position after rehabilitation ($P < 0.01$). The odds ratio (OR) was maximal for strength in the chest press position after rehabilitation (OR = 1.06, 95% CI 0.98–1.15, chi-square $P < 0.009$) and negligible for variation in PPO and METs (OR = 1.01, −9.5–12.5, and OR = 1.04, −15.9–18). The coefficients of determination (R^2) between the baseline variables and these 3 independent variables were all < 0.5, thereby indicating no robust variable predicting change.

5. Discussion

Despite its widespread use in physiotherapy clinics worldwide, the HML has been poorly studied among patients with chronic disease. The HML is an alternative form of exercise known to have a positive effect on both equilibration and strength in different

Table 2
Four-week changes in anthropometric features, body composition and endothelial function before (pre) and after (post) exercise training.

	Total ($n = 50$)		HML ($n = 25$)		TST ($n = 25$)	
	Pre	Post	Pre	Post	Pre	Post
Weight (kg)	84.5 ± 13.2	84.1 ± 13.2	85.6 ± 11.9	84.5 ± 11.4	83.4 ± 14.6	83.7 ± 14.9
Body mass index (kg/m^2)	28 ± 4.1	27.9 ± 4	28.3 ± 3.8	27.8 ± 3.7	27.8 ± 4.3	27.9 ± 4.3
Waist circumference (cm)	100 ± 11.5	98.7 ± 11	100.7 ± 12	99.3 ± 10.7	99.2 ± 11.3	98.1 ± 11.6
Fat mass (kg)	21 ± 6.8	20.3 ± 6.4[a]	20.5 ± 6.1	19.4 ± 5.4[a]	21.4 ± 7.5	21.3 ± 7.2
Fat-free mass (kg)	63.2 ± 9.9	63.3 ± 9.7	65 ± 7.6	65.2 ± 7.5	61.3 ± 11.7	61.4 ± 11.4
Logarithmic-scaled RH-PAT index (Endopath)	0.71 ± 0.27	0.75 ± 0.27	0.70 ± 0.29	0.78 ± 0.29	0.72 ± 0.26	0.72 ± 0.26

Data are mean ± SD. No significant differences between groups at $P < 0.05$).
[a] Time effect ($P < 0.05$)

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Table 3
Four-week changes in exercise testing before (pre) and after (post) training.

	Total ($n=50$)		HML ($n=25$)		TST ($n=25$)		Between-group P value
	Pre	Post	Pre	Post	Pre	Post	
Cardiopulmonary stress test							
Peak power output (W)	151.4 ± 38.9	178.8 ± 44.5[a]	164.4 ± 37.6	199.2 ± 31.5[a]	138.4 ± 36.2	158.4 ± 46.8[a]	0.035
Maximal heart rate (beats/min)	117.6 ± 18.7	125 ± 19.9[b]	121.8 ± 20.9	132.2 ± 20[b]	113.4 ± 36.2	117.8 ± 17.3	ns
Maximal SBP, mm Hg	160.6 ± 22.8	165.4 ± 28.7	158.6 ± 21.9	164.7 ± 26.4	162.5 ± 24	166 ± 31.3	ns
Maximal DBP, mm Hg	81 ± 13.9	81 ± 17.4	83.4 ± 14.7	81 ± 14.9	78.6 ± 13	80.9 ± 19.9	ns
Maximal voluntary isometric contraction							
Force, upper limbs (kN)	0.29 ± 0.11	0.34 ± 0.11[b]	0.31 ± 0.10	0.38 ± 0.09[a]	0.26 ± 0.11	0.31 ± 0.11[a]	ns
Force, lower limbs (kN)	0.56 ± 0.20	0.76 ± 0.29[b]	0.59 ± 0.19	0.77 ± 0.24[a]	0.53 ± 0.21	0.75 ± 0.34[b]	ns

Data are mean ± SD; SBP: systolic blood pressure; DBP: diastolic blood pressure.
[a] Time effect ($P<0.05$).
[b] Time effect ($P<0.01$).

Table 4
Four-week changes in quality of life and sleep quality before (pre) and after (post) exercise training.

Questionnaires	Total ($n=50$)		HML ($n=25$)		TST ($n=25$)	
	Pre	Post	Pre	Post	Pre	Post
SF-36						
Physical component subscale	67.8 ± 16.3	76 ± 16.1[b]	72.3 ± 15.1	80.2 ± 15.3[a]	63.2 ± 16.1	71.8 ± 16.1[a]
Mental component subscale	65.2 ± 20.8	73.7 ± 15.3[a]	71 ± 20.5	76.9 ± 12.4	59.5 ± 19.9	70.5 ± 17.4[a]
Pittsburgh Sleep Quality Index[c]	5.4 ± 3.1	4.6 ± 2.9	4.8 ± 3.5	3.8 ± 2.6	6 ± 2.5	5.4 ± 3

Data are mean ± SD; no significant differences between groups at P<0.05; SF-36, Medical Outcomes Study Short Form 36.
[a] Time effect ($P<0.05$).
[b] Time effect ($P<0.01$).
[c] Total score, 0 to 21 points, 0, no sleep difficulty, and 21, major difficulties.

populations: older people, and those with stroke and obesity. In our study, we compared the effects of long-term HML versus TST in CHD patients to verify the potential superiority of this "all-in-one" machine. We found that both types of strength exercise sessions improved cardiovascular health parameters. However, both types did not improve body composition features.

Our results show a large inter-individual heterogeneity concerning the response to strength training. We found no relationship between changes in variables, so for example, a patient can improve physical fitness without improving endothelial function. Patients receiving HML treatment showed improved upper body muscles to a greater extent than with TST. As well, we still do not have good predictors of response to whatever training, yet it is one of the main challenges to study, rather than the efficiency.

6. Strength training and endothelial function

The patients who benefited from HML showed improvement, although non-significant, in endothelial function (pre, 0.70 ± 0.29; post, 0.78 ± 0.29), with no change in the TST group. Current guidelines recommend both aerobic and dynamic resistance exercise-training modalities to reduce BP and induce vascular adaptations [20]. Most studies suggest that isometric exercise training in normotensive and hypertensive (medicated and non-medicated) cohorts of young and old participants may produce similar, if not greater, reductions in BP, with meta-analyses reporting mean reductions of 10 to 13 mmHg SBP and 6 to 8 mmHg DBP [20–22]. Although the mechanisms responsible for these adaptations remain to be fully clarified, conduit- and resistance-vessel endothelium-dependent dilation, oxidative stress, and autonomic regulation of the heart rate and BP have been improved [20].

In our study, the isometric exercise training protocols differed from dynamic resistance training but were close to that typically used (consisting of 4 sets of 2-min handgrip or leg contractions sustained at 20–50% MVC, with each set separated by a rest of 1–4 min). During a brief submaximal isometric manoeuver, both cardiac output and total peripheral resistance are increased [23], which significantly increases wall shear stress on the entire arterial tree. This pressure response continues as long as the isometric contraction is maintained and produces a small but significant increase in mean arterial pressure during submaximal effort [24]. Dynamic exercise produces a transient increase in shear stress, which is offset by the subsequent nitric oxide (NO) release, which leads to dilatation, decreased shear stress, and increased flow during the effort. Isometric exercise produces a sustained, increasing shear stress, which is not completely offset by NO release during the effort. Maintaining an isometric effort could be a stimulus for upregulating endothelial NO synthase activity by initiating signalling events that are activated by shear stress response elements in the endothelium [25]. We have few studies of BP control with isometric exercises, involving moderate isometric contractions (< 30 or 50% MVC) and low solicited muscle volume [26].

7. Rehabilitation and quality-of-life features

The scores obtained on the SF-36 questionnaire revealed improved physical and mental components after our 4-week CRP, whatever the treatment. These data match those from Stahle et al. and Yohannes et al., who reported long-term benefits of CR on quality of life [27,28]. The quick efficacy we found could be explained by the multidisciplinary rehabilitation approach, because adapted physical activity sessions (3 hr/day) were associated with relaxation sessions and personalized dietary follow-up. Furthermore, the quality of life of patients with diabetes after myocardial infarction is even more altered [29,30].

Our results agree with a previous study published by our group [31] based on 101 cardiac patients that highlighted a 25% improvement in quality of sleep, a 29% decrease in anxiety levels

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and a 32% decrease in depression ($P < 0.0001$), as well as a 28% improvement in morale ($P < 0.0001$) after a CRP. Finally, Schiza et al. showed that patients with acute coronary syndrome had altered sleep parameters, leading to poor sleep quality [32]. We observed a true amelioration of sleep quality regardless of treatment.

8. Physical activity

The benefits of physical activity are widely accepted in secondary prevention and are subject to regularly updated recommendations by international societies. Nevertheless, a few controversies still exist, especially regarding the type and intensity of the activity. However, the main challenges relate to the means, making the activity "enjoyable," and improving compliance by creating long-term lasting behaviour changes. The notion of pleasure is often forgotten in exercise prescription, but it is one of the most important features in promoting compliance [33]. An emerging trend has been inspired by a relatively new technology referred to as active gaming or exergaming. Exergaming is defined as technology-driven physical activities, such as video game play, that requires participants to be physically active or exercising to play the game. Among the range of technologies, the HML and the new version (HUBER360) can be defined as exergames. The programs are sometimes very guided and supervised. Thus, "all-in-one" devices such as HML that associate pleasure in training with equilibration, coordination, cerebral and strength training may have a place in therapy.

We need to assess the effects of a training HML (not associated with usual training) that is more prolonged, with assessment of metabolic and systemic effects, versus a dynamic global reconditioning. Moreover, the effects of HML on balance needs quantification, and determining better muscular games (kinematic analysis, electromyography) is needed to determine the respective involvement of static, concentric and eccentric contractions (related to equilibration).

9. Limitations

Our study has some limitations. First, it involved an intense and short-duration CRP (4 weeks) as compared to the recommendations (2–3 months), which most likely limited the appearance of systemic effects (autonomic, endothelial, etc.) and a decrease in fat mass. We also did not measure gas exchange, the gold standard for verifying improvements in aerobic capacity and the maximal criterion of the CPET. Furthermore, we used the EndoPAT system for measuring endothelial dysfunction, but some authors have reported that the system might reflect neurovegetative modifications rather than microcirculatory adaptations after an exercise program [34]. As well, we could have tested the effects on proprioceptive settings, particularly in the context of rehabilitation after falls in older patients. The work of balance with the HML would probably have an advantage over TST for this indicator.

10. Conclusions

Our study showed that gain of chest force and PPO were improved with a 4-week CRP involving strength training on a HML as well as TST in CHD patients. Both treatments improved all other factors in the same range. Both protocols appeared to be well tolerated, safe and feasible in this group of CHD patients. The HML training protocol, which consisted of repeating 6 s phases of contractions with 10 s of passive recovery could be implemented in programs for patients with different chronic diseases, and its innovative character can vary the types of exercises. However, possible harmful effects must be assessed. Our study is a preliminary study, because of its limitations, so the HML is not yet a validated method of reconditioning in CVD. Ultimately, the HML could be included in phase II CR and be proposed to deconditioned patients, notably older patients. The game-like aspects of the HML have a slight advantage for patient adherence to physical activity as compared to TST. Moreover, the "all-in-one" treatment aspect could be interesting for centres with limited space or financial resources.

Ethical statement

All the authors have read and agree with the manuscript as written.

Disclosure of interest

The authors declare that they have no competing interest.

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References

[1] Ades PA. Cardiac rehabilitation and secondary prevention of coronary heart disease. N Engl J Med 2001;345(12):892–902.
[2] Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 2001;104(14):1694–740.
[3] O'Connor GT, Buring JE, Yusuf S, Goldhaber SZ, Olmstead EM, Paffenbarger Jr RS, et al. An overview of randomized trials of rehabilitation with exercise after myocardial infarction. Circulation 1989;80(2):234–44.
[4] Oldridge NB, Guyatt GH, Fischer ME, Rimm AA. Cardiac rehabilitation after myocardial infarction. Combined experience of randomized clinical trials. JAMA 1988;260(7):945–50.
[5] Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med 2004;116(10):682–92.
[6] Larsson L, Grimby G, Karlsson J. Muscle strength and speed of movement in relation to age and muscle morphology. J Appl Physiol 1979;46(3):451–6.
[7] Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, et al. AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: an advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. Circulation 2000;101(7):828–33.
[8] Ades PA, Ballor DL, Ashikaga T, Utton JL, Nair KS. Weight training improves walking endurance in healthy elderly persons. Ann Intern Med 1996;124(6):568–72.
[9] Ades PA, Waldmann ML, Poehlman ET, Gray P, Horton ED, Horton ES, et al. Exercise conditioning in older coronary patients. Submaximal lactate response and endurance capacity. Circulation 1993;88(2):572–7.
[10] Guiraud T, Nigam A, Gremeaux V, Meyer P, Juneau M, Bosquet L. High-intensity interval training in cardiac rehabilitation. Sports Med 2012;42(7):587–605.
[11] Guiraud T, Labrunee M, Pillard F, Granger R, Bousquet M, Richard L, et al. 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 2015;94(5):385–94.
[12] Fabre JB, Martin V, Borelli G, Fritsch N, Theurel J. Effects of a whole-body strength training program on metabolic responses and body composition. Gazzetta Med Ital Arch Sci Med 2014;173(1-2):47–56.
[13] Balady GJ, Williams MA, Ades PA, Bittner V, Comoss P, Foody JM, et al. Core components of cardiac rehabilitation/secondary prevention programs: 2007 update: a scientific statement from the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee, the Council on Clinical Cardiology; the Councils on Cardiovascular Nursing, Epidemiology and Prevention, and Nutrition, Physical Activity, and Metabolism; and the American Association of Cardiovascular and Pulmonary Rehabilitation. Circulation 2007;115(20):2675–82.

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[14] Tabet JY, Meurin P, Ben Driss A, Thabut G, Weber H, Renaud N, et al. Determination of exercise training heart rate in patients on beta-blockers after myocardial infarction. Eur J Cardiovasc Prev Rehabil 2006;13(4):538–43.
[15] Rubinshtein R, Kuvin JT, Soffler M, Lennon RJ, Lavi S, Nelson RE, et al. Assessment of endothelial function by non-invasive peripheral arterial tonometry predicts late cardiovascular adverse events. Eur Heart J 2010;31(9):1142–8.
[16] Froelicher VF, Myers J. Exercise and the heart, 5th ed., Philadelphia (PA): Saunders-Elsevier; 2006.
[17] Ware Jr JE, Gandek B. Overview of the SF-36 Health Survey and the International Quality of Life Assessment (IQOLA) Project. J Clin Epidemiol 1998;51(11):903–12.
[18] Ware JE, Kosinski M. Interpreting SF-36 summary health measures: a response. Quality Life Res 2001;10(5):405–13 [discussion 15-20].
[19] Buysse DJ, Reynolds 3rd CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28(2):193–213.
[20] Millar PJ, McGowan CL, Cornelissen VA, Araujo CG, Swaine IL. Evidence for the role of isometric exercise training in reducing blood pressure: potential mechanisms and future directions. Sports Med 2014;44(3):345–56.
[21] Kelley GA, Kelley KS. Isometric handgrip exercise and resting blood pressure: a meta-analysis of randomized controlled trials. J Hypertens 2010;28(3):411–8.
[22] Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. J Am Heart Assoc 2013;2(1):e004473.
[23] Longhurst JC, Stebbins CL. The power athlete. Cardiol Clin 1997;15(3):413–29.
[24] Lind AR, McNicol GW. Muscular factors which determine the cardiovascular responses to sustained and rhythmic exercise. CMAJ 1967;96(12):706–15.
[25] Davies PF. Flow-mediated endothelial mechanotransduction. Physiol Rev 1995;75(3):519–60.
[26] Badrov MB, Freeman SR, Zokvic MA, Millar PJ, McGowan CL. Isometric exercise training lowers resting blood pressure and improves local brachial artery flow-mediated dilation equally in men and women. Eur J Appl Physiol 2016;116(7):1289–96.
[27] Stahle A, Mattsson E, Ryden L, Unden A, Nordlander R. Improved physical fitness and quality of life following training of elderly patients after acute coronary events. A 1 year follow-up randomized controlled study. Eur Heart J 1999;20(20):1475–84.
[28] Yohannes AM, Doherty P, Bundy C, Yalfani A. The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. J Clin Nurs 2010;19(19–20):2806–13.
[29] Jarvinen O, Julkunen J, Saarinen T, Laurikka J, Tarkka MR. Effect of diabetes on outcome and changes in quality of life after coronary artery bypass grafting. Ann Thorac Surg 2005;79(3):819–24.
[30] Simpson E, Pilote L. Quality of life after acute myocardial infarction: a comparison of diabetic versus non-diabetic acute myocardial infarction patients in Quebec acute care hospitals. Health Qual Life Outcomes 2005;3:80.
[31] Duarte Freitas P, Haida A, Bousquet M, Richard L, Mauriege P, Guiraud T. Short-term impact of a 4-week intensive cardiac rehabilitation program on quality of life and anxiety-depression. Ann Phys Rehab Med 2011;54(3):132–43.
[32] Schiza SE, Simantirakis E, Bouloukaki I, Mermigkis C, Arfanakis D, Chrysostomakis S, et al. Sleep patterns in patients with acute coronary syndromes. Sleep Med 2010;11(2):149–53.
[33] Ekkekakis P, Parfitt G, Petruzzello SJ. The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. Sports Med 2011;41(8):641–71.
[34] Cornelissen VA, Onkelinx S, Goetschalckx K, Thomaes T, Janssens S, Fagard R, et al. Exercise-based cardiac rehabilitation improves endothelial function assessed by flow-mediated dilation but not by pulse amplitude tonometry. Eur J Prevent Cardiol 2014;21(1):39–48.

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