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**RESEARCH LETTER**
*Cardiac rehabilitation*

# Effects of low vs. moderate intense resistance exercise training combined with endurance exercise training in patients with heart failure: a randomized clinical trial†

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Exercise-based cardiac rehabilitation (CR) reduces the risk of hospital admissions and improves the quality of life (QoL), aerobic and walking capacity, and muscle strength in patients with congestive heart failure (CHF).[1] According to EAPC/ESC recommendations, low intense (LI) to moderate intense (MI) endurance exercises should be supplemented by dynamic resistance exercises [40–60% of 1-maximal repetition (1RM)].[2] Currently, the optimal intensity of these resistance exercises has not been experimentally established in HF. In coronary artery disease (CAD), however, MI resistance exercise training (combined with endurance exercise training) is superior to LI resistance exercise training to improve muscle strength.[3] Therefore, in this study, we investigate the effects of LI vs. MI resistance training, combined with endurance training, on aerobic fitness, walking capacity, muscle strength, and QoL in patients with CHF, and hypothesize that MI resistance exercise training might be superior to LI resistance training.

In this randomized clinical trial (NCT04688827), participants were recruited consecutively upon initiation of the CR programme and they were referred independently from acute events (see Supplementary material online, *Figure S1*). Eligible participants were men and women >18 years, with an echocardiographic diagnosis of CHF independent of left ventricular ejection fraction, without ventricular assist device. Participants with (i) orthopaedic or neurological comorbidities affecting strength, (ii) cognitive impairment, and/or (iii) lung disease (e.g. chronic obstructive pulmonary disease) were ineligible. All participants gave their informed consent. The assessments were done before or in the first 2 weeks of the CR programme and during/after the last training week. An independent researcher block-stratified participants [size 2–4; factors: age (</≥50) and sex (M/F) via 'sealedenvelope.com' to LI or MI resistance exercise training plus endurance exercise training group (MI).

The participants followed a CR programme of 45 supervised sessions (3×/week). The sessions comprised of ∼20–40 min of endurance exercises [on treadmill, cycle/arm ergometer, stepper, cross-trainer, and/or rowing machine (at ∼50–75% of $VO_2$peak)] and ∼15–25 min of resistance exercises. Resistance exercises in the MI group included 3 × 12 repetitions of leg press, dips, and pulldown at 55–70%1RM, while the LI group did 3 × 18–22 repetitions at 35–40%1RM. Resistance exercises were volume-matched between groups [volume = intensity (%1RM) × repetitions].

The main outcomes were changes of aerobic capacity (peak oxygen consumption = $VO_2$peak), walking capacity [6 min walk test distance (6MWTdistance)], muscle strength (1RM), and QoL.

A cardiopulmonary exercise test (ramp protocol: +5–30 W/min) with 12-lead electrocardiogram (GE Medical Systems, Germany) was done on a bicycle ergometer to determine the 10 s averaged $VO_2$peak and peak heart rate (HRpeak).

For assessing muscle strength, a 1RM trial was repeated ≤5 times with 1 min between-set rests, and Brzycki's formula was used to estimate the 1RM.[4] 1-Maximal repetition was reassessed every nine exercise sessions to allow progression. A 6MWT was done in the hospital hallway between the two cones 30 m apart.[5] The QoL was assessed with the Minnesota-Living with Heart Failure questionnaire (Minnesota) during supervised hospital visits.[6] The total score was a sum of 21 questions on a 0–5 Likert scale. Total scores were categorized into low (>45 points), moderate (24–45 points), or high QoL (<24 points).[7] Changes in the physical (q2–7 and 12–13),[8] social (q8–10 and 14–16),[9] and emotional component (q17–21)[8,9] were evaluated.

Normality was assessed by using the Shapiro–Wilk test (IBM-SPSS-Statistics-v28.0.1.1.). An independent *t*-test, Mann–Whitney *U* test, or Fisher's exact test were used for the between-group analysis at baseline and for pre-post changes, while the paired *t*-test, Wilcox sign-rank test, and McNemar's $\chi^2$ test were used for testing changes within groups (two-tailed significance level $P < 0.05$).

Groups had similar baseline characteristics and training adherence (*Table 1*).

$VO_2$peak, 6MWT distance, and 1-RM significantly increased within groups ($P < 0.001$), and similarly between groups ($P > 0.05$, *Table 2*). The total score of Minnesota and the separate scores for the physical, emotional, and social components significantly improved in the LI group ($P \leq 0.01$; *Table 2*), but not in the MI group ($P > 0.09$). Only the emotional component improved significantly more in the LI than the MI group ($P = 0.048$), and there were more patients with a high QoL in

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**Table 1 Baseline characteristics**

| Variables | n | LI (n = 28) | n | MI (n = 28) | P-value |
|---|---|---|---|---|---|
| Male sex (n/%) | | 23 (82) | | 23 (82) | 1.000 |
| Age (years) | 28 | 63 (15) | 28 | 64 (14) | 0.417 |
| Height (cm) | 28 | 173 ± 9 | 28 | 172 ± 8 | 0.391 |
| Body mass (kg) | 28 | 86 ± 15 | 28 | 79 ± 14 | 0.105 |
| BMI (kg/m$^2$) | 28 | 28 ± 4 | 28 | 27 ± 4 | 0.173 |
| LVEF (%) | 24 | 38 ± 9 | 24 | 39 ± 11 | 0.720 |
| LVEF (≥50%, 41–49%, ≤ 40%, unknown; n) | 28 | 4/6/14/4 | 28 | 4/11/9/4 | |
| DD (grade I/2/unclear) | 28 | 16/7/5 | 28 | 24/2/2 | |
| Training adherence (tc) | 28 | 40 ± 7 | 28 | 35 ± 10 | 0.119 |
| Devices | | | | | |
| PM | 28 | 13 (46) | 28 | 11 (39) | 0.787 |
| CRT + ICD combined | 28 | 5 (18) | 28 | 4 (14) | >0.99 |
| Smoking | | | | | |
| Smoker | 28 | 2 (7) | 28 | 2 (7) | >0.99 |
| Ex-smoker | 28 | 14 (50) | 28 | 12 (43) | 0.789 |
| Comorbidities and risk factors | | | | | |
| Arterial hypertension | 28 | 16 (57) | 28 | 18 (64) | 0.784 |
| Diabetes (T2DM) | 28 | 3 (11) | 28 | 7 (25) | 0.296 |
| Dyslipidaemia | 28 | 18 (64) | 28 | 20 (67) | 0.451 |
| Obesity | 28 | 10 (36) | 28 | 5 (18) | 0.227 |
| OSA | 28 | 5 (18) | 28 | 4 (13) | >0.99 |
| Medication | | | | | |
| Beta-blocker | 27 | 27 (96) | 25 | 24 (86) | 0.481 |
| ACE inhibitors | 27 | 13 (46) | 25 | 15 (54) | 0.419 |
| Statins | 27 | 22 (76) | 25 | 20 (71) | >0.99 |
| Diuretics | 27 | 16 (82) | 25 | 12 (43) | 0.578 |
| ARB | 27 | 12 (43) | 25 | 7 (25) | 0.259 |
| Antiarrhythmics | 27 | 5 (18) | 25 | 1 (3) | 0.193 |

Normally distributed data are means ± standard deviations (SDs), non-normally distributed data are medians, frequencies are n (%).
ACE, angiotensin-converting enzyme; LIG, low-intense resistance training group; MIG, moderate-intense resistance training group; tc, trainings completed out of maximal 45; BMI, body mass index; LVEF, left ventricle ejection fraction; DD, diastolic dysfunction; PM, pacemaker; CRT, cardiac resynchronization therapy; ICD, implantable cardioverter-defibrillator; OSA, obstructive sleep apnoea.

the LI ($P = 0.008$), but not in the MI group ($P = 0.480$) after the intervention.

This study shows for the first time that LI and MI resistance exercise training, combined with endurance exercise training, are equally effective in improving $VO_2$peak, walking capacity, muscle strength, and QoL in patients with CHF.

The lack of differences in changes of aerobic capacity between groups is in line with data from CAD.[3] The likely driver of changes in the aerobic capacity is better peripheral oxygen extraction or increased left ventricle ejection fraction primarily due to endurance training.[10,11]

In contrast to healthy adults[12] and patients with CAD,[3] both training regimes were equally effective in improving muscle strength in patients with CHF. Since training intensity drives improvements in muscle strength in older adults[12] and CAD,[3] MI resistance training from this study (65%1RM) might have been too similar to LI resistance training (35–40%1RM) to induce superior improvements in strength, although these are the guideline-directed lower and upper ranges of resistance exercise training.[2] The QoL improved in the LI group and improvements were in the range of the MCID of −8.2 points from the ROC analysis,[13] and −9.82 points from other combined-modality exercise-rehabilitation studies in HF.[14] Considering that the full-intervention potential might have been partially masked in this study by too-similar resistance training programmes, future studies should focus on comparing the effects of volume-matched high intense (>65%1RM) vs. LI to MI resistance training programmes combined with endurance training.

In conclusion, LI and MI resistance exercise training, combined with endurance exercise training, similarly improves $VO_2$peak, walking capacity, and muscle strength, but LI resistance exercise training might be superior in improving QoL in patients with CHF.

## Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

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**Conflict of interest:** None declared.

**Table 2 Changes of aerobic and walking capacity, muscle strength, and quality of life**

| Variable | *n* | LI (*n* = 28) | | Change | *P*-value | *n* | MI (*n* = 28) | | Change | *P*-value | *P*-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre | Post | | Within LI | | Pre | Post | | Within MI | Between |
| Cardiopulmonary exercise test | | | | | | | | | | | |
| $VO_2$peak (mL/kg/min) | 28 | 16.5 (9.3) | 19.4 (7.5) | 3.9 (2.62) | <0.001 | 28 | 17.1 (9.3) | 21.4 (9.0) | 3.25 (4.85) | <0.001 | 0.731 |
| Load (W) | 28 | 120 (66) | 144 (60) | 22 (26) | <0.001 | 28 | 116 (79) | 124 (82) | 25 (25) | <0.001 | 0.883 |
| HRmax (b.p.m.) | 28 | 108 ± 22[a] | 118 + 26 | 7.1 ± 12.1 | 0.002 | 28 | 124 ± 23 | 124 ± 21 | 0.3 (22) | 0.936 | 0.016 |
| 6-min walk test | | | | | | | | | | | |
| Distance (m) | 28 | 473 (117) | 508 (142) | 31.5 (43) | <0.001 | 27 | 507 (134 | 570 (104) | 46.5 (71) | <0.001 | 0.794 |
| HR (b.p.m.) | 28 | 78 (22) | 85 (24) | 18 (23) | 0.091 | 27 | 84 (28) | 92 (35) | 22 (25) | 0.715 | 0.933 |
| Saturation (%) | 27 | 98 (3) | 98 (3) | −0.5 (3) | 0.312 | 26 | 98 (2) | 98 (1) | 0 (2) | 0.477 | 0.276 |
| Muscle strength—1RM | | | | | | | | | | | |
| Dip (kg) | 28 | 76 (24) | 87 (47) | 10.5 (18) | <0.001 | 27 | 75 (29) | 82 (32) | 12.5 (21) | <0.001 | 0.573 |
| Leg-press (kg) | 25 | 126 (90) | 167 (107) | 32 (48) | <0.001 | 26 | 136 (70) | 153 (111) | 22.5 (30) | <0.001 | 0.699 |
| Pulldown (kg) | 27 | 67 ± 17 | 74 ± 18 | 4 (12) | <0.001 | 27 | 63 ± 19 | 71 ± 18 | 7.5 (8) | <0.001 | 0.430 |
| Quality of life—Minnesota questionnaire | | | | | | | | | | | |
| Physical score (points) | 22 | 10 (12) | 5.5 (5) | −3 (9) | 0.005 | 23 | 6 (18) | 5 (8) | −1 (8) | 0.259 | 0.184 |
| Social score (points) | 21 | 4 (13) | 2 (4) | −3.5 (7) | 0.004 | 23 | 3 (12) | 3 (7) | −0.5 (8) | 0.093 | 0.233 |
| Emotional score (points) | 23 | 6 (9) | 2 (4) | −2 (7) | 0.002 | 23 | 3 (10) | 2 (4) | 0 (4) | 0.637 | 0.048 |
| Total score (points) | 19 | 15 (31) | 9 (12) | −7 (21) | 0.016 | 21 | 15 (47) | 13 (29) | −1.5 (16) | 0.390 | 0.236 |
| Low QoL (*n*, %) | 19 | 1 (5) | 0 (0) | −1 | 0.480 | 21 | 5 (22) | 3 (14) | −2 | 1.000 | 0.233 |
| Moderate QoL (*n*, %) | 19 | 9 (47) | 2 (11) | −7 | 0.023 | 21 | 2 (8) | 5 (24) | +3 | 0.371 | 0.414 |
| High QoL (*n*, %) | 19 | 10 (53) | 18 (95) | +8 | 0.008 | 21 | 16 (70) | 15 (71) | −1 | 0.480 | 0.095 |

Data are mean ± SD or median (interquartile) or *n* (% group); Change = post-pre.
LI, low-intense group; MI, moderate-intense group; high QoL, Score 0–23; moderate QoL, Score 24–45; low QoL, Score >45.
[a]Difference between groups at baseline ($P < 0.05$); between-group differences in pre-post changes, Mann–Whitney *U* test, independent *t*-test or Fisher's exact test; within-group differences, paired *t*-test, Wilcox sign-rank, and McNemar $\chi 2$

## Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

## Authors' contributions

T.G., K.G., N.T.D.S., B.T., W.M., and D.H. contributed to the conception or design of the work. T.G., K.G., B.T., and N.T.D.S. contributed to the acquisition, analysis, or interpretation of data for the work. T.G., K.G., and D.H. drafted the manuscript. Everyone critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

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