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COMMENTARY

High-load resistance training in cardiac rehabilitation: is it time to debunk old clinical dogmas for a better clinical tomorrow?

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The first recommendations on dynamic resistance training (RT) for patients with cardiovascular diseases (CVD) were published in 1996, acknowledging the beneficial effects on muscle strength and mass.[1] Due to safety concerns associated with the presumed acute physiological responses to RT, such as abnormal haemodynamic responses, its use, optimization, and implementation in cardiac rehabilitation (CR) programmes remained limited and debated for a long time.[2] In 2016, more than 50% of (inter)national guidelines on CR did not include RT in their exercise-based recommendations, mostly due to a lack of consensus on the interpretation of available evidence of RT characteristics (i.e. progression, intensity, and volume).[3]

Maximal muscle strength is associated with a lower incidence of heart failure (HF), all-cause, and CVD mortality in coronary artery disease (CAD) patients.[4,5] Several studies showed that concurrent exercise training programmes, including RT and aerobic training (AT), elicited greater improvements in maximal aerobic capacity (VO_2max), muscle strength, and mass when compared to AT alone.[6] The combination of RT with AT has, therefore, recently gained popularity among out-patient centre-based CR programmes. However, it must be noted that large differences in RT loads are applied, with most interventions merely adopting a progressive relative low-load [LL, 30–40% of one repetition maximum (1-RM)] to moderate-load (ML, 20–50% of 1-RM) approach in patients with CAD or HF,[6,7] while only two studies applied HL-RT in already stable and well-conditioned patients with CAD.[8,9] Both latter studies showed a superior effect of combined AT with HL-RT over AT alone in improvements of VO_2max and muscle strength.[8,9] Therefore, LL-RT characteristics may provide a suboptimal stimulus for muscle adaptations among older and/or frail patients, as studies among healthy older adults have shown a greater increase in maximal muscle strength following high-load RT (HL-RT, 70–90% of 1-RM) compared to LL-RT.[10] In light of the contradiction between recent (pre-)clinical evidence on RT modalities and the clinical application of RT in CR, this viewpoint provides an overview of the recent advances in the safety and efficacy of HL-RT when compared to traditionally-used LL-RT, and how this may be adopted in early phases of CR among patients recovering from an acute myocardial infarction or decompensation of HF.

Safety developments of resistance training

Resistance training was traditionally perceived as unsafe among the clinical community due to its presumed potential excessive increase or even drifts in haemodynamics [e.g. heart rate (HR), blood pressure (BP), and cardiac output], which may increase the risk for acute cardiovascular complications (e.g. syncope, hypertension, myocardial ischaemia, and atrial fibrillation).[1,2] However, recent mechanistic studies have challenged these old clinical dogmas by assessing the impact of isolated RT characteristics (lifting technique and cadence, breathing during exercise, training volume per exercise and set, rest between sets and exercises) on physiological responses.[11–13] For example, a lower HR and BP response was found following a single session of HL-resistance exercise (RE) (4–10 repetitions/set at 70–90% of 1-RM) compared to LL-RE (15–20 repetitions/set at 30–40% of 1-RM) in CAD patients.[11,13] Furthermore, a lower HR, systolic BP, and cardiac output was also found following a faster lifting cadence (1 s:1 s for concentric and eccentric contraction) with longer breaks between sets (≥60–90 s) compared to a slower lifting cadence (>2 s:2 s) with shorter breaks between sets (≤45 s).[12,13] These emerging insights highlighted the possibility to minimize the potential deleterious effects of RT on haemodynamics and gave momentum to further study the implementation of RT in CR.[2]

Transition from low- to high-load resistance training

While the safety and benefits of a single session of HL-RT were established in healthy older adults[10] and CVD patients,[2] the safety and exercise tolerability of HL-RT in early CR after myocardial infarction and/or HF-related hospitalization remained unknown. These knowledge gaps were recently addressed in a randomized cross-over study that compared the safety and haemodynamic responses to three sets of LL-RE (16 repetitions/set at 40% of 1-RM) and HL-RE (8 repetitions/set at 80% of 1-RM) in 41 patients with CAD prior to CR enrolment (≤1.5 months after an acute coronary event).[14] No major adverse

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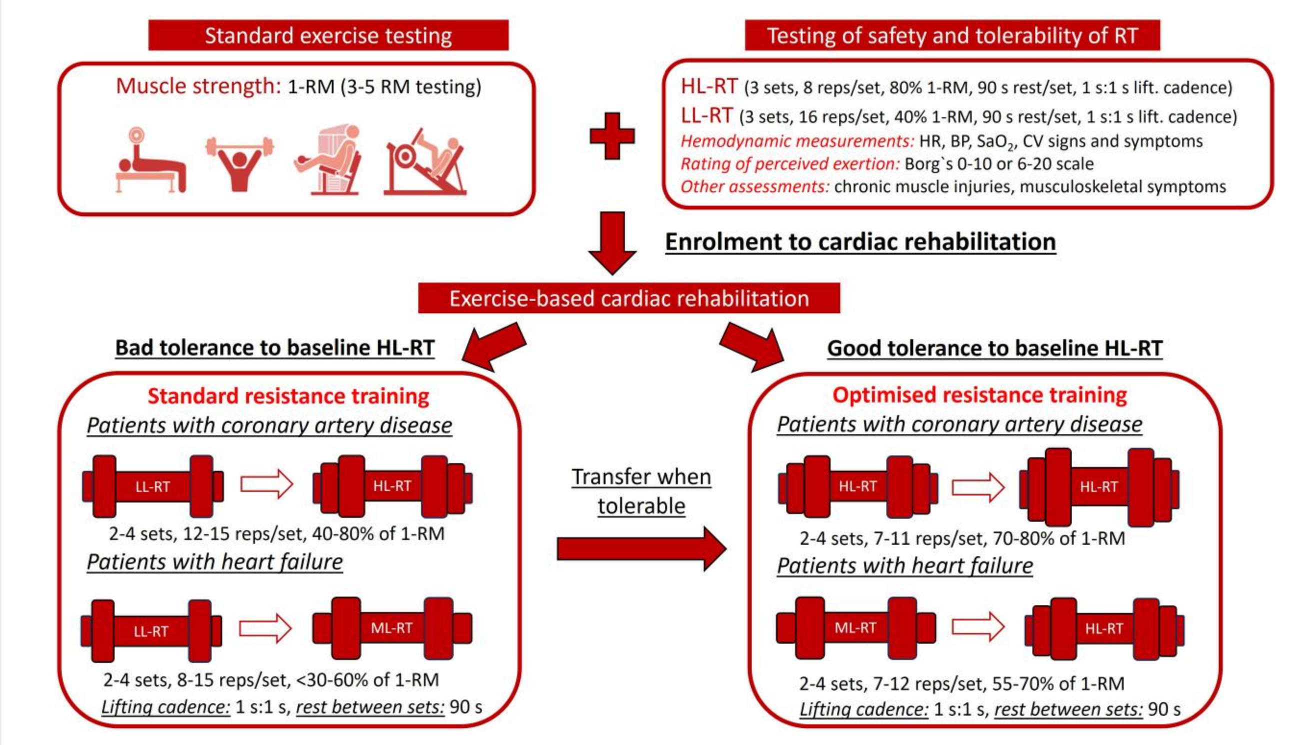

Figure 1 Proposal of optimization of resistance training in exercise-based cardiac rehabilitation.[2,16,17] Measurement of haemodynamic response should be performed using heart rate telemetry with build-in ECG monitoring; blood pressure and oxygen saturation should be monitored using pulse oximeter and standard blood pressure monitor or using beat-by-beat photoplethysmography. BP, blood pressure; CV, cardiovascular; HL-RT, high-load resistance training; HR, heart rate; lift. cadence, lifting cadence; LL-RT, low-load resistance training; ML-RT, moderate-load resistance training; RM, repetition maximum; SaO_2, oxygen blood saturation. Weight machine icons were designed in BioRender.

cardiovascular or musculoskeletal adverse events occurred in both RT interventions. Moreover, a similar increase in HR (66 ± 9 to 86 ± 11 beats/min vs. 68 ± 10 to 86 ± 13 beats/min), systolic BP (129 ± 20 to 146 ± 23 mmHg vs. 130 ± 17 to 146 ± 21 mmHg), and rating of perceived exertion [7 (5–8) points vs. 7 (6–8) points] was observed during LL-RE and HL-RE, respectively.[14]

Based on these findings, a three-arm randomized controlled trial was subsequently conducted to compare the effects of LL-RT and HL-RT in early phases of CR on VO_2max and muscle strength. Coronary artery disease patients performed progressive moderate-to-high intensity AT (50–80% of baseline peak power output) alone or in combination with either progressive LL-RT (3 sets, 12–20 repetitions/set at 35% −40% of 1-RM) or HL-RT (3 sets, 6–11 repetitions/set at 70–80% of 1-RM) during 36 supervised exercise training sessions over 12 weeks.[15] Resistance training in combination with AT was safe, and AT + HL-RT elicited a greater improvement in VO_2max ($+35 \pm 25\%$) compared with AT alone ($+17 \pm 22\%$, $P = 0.032$), but not when compared with LL-RT ($+24 \pm 21\%$, $P = 0.57$). Furthermore, a greater increase in maximal muscle strength of knee extensors was found following AT + HL-RT ($+17 \pm 9\%$) when compared to AT + LL-RT ($+10 \pm 5\%$, $P = 0.018$) or AT alone ($+1 \pm 8\%$, $P < 0.001$).[16] In a comparable study among patients with chronic HF, the excellent safety (i.e. no adverse CVD or musculoskeletal events) of concurrent AT with LL-RT (3 sets, 18–22 repetitions/set at 35–40% of 1-RM) and AT with ML-to-HL-RT (3 sets, 12 repetitions/set at 55–70% 1-RM) was confirmed. Similar improvements in VO_2max ($+24 \pm 28\%$ vs. $+ 19\% \pm 52\%$, $P = 0.73$) and maximal muscle strength ($+25 \pm 53\%$ vs. $+ 17 \pm 43\%$, $P = 0.70$) were observed following LL-RT and HL-RT.[17] These neutral findings may be attributable to the small differences in RT loads between treatment arms (but within the guideline-directed RT intensities) and suggest the need for high RT intensities (≥70% of 1-RM) to induce superior increases in muscle strength, at least in active HF patients, as was shown in CAD patients.[16] Furthermore, the use of HL-RT was recently extended to teenagers with Fontan circulation. In this study, the young patients [13 (5) years old] performed HL-RT (3 sets, 6–8 repetitions/set) consisted of predominantly lower limb REs and received a complimentary high protein diet (daily intake of 2 g/kg of body weight). High-load RT was superior to standard care in improving maximal aerobic capacity [+2.2 (1.4) mL kg/min vs. −1.9 (3.0) mL kg/min, $P < 0.001$], maximal strength of lower limbs [knee extension, +51 (31) Newtons vs. −1 (12) Newtons, $P = 0.017$], and even cardiac function [indexed stroke volume post HL-RT vs. baseline, +3.2 (3.1) mL/m^2, $P = 0.014$].[18]

Implementation of high-load resistance training

A recent position statement of the European Association of Preventive Cardiology recommends that HL-RT could be adopted in the later phase of CR.[19] However, based on the emerging data on the safety and efficacy of HL-RT in early CR phases, we propose to revise this approach. Within the limited time of standard CR programmes (≤12 weeks) in most European countries, HL-RT should be prioritized as early as possible to achieve optimal benefits for patients. Early implementation of HL-RT is particularly important in patients who were physically more active before diagnosis and/or have a desire to regain muscle strength for daily life routines and/or re-employment.

The benefits of HL-RT should be also promoted among female patients to increase their adherence and benefits in comparison to male patients.[20] This liberal approach would also allow greater room for shared decision-making, hence optimizing the prescription and adherence to CR.[21] We propose to conduct a standardized RE test upon CR enrolment with the aim to assess the patient`s exercise tolerability and haemodynamic responses to HL-RT. Patients can be directly referred to HL-RT in absence of abnormal responses. Alternatively, patients could participate in a run-in phase of LL-to-ML-RT followed by a transfer to HL-RT, when possible (*Figure 1*). The run-in phase of LL-to-ML-RT could rely on recent progression models in patients with CAD and HF, which allow patients to overcome similar RT volume (e.g. total training load lifted), as they would during HL-RT.[15,17,22] In addition, alternative methods for easier and safer application of HL-RT were also recently introduced.[23] A recent review proposed different set redistributions by adjusting the number of repetitions/set to lower the exercise time, which is well-established to be the main factor of the magnitude of the haemodynamic response.[2] For example, HL-RE distributed in 4 sets of 5 repetitions/set at 80% of 1-RM separated by 30 s of rest could potentially yield even lower haemodynamic responses[23] compared with traditional HL-RE consisted of 4 sets of 6–8 repetitions/set at 80% of 1-RM separated by 90 s of rest.[16] However, the effects of such modifications of HL-RT on exercise tolerability and safety remain to be elucidated in CR.

Conclusions and future research directions

For now, HL-RT has been shown to be safe and tolerable in the early phase of CR.[14,16,17,22] Concurrent exposure to AT and HL-RT induces a greater improvement in maximal muscle strength compared to LL-RT in CAD patients. In HF patients, HL-RT and LL-RT induced similar improvements, likely due to a lower initial RT load applied in HF than CAD patients (55% vs. 70% of 1-RM). Future HL-RT studies should thus focus on (i) the benefits of higher initial RT loads in HF patients, (ii) the safety and efficacy among sarcopenic and/or frail patients with valvular disease, peripheral artery disease, and elderly patients, and (iii) the possibility to enrich hybrid and home-based CR with concurrent exercise training programmes. These efforts may strengthen CR-induced health outcomes, as greater increases in fitness, muscle mass, and muscle strength are likely to contribute to a better clinical tomorrow for patients with CAD and HF.[2,19]

Author contribution

All authors contributed to the conception or design of the work. T.K. drafted the manuscript. D.H. and T.M.H.E. critically revised the manuscript. All gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

Conflict of interest: None declared.

Data availability

No new data were generated or analysed in support of this research.

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