# The Effect of Resistance Training on Muscle Strength and VO2 Peak in Middle-aged and Older Patients with Heart Failure: A Meta-analysis

*Loura Caroline Korengkeng, Elisa Anderson, Ailine Yoan Sanger, Denny Maurits Ruku**

**Abstract:** Several interventions using resistance training have been attempted for people with heart failure. Still, the overall effectiveness of resistance training in improving muscle strength and peak oxygen uptake based on age remains inconclusive. This study aimed to investigate the efficacy of resistance training on muscle strength and VO2 peak in patients with heart failure based on age. A search was conducted using English articles from 2000 to 2023 to find information on resistance training from Embase, CINAHL, MEDLINE, Cochrane, PEDro, and Google Scholar. Standardized mean difference and 95% confidence intervals were calculated, and publication biases were presented by funnel plots and Egger's test. The Critical Appraisal Skills Programme was used to examine the quality of the studies.

Results showed that 23 randomized control trial articles fulfilled the inclusion criteria, comprising 830 respondents, with 422 in the intervention and 408 in the control group. In the middle-aged subgroup, resistance training had a significant effect on increasing muscle strength in the upper limb and lower limb. Similarly, a significant effect was observed in the older subgroup for the upper limb and lower limb. Resistance training significantly increased VO2 peak in middle-aged and older patients with heart failure. Resistance training was identified as one of the effective ways to improve muscle strength and VO2 peak, and it should be recommended as a part of the rehabilitation for people with heart failure. Additionally, the components of interventions should be considered based on the patient's age to maximize the exercise programs using resistance training.

**Keywords:** Heart failure, Meta-analysis, Middle age, Muscle strength, Older people, Resistance training, Resistance training, VO2 peak

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## Introduction

Heart failure (HF) is a significant public health issue requiring special attention.[1] Patients with this condition often face challenges such as shortness of breath (dyspnea) and shortness of breath (SOB), particularly during physical activities or exercise.[2] As stated by a previous study, limitations in physical activities are more pronounced in patients with a low left ventricle ejection fraction (LVEF) and a high New York Heart Association (NYHA) Classification.[3]



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The signs and symptoms of HF are often linked to a lack of oxygen consumption (VO2) in facilitating tissue metabolism. A previous study indicated that low VO2 levels, especially in those with a high NYHA Class and low LVEF, can lead to the development of sarcopenia.[4] This condition contributes to changes in peripheral skeletal muscle mass, muscle atrophy, and, subsequently, a decrease in muscle strength.[5] Furthermore, sarcopenia is considered a leading cause of reduced physical performance and decreased cardiorespiratory fitness in patients with HF.[6]

The decline in muscle strength is associated with a reduced quality of life (QOL).[7,8] Muscle strength is also often linked to aging, as several organs experience a decline in function.[9] However, it is a critical indicator of successful rehabilitation for patients as well as contributes to morbidity and mortality rates in patients with HF.[10] This indicates that families and healthcare providers need to focus on finding solutions to improve patients' muscle strength.

Promoting rehabilitation programs for patients with HF is a significant responsibility of professional nurses. Resistance training (RT) is a recommended cardiac rehabilitation strategy for patients who have stable HF.[11] According to a previous study, routine RT can improve physical performance, cardiorespiratory fitness, and quality of life (QOL).[12] To our knowledge, from 2015 to 2023, eight meta-analyses investigated the effect of RT on patients with HF.[11-18] However, evidence-based studies focusing on muscle strength (upper/lower limb) and VO2 peak based on age are yet to be conducted. Therefore, there is a need to examine the effectiveness of RT on muscle strength, and VO2 peak based on age (middle-aged or older) in those with HF. Moreover, this study provides information on cardiac rehabilitation using RT, which can benefit patients, their families, and healthcare providers in treating individuals with HF. Finally, the purpose of this study was to compare the effectiveness of RT on muscle strength and VO2 peak based on age. Furthermore, the examination was conducted to analyze the intervention component (type of RT, frequency/duration of exercise) in patients with HF.

## Methods

**Systematic Literature Review and Data Sources:** This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (**Figure 1**). The PICO format was used, with Population (P) comprising patients with HF, Intervention (I) in the form of RT, Comparison (C) namely usual care as well as Outcome (O), including muscle strength, VO2 peak, and physical performance. Relevant articles for this study were obtained from six databases: Embase, CINAHL, MEDLINE, Cochrane, PEDro, and Google Scholar. Keywords and Emtree/MESH terms used in the article search included cardiac decompensation, cardiac failure, cardiac incompetence, cardiac insufficiency, chronic heart failure, chronic heart insufficiency, heart backward failure, myocardial failure, myocardial insufficiency (HF); resistance exercise, resistance exercise training, strength training, weight-bearing exercise (resistance training); muscle strength, muscle force, muscle power, and muscular dynamic strength (muscle strength). The inclusion criteria were articles in English describing studies with a randomized controlled trial design (RCT), the intervention used RT or RT combined with other exercises, patients with HF (middle-aged or older), and published from 2000 to 2023. Meanwhile, studies without a control group and reviews (systematic/meta-analysis) were excluded.

The literature was searched in September and October 2023. After the PICO format was used to identify studies with relevant studies, these were scrutinized to remove duplicates. This was followed by a screening process that assessed the titles and abstracts. After that, all three reviewers stopped after investigating the reference lists and reading the full-text articles and did not identify additional studies that met the inclusion criteria.

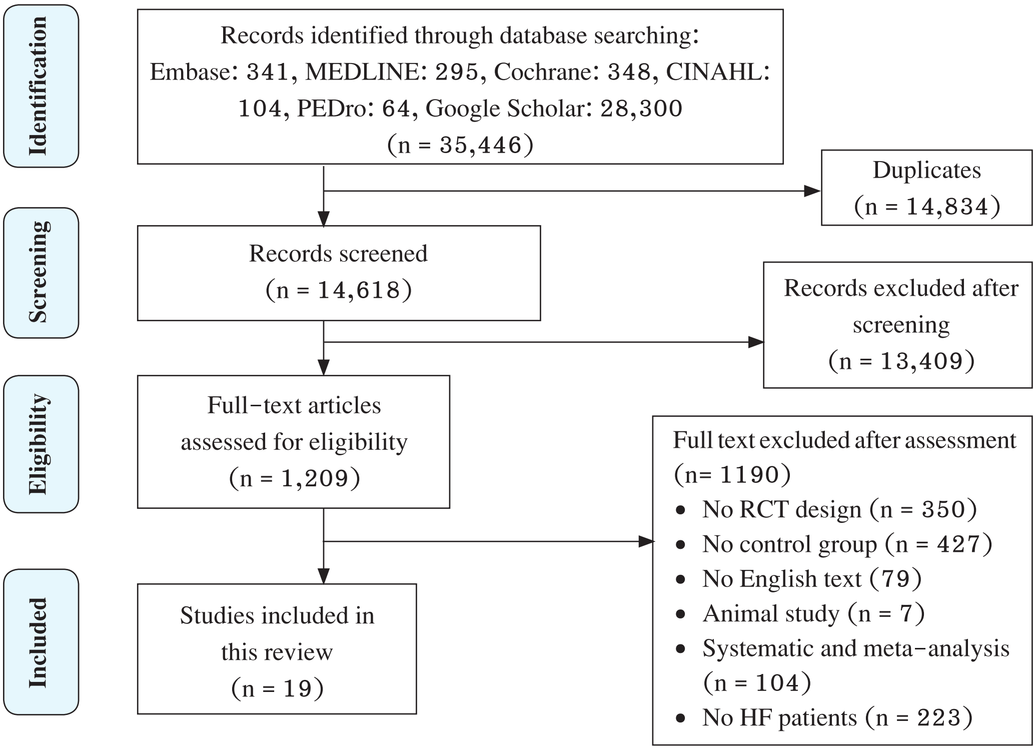


**Figure 1.** Flow diagram of the studies selection process

**Data Extraction and Quality Assessment:** Data extraction was independently performed by both reviewers to collect information on the study design, age, LVEF, intervention details (type of RT and frequency/duration of intervention), and outcomes, as presented in **Appendix, Table 1.** Both reviewers also independently assessed quality using the Critical Appraisal Skills Programme (CASP) **(Appendix, Table 1).** Publication bias was tested with Funnel plots and Egger's test for meta-analysis.

**Data Synthesis and Statistical Analysis:** RevMan 5.4 software was used for data synthesis, and the intervention results were depicted with changes from baseline to follow-up. Standardized mean difference (SMD) was utilized for data synthesis. Significance was set at $p < .05$ with a 95% confidence interval (CI), and heterogeneity among studies was measured using the $I^2$ test. Furthermore, changes in muscle strength and VO2 peak were presented with effect sizes (ES), and a random effects model was used due to high heterogeneity (more than 50%).

## Results

### Description of Selected Studies

A total of 29,452 studies from six databases, namely Embase (n = 341), MEDLINE (n = 295), Central (n = 348), CINAHL (n = 104), PEDro (n = 64), and Google Scholar (n = 28,300), were included in the initial screening process. Subsequently, 14,834 were removed due to duplication, and 13,409 were excluded based on title and abstract screening. Following the full-text screening, 1,209 articles fulfilled the criteria for identification but 1,191 were excluded from the review due to the failure to meet the criteria, including not having an RCT design (n = 350), lacking a control group (n = 427), not being in English (n = 79), being animal studies (n = 7), systematic and meta-analyses (n = 105), or not centered on patients with HF (n = 223). Finally, 19 studies that met the criteria were included in this review.[19-38]

**Characteristics of the Studies**

A total of 19 studies with RCT designs were included in this review from 2000 to 2023. The total number of male and female respondents was 830, divided into 422 in the intervention and 408 in the control group. The mean age ranged from 54±10 to 76.6±2 years old, and the mean LVEF was between 25% to 41.5%. Furthermore, the quality of the studies was assessed using the CASP, scoring between 7 and 11 out of the total score **(see Appendix, Table 1)**. The risk of bias was summarized in **Figure 2**, where less than 50% was unclear in the random sequence generation, allocation concealment, incomplete outcome, selection reporting, and other biases, and less than 25% was vague in the blinding of outcomes.

**The Effect of RT on Muscle Strength (Upper Limb) in Patients with HF**

**Appendix, Table 2** shows that there were 18 studies, eight in the middle-aged group (128 respondents in the intervention group and 133 in the control) and ten studies in the older group, with 194 respondents in the intervention group and 192 in the control. In the middle-aged group, RT significantly increased muscle strength (upper limb) in the intervention group (SMD: 1.00, 95% CI: 0.37 to 1.64, $I^2$: 80%). Similarly, in the older group, a significant effect was found in the intervention group (SMD: 0.72, 95% CI: 0.39 to 1.04, $I^2$: 51%) compared to the control.

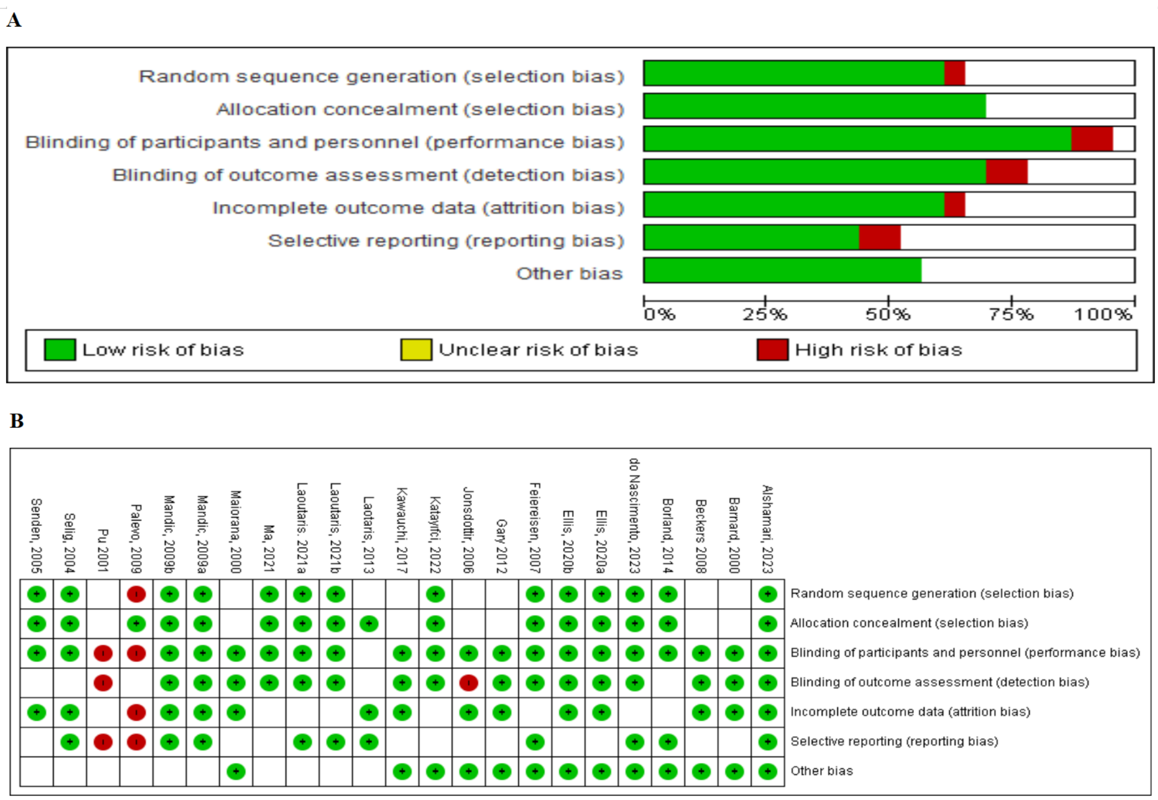


**Figure 2.** Risk of bias: (A) Risk of bias graph, (B) Risk of bias summary

**The Effect of RT on Muscle Strength (Lower Limb) in Patients with HF**

Based on the results in **Appendix, Table 2**, a total of 18 studies were obtained consisting of eight RCTs in the middle-aged group with 129 respondents in the intervention group and 129 in the control as well as 10 RCTs in the older group with 138 respondents in the intervention group and 133 in the control. The middle-aged group's forest plot presented that RT significantly increased muscle strength (lower limbs) in the intervention group (SMD: 0.87, 95% CI: 0.41 to 1.33, $I^2$: 66%) compared to the control group. Similar results were obtained in the older group, with RT causing a significant increase in muscle strength (lower limbs) in the intervention group (SMD: 1.20, 95% CI: 0.69 to 1.71, $I^2$: 70%) compared to the control.

**The Effect of RT on Increasing VO2 Peak in Patients with HF**

Thirteen studies were included in this analysis, comprising six in the middle-aged group and seven in the older group (**Appendix, Table 3**). The results for the middle-aged group are 106 respondents in the intervention group and 114 in the control group, as well as seven studies in the older group, with 104 respondents in the intervention group and 105 in the control group. The middle-aged group presented that RT significantly increased VO2 peak in the intervention group (SMD: 0.55, 95% CI: 0.11 to 1.00, $I^2$: 60%) compared to the control. Similar results were obtained in the older group, with RT causing a significant increase in VO2 peak in the intervention group (SMD: 0.28, 95% CI: 0.00 to 0.55, $I^2$: 0%) compared to the control.

**Component of RT**

The middle-aged group used only RT or RT combined with endurance, strength, and high-intensity interval training for exercise,[19-21,25,26,29,31,33,37,38] whereas the older group used only RT or RT combined with aerobic, bicycle, Baduanjin (*qigong*) or inspiratory muscle training, and concentric/eccentric exercise.[22-24,27,30,32,34-36] Furthermore, the frequency of exercise in both groups was almost the same (3 times/week). However, the average duration of exercise in both groups differed; the middle-aged had a longer duration of exercise (8 to 40 weeks) than the older people (8 to 24 weeks).

**Methodological Quality and Risk of Bias of the Study**

The evaluation of methodological quality using the CASP score is described in **Appendix, Table 1**. The result showed that the methodological quality of this study was moderate to high.[39] The overall risk of bias presenting of all studies was good in blinding participants/personnel and outcome assessment. More than half of the studies were reported based on allocation concealment, random sequence generation, and incomplete outcome assessment. Based on selective reporting and other biases, half of the studies did not report (**Figure 2**). Sensitivity analysis was carried out on two studies in the middle-aged group and one study in the older group. However, no changes in either sub-group persisted statistically significant after sensitivity analysis.

## Discussion

To recognize the issues associated with the effectiveness of RT in improving muscle strength and VO2 peaks generally observed in the adult population, this literature review and meta-analysis compared the effects of RT on muscle strength and VO2 peaks in middle-aged or older people with HF. We also wanted to establish whether differences existed between the groups on the intervention component. This study aimed to compare the effectiveness of RT on increasing muscle strength (upper/lower limb) and VO2 peak in intervention and control groups among 773 patients with HF categorized by age into middle-aged and older. The quality of evidence from the selected studies for analysis was considered moderate to high. We also wanted to find whether differences existed between both groups with components of the intervention (type of exercise and duration/frequency of exercise). This study found that RT positively increased muscle strength in both the upper and lower limbs for patients with HF (**See Appendix, Tables 2 and 3**). There was no significant difference in subgroup analysis, with RT offering a positive benefit for middle-aged and older patients. Aging negatively affects muscle strength as several organs in the body begin to experience a decline in function, which in turn affects skeletal muscle metabolism.[4,5,7] Additionally, muscle strength is associated with life expectancy, resulting in a lower survival rate for HF patients.[40] The decline in LVEF function tends to affect oxygen consumption for skeletal muscle metabolism, leading to decreased muscle strength.[31] This problem can be overcome through routine exercise using RT to enhance muscle blood flow.[30,31] A previous study states that engaging in RT alone or combined with other exercises provides better benefits than single exercises.[41] RT is recommended for improving the function of low LVEF in patients with HF.[31] Moreover, routine exercise using RT is helpful for several physiological systems and in increasing the health-related quality of life of patients with HF.[11]

This study also evidences that RT can increase VO2 peak in patients with HF, both in the middle-aged and older groups (**Appendix, Table 4**). The rationale is that when patients engage in RT, there is a gradual increase in VO2, significantly aiding the metabolic process.[11] The heart enhances aerobic capacity and oxygen delivery to various tissues more effectively.[12,42] Several studies acknowledged that an increased VO2 peak has a potentially positive effect on improving muscle strength.[11,12,15] Therefore, RT has become a recommended approach for rehabilitation in stable patients.[11,12,43]

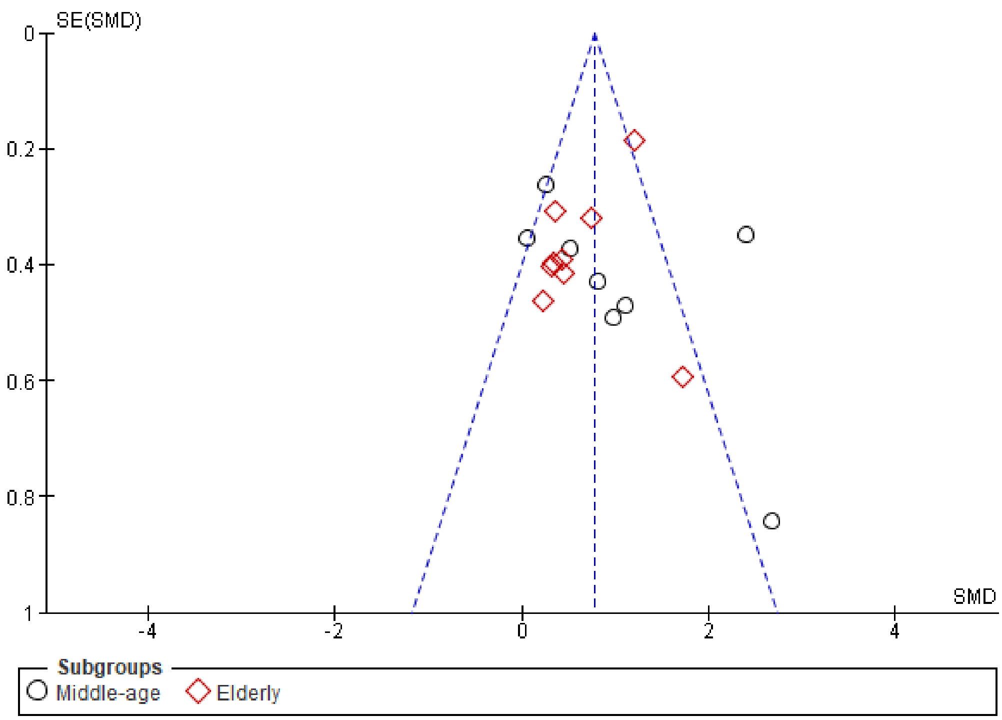


**Figure 3.** Funnel plot upper extremity

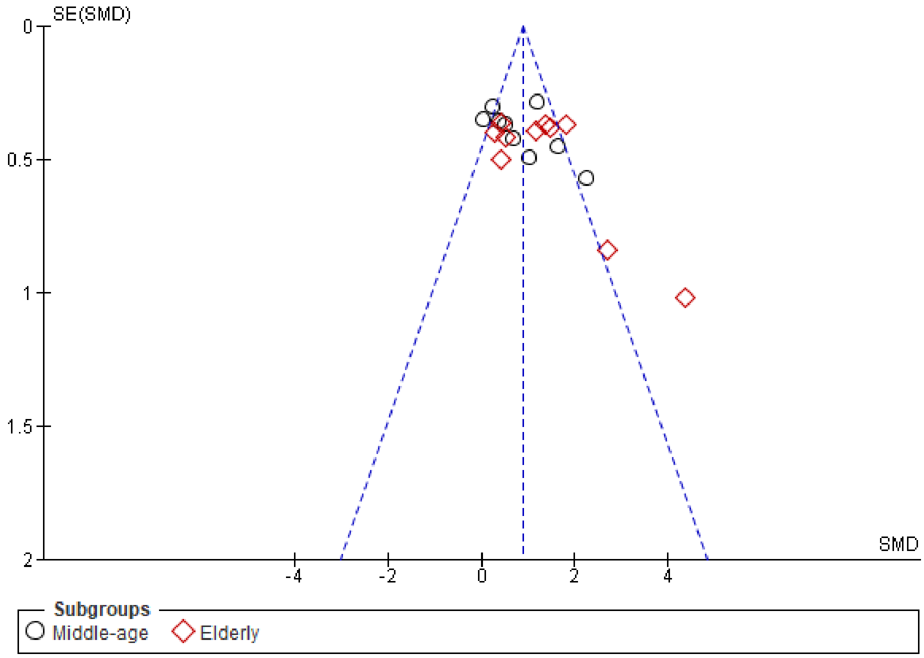


**Figure 4.** Funnel plot lower extremity

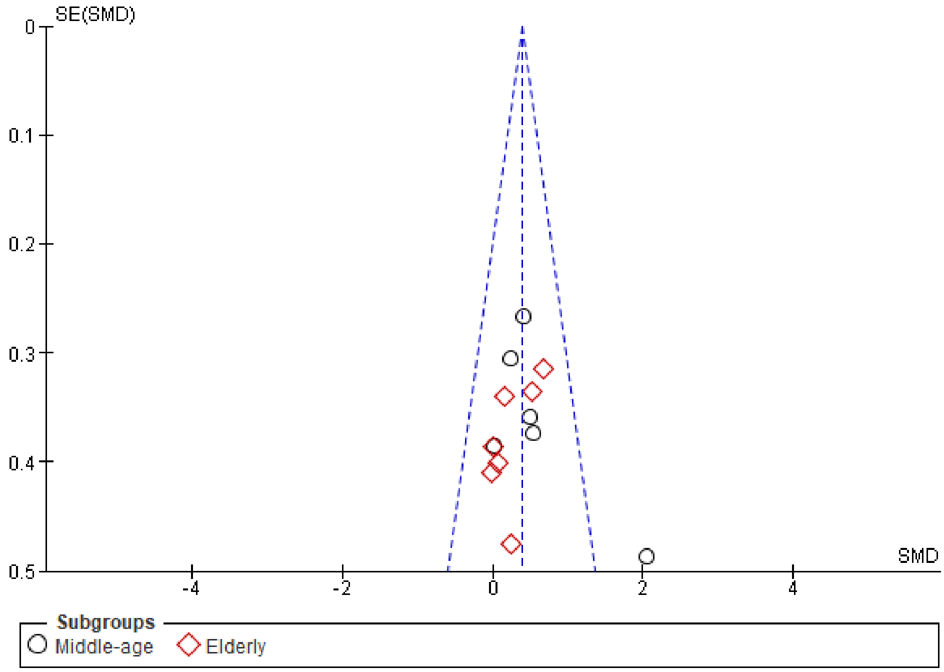


**Figure 5.** Funnel plot VO2 max

The results showed that the middle-aged and older groups had different RT types. The older group had more straightforward exercises using only RT or combined with other exercises than the middle-aged group. However, both groups showed a similar effect of RT in increasing muscle strength and VO2 peak in people with HF. Simple exercises were needed in the older group,[31] wherein the decline in postural control in an older group can be shown or described by decreased cognitive function,[4] deterioration in motor responses and other musculoskeletal and neuromuscular systems,[9] resulting in reduced muscle strength, decreased knee or plantar reflexes, slow reaction time, and reduced efficacy of defensive movement;[44] Consequently, simple exercises were needed in the older group.

Both groups had several similarities in the frequency of exercise. Most of the studies used the frequency of exercise three times a week; only in the middle-aged group did two studies exercise seven times a week,[29 a,b,] while one exercised for 36 sessions.[19] On the other hand, both groups had some differences in exercise duration. The middle-aged group had a longer duration of exercise (8 to 40 weeks) than the older group (8 to 24 weeks). It does seem that the advantages of exercise increase linearly with exercise duration. The findings of this study indicate that resistance training, both in terms of frequency and duration of exercise, is critical for improving muscle strength and VO2 peak. In essence, Palevo et al.[35] suggested a routine exercise that includes both frequency and duration of exercise as one of the rehabilitation methods for patients with HF. In this case, RT can aid in skeletal muscle oxidative metabolism,[14] improving physical function, such as muscle strength and VO2 peak in patients with HF.[11]

## Limitations of the Study

This study has several limitations; firstly, only studies in the English language were included. Secondly, there was evidence of publication bias among the studies reviewed. **Figure 2** shows that some studies had incomplete information about random sequence generation, allocation concealment, incomplete outcome reporting, and other biases. At the same time, a few studies were unclear in the blinding of outcomes. Furthermore, the analysis presented high heterogeneity, as shown by forest and funnel plots. This can be attributed to various factors such as differences in LVEF, NYHA Class, frequency/duration of exercise, type of RT, and variations in sample size among the studies. However, with the efforts of three independent reviewers, the use of six databases in the study search, the application of unique methods in the analysis, the risk of bias, and high heterogeneity in this study were handled. Further research studies with similar measurements, types of exercise, and characteristics of respondents are needed to support the effectiveness of RT on the improvement of muscle strength and VO2 peak in people with HF.

## Conclusion

In conclusion, this meta-analysis found that RT exercise had benefits for patients with HF. RT, either alone or in combination with other exercises, enhanced muscle strength (upper/lower limb) and VO2 peak in middle-aged or older patients with HF. The middle-aged and older groups had a difference in the type of exercise and duration of exercise; however, they had similarities in the frequency of exercise. The studies that were considered showed a high degree of heterogeneity. More research is needed to provide robust evidence-based RT for patients with HF, especially RCTs with larger sample sizes and homogeneity verification.

## Implications for Nursing Practice

Nurse practitioners and other healthcare professionals should consider the age of patients who exercise using RT. It is suggested that older people with HF who exercise using RT, exercise more straightforwardly, which is easier to do and has a longer duration of exercise than the middle-aged group. However, further testing on the type of exercise and duration of exercise in people living with HF for the generalizability of the program is needed. Generally, exercise using RT is an effective modality in cardiac rehabilitation that should be considered a part of the rehabilitation care of patients with HF.

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## Conflicts of interest

No conflicts of interest were declared.

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# Appendix

**Table 1.** Characteristics of the studies in meta-analysis

| No | Author | Design | Age (Mean±SD) | Total (I/C) | LVEF (%) | NYHA Class | Component of intervention: Type of RT | Component of intervention: F/D of exercise (Time/week) | Control | Outcome | CASP score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alshamari, 2023 | RCT | 56±10 | 25/19 | 30 | II, III | RT + HIIT Warm-up: 7 min, main exercise: 30 min (bicycle, aerobic, resistance training) | 36-session intervention programs | HIIT | Muscle strength (lower), VO2 peak | 10/11 |
| 2 | Barnard, 2000 | RCT | 60.3±9.5 | 14/7 | 25 | - | RT + aerobic: Bicycle and treadmill: 30 min, Strength exercise: 60 to 80% | 3/8 | Aerobic | Muscle strength (upper/lower) | 10/11 |
| 3 | Beckers, 2008 | RCT | 58±11 | 28/30 | 26 | II, III | RT + ET Warm-up/cool-down: 10 min, main exercise: 50% to 60% 1RM (treadmill, bicycle, and RT) | 3/24 | ET | Muscle strength (upper/lower) | 9/11 |
| 4 | Borland, 2014 | RCT | 70±6 | 25/23 | 26 | II, III | RT Warm-up/cool-down, and cycling: 15 min, main exercise: dumbbell, quadriceps exercise, and leg press | 3/12 | Usual care | Muscle strength (upper/lower) | 10/11 |
| 5 | do Nascimento, 2023 | RCT | 60±7 | 13/14 | 29 | II, III | ST (36 session) | 3/12 | FTG | Muscle strength (upper), VO2 peak | 10/11 |
| 6 | Ellis, 2020[a] | RCT | 68±10 | 16/15 | 27 | I–III | Warm-up: 10 min, concentric exercise, climbing + weight, and bicycle:30 min | 3/8 | Usual care | Muscle strength (lower) | 11/11 |
| 7 | Ellis, 2020[b] | RCT | 66±14 | 16/15 | 34 | I–III | Warm-up: 10 min, walking: 1 to 2 min, Eccentric exercise: 20 min, treadmill, and exercise upper/lower limb: 10 min, RT: 20 min. | 3/8 | Usual care | Muscle strength (lower) | 11/11 |

**Table 1.** Characteristics of the studies in meta-analysis (Cont.)

| No | Author | Design | Age (Mean±SD) | Total (I/C) | LVEF (%) | NYHA Class | Component of intervention | | Control | Outcome | CASP score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Type of RT | F/D of exercise (Time/week) | | | |
| 8 | Feiereinsen, 2007 | RCT | 57.9±5.8 | 15/15 | < 35 | II, III | Warm-up: 5 min, ST: 40 min | 3/40 | Usual care | Muscle strength (upper/lower) | 8/11 |
| 9 | Gary, 2011 | RCT | 60±10 | 12/12 | 25 | II, III | Warm-up and stretching: 5 to 10 min, RT: 45-60 min | 2-3/12 | Aerobic | Muscle strength (upper/lower) | 10/11 |
| 10 | Jonsdontir, 2006 | RCT | 68±6.6 | 22/21 | 41.5 | - | Warm-up: 10 min, bicycle: 15 min, RT: 20 min, cool-down: 5 min | 3/20 | Usual care | Muscle strength (upper), VO2 peak | 7/11 |
| 11 | Kawauchi, 2017[a] | RCT | 56±7 | 13/9 | 28 | II, III | Moderate RT: 30%, inspiratory muscle: 50% | 7/8 | Usual care | Muscle strength (lower) | 10/11 |
| 12 | Kawauchi, 2017[b] | RCT | 54±10 | 13/9 | 28 | II, III | Low RT: 15%, peripheral muscle training: 0.5kg | 7/8 | Usual care | Muscle strength (lower) | 10/11 |
| 13 | Laoutaris, 2021[a] | RCT | 63.9 | 19/18 | 28.3 | II, III | Aerobic: 30 min, RT: 50%, and high-intensity IMT (60%): 20 min | 3/12 | Aerobic | Muscle strength (lower), VO2 peak | 10/11 |
| 14 | Laoutaris, 2021[b] | RCT | 67.5 | 17/18 | 26.8 | II, III | Aerobic: 30 min, RT (50%): 30 min | 3/12 | Aerobic | Muscle strength (lower), VO2 peak | 10/11 |
| 15 | Laoutaris, 2013 | RCT | 57.1±11 | 13/14 | 27.8 | II, III | Warm-up/cooling-down: 5 min, Aerobic: 20-30 min, RT: 15 min | 3/12 | Aerobic | Muscle strength (lower), VO2 peak | 9/11 |
| 16 | Ma, 2021 | RCT | 64.18±8.70 | 68/68 | - | I - III | Warm-up/cool-down: 20 min, Baduanjin: 30 min, RT: 20 to 30 min | 3/24 | Usual care | Muscle strength (upper) | 10/11 |
| 17 | Maiorana, 2000 | RCT | 60±62 | 6/7 | < 40 | I - III | Warm-up/cool-down: 10 min, RT: 50 min | 1/8 | Usual care | Muscle strength (lower) | 9/11 |
| 18 | Mandic, 2009[a] | RCT | 63±11 | 12/12 | 33.4 | I - III | Treadmill 15 min, aerobic + RT: 50 to 70% | 3/12 | Aerobic | Muscle strength (upper/lower), VO2 peak | 10/11 |
| 19 | Mandic, 2009[b] | RCT | 63±11 | 12/13 | 33.4 | I - III | Treadmill 15 min, aerobic + RT: 50 to 70% | 3/12 | Usual care | Muscle strength (upper/lower), VO2 peak | 10/11 |

**Table 1.** Characteristics of the studies in meta-analysis (Cont.)

| No | Author | Design | Age (Mean±SD) | Total (I/C) | LVEF (%) | NYHA Class | Component of intervention: Type of RT | Component of intervention: F/D of exercise (Time/week) | Control | Outcome | CASP score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Palevo, 2009 | RCT | 70±12 | 10/6 | 32 | II, III | Warm-up and Stretching: 5 to 8 min, RT: 60% 1RM | 3/8 | Usual care | Muscle strength (upper/lower) | 7/11 |
| 21 | Pu, 2001 | RCT | 76.6±2 | 9/7 | 36.3 | I - IV | Warm-up: 2 min, stretching: 5 min, RT: 80% 1RM | 3/10 | Sham exercise | Muscle strength (upper/lower), VO2 peak | 8/11 |
| 22 | Selig, 2004 | RCT | 65±13 | 19/20 | 27 | I - IV | Warm-up/cool-down: 5 min, moderate intensity: 2 min, RT: 7 min | 3/12 | Usual care | Muscle strength (upper/lower), VO2 peak | 8/11 |
| 23 | Senden, 2005 | RCT | 59.8±9.3 | 25/36 | 29 | II, III | Warm-up: 3 min, RT: 11 min, endurance training: 6 min, cool-down: 5 min | 3/26 | Usual care | Muscle strength (upper), VO2 peak | 9/11 |

I/C: intervention/control; F/D: frequency/duration; ST: strength training, RT: resistance training, min: minute, RM: repetition maximum; HIIT: high-intensity interval training; FTG: functional training group; MIPRT: moderate-intensity inspiratory and peripheral resistance training; LIPRT: low-intensity inspiratory and peripheral resistance training; IMT: inspiratory muscle training

**Table 2.** Upper limb

| Study or Subgroup | Experimental Mean | Experimental SD | Experimental Total | Control Mean | Control SD | Control Total | Weight | Std. Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| **2.1.1 Middle-age** | | | | | | | | |
| Selig, 2004 | 121 | 43 | 15 | 119 | 39 | 17 | 6.1% | 0.05 [-0.65, 0.74] |
| Senden, 2005 | 456.9 | 176.4 | 25 | 417.8 | 133.4 | 36 | 7.0% | 0.25 [-0.26, 0.77] |
| Feiereisen, 2007 | 113 | 30 | 15 | 98 | 26 | 15 | 5.9% | 0.52 [-0.21, 1.25] |
| Gary 2012 | 35.1 | 9 | 12 | 24.2 | 16 | 12 | 5.3% | 0.81 [-0.03, 1.65] |
| Barnard, 2000 | 47.2 | 7.9 | 14 | 39.6 | 6.5 | 7 | 4.8% | 0.97 [0.01, 1.94] |
| Kawauchi, 2017 | 279 | 75 | 13 | 204 | 45 | 9 | 4.9% | 1.12 [0.19, 2.04] |
| Beckers 2008 | 13.2 | 2.8 | 28 | 7.8 | 1.5 | 30 | 6.1% | 2.40 [1.71, 3.08] |
| Maiorana, 2000 | 462 | 22 | 6 | 392 | 26 | 7 | 2.5% | 2.68 [1.04, 4.33] |
| **Subtotal (95% CI)** | | | **128** | | | **133** | **42.7%** | **1.00 [0.37, 1.64]** |
| Heterogeneity: Tau² = 0.64; Chi² = 35.82, df = 7 (P < 0.00001); I² = 80% | | | | | | | | |
| Test for overall effect: Z = 3.10 (P = 0.002) | | | | | | | | |
| **2.1.2 Elderly** | | | | | | | | |
| Palevo, 2009 | 46 | 21 | 10 | 42 | 13 | 9 | 5.0% | 0.22 [-0.69, 1.12] |
| Mandic, 2009b | 48.5 | 16 | 12 | 42.8 | 19.3 | 13 | 5.6% | 0.31 [-0.48, 1.10] |
| Barnard, 2000 | 42.7 | 8.9 | 14 | 40 | 6 | 12 | 5.6% | 0.34 [-0.44, 1.12] |
| Jonsdottir, 2006 | 14.1 | 3.2 | 21 | 13 | 2.9 | 22 | 6.6% | 0.35 [-0.25, 0.96] |
| do Nascimento, 2023 | 32.4 | 9.4 | 13 | 28.4 | 9.1 | 14 | 5.7% | 0.42 [-0.35, 1.18] |
| Mandic, 2009a | 48.5 | 16 | 12 | 40.8 | 17.3 | 12 | 5.5% | 0.45 [-0.37, 1.26] |
| Borland, 2014 | 38 | 19 | 22 | 26 | 12 | 20 | 6.4% | 0.73 [0.11, 1.36] |
| Ma, 2021 | 24.26 | 2.18 | 68 | 21.57 | 2.28 | 68 | 7.8% | 1.20 [0.83, 1.57] |
| Laotaris, 2013 | 24.6 | 3.6 | 13 | 20.2 | 1.2 | 14 | 5.1% | 1.62 [0.73, 2.50] |
| Pu 2001 | 123 | 11 | 9 | 103 | 11 | 8 | 4.0% | 1.73 [0.57, 2.89] |
| **Subtotal (95% CI)** | | | **194** | | | **192** | **57.3%** | **0.72 [0.39, 1.04]** |
| Heterogeneity: Tau² = 0.13; Chi² = 18.52, df = 9 (P = 0.03); I² = 51% | | | | | | | | |
| Test for overall effect: Z = 4.32 (P < 0.0001) | | | | | | | | |
| **Total (95% CI)** | | | **322** | | | **325** | **100.0%** | **0.82 [0.51, 1.13]** |
| Heterogeneity: Tau² = 0.29; Chi² = 54.40, df = 17 (P < 0.00001); I² = 69% | | | | | | | | |
| Test for overall effect: Z = 5.15 (P < 0.00001) | | | | | | | | |
| Test for subgroup differences: Chi² = 0.62, df = 1 (P = 0.43), I² = 0% | | | | | | | | |

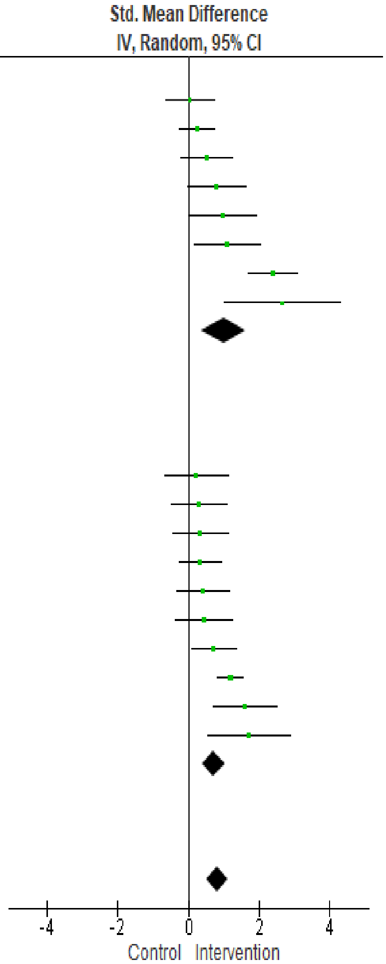


**Table 3.** Lower limb

| Study or Subgroup | Intervention Mean | Intervention SD | Intervention Total | Control Mean | Control SD | Control Total | Weight | Std. Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| **2.2.1 Middle-age** | | | | | | | | |
| Alshamari, 2023 | 57 | 20 | 19 | 52 | 19 | 25 | 6.8% | 0.25 [-0.35, 0.85] |
| Barnard, 2000 | 69.1 | 14.1 | 14 | 54.2 | 13.6 | 7 | 5.1% | 1.03 [0.06, 2.00] |
| Beckers 2008 | 12.8 | 1.4 | 28 | 10.9 | 1.7 | 30 | 7.0% | 1.20 [0.64, 1.76] |
| Feiereisen, 2007 | 113 | 30 | 15 | 98 | 26 | 15 | 6.2% | 0.52 [-0.21, 1.25] |
| Gary 2012 | 37.8 | 10 | 12 | 31 | 9 | 12 | 5.7% | 0.69 [-0.14, 1.52] |
| Kawauchi, 2017 | 69 | 28 | 13 | 16 | 11 | 9 | 4.5% | 2.24 [1.12, 3.36] |
| Laotaris, 2013 | 24.6 | 3.6 | 13 | 20.2 | 1.2 | 14 | 5.5% | 1.62 [0.73, 2.50] |
| Selig, 2004 | 111 | 37 | 15 | 110 | 32 | 17 | 6.4% | 0.03 [-0.67, 0.72] |
| **Subtotal (95% CI)** | | | **129** | | | **129** | **47.3%** | **0.87 [0.41, 1.33]** |
| Heterogeneity: Tau² = 0.28; Chi² = 20.31, df = 7 (P = 0.005); I² = 66% | | | | | | | | |
| Test for overall effect: Z = 3.71 (P = 0.0002) | | | | | | | | |
| **2.2.2 Elderly** | | | | | | | | |
| Borland, 2014 | 18 | 6 | 22 | 6 | 7 | 20 | 6.2% | 1.81 [1.08, 2.54] |
| Ellis, 2020a | 49.88 | 6.7 | 16 | 46.97 | 6.89 | 15 | 6.3% | 0.42 [-0.30, 1.13] |
| Ellis, 2020b | 55.23 | 6.98 | 15 | 46.97 | 6.89 | 16 | 6.0% | 1.16 [0.39, 1.93] |
| Laoutaris, 2021b | 30.1 | 5.4 | 17 | 21.9 | 5.7 | 18 | 6.1% | 1.44 [0.69, 2.20] |
| Laoutaris. 2021a | 29.8 | 5.6 | 19 | 21.9 | 5.7 | 18 | 6.2% | 1.37 [0.64, 2.09] |
| Maiorana, 2000 | 462 | 22 | 6 | 392 | 26 | 7 | 2.9% | 2.68 [1.04, 4.33] |
| Mandic, 2009a | 51.5 | 16.8 | 12 | 41.8 | 18.9 | 12 | 5.8% | 0.52 [-0.29, 1.34] |
| Mandic, 2009b | 51.5 | 16.8 | 12 | 46.3 | 18.8 | 13 | 5.9% | 0.28 [-0.51, 1.07] |
| Palevo, 2009 | 71 | 14 | 10 | 65 | 14 | 7 | 5.1% | 0.41 [-0.57, 1.39] |
| Pu 2001 | 248 | 30 | 9 | 131 | 18 | 7 | 2.2% | 4.33 [2.34, 6.32] |
| **Subtotal (95% CI)** | | | **138** | | | **133** | **52.7%** | **1.20 [0.69, 1.71]** |
| Heterogeneity: Tau² = 0.45; Chi² = 30.14, df = 9 (P = 0.0004); I² = 70% | | | | | | | | |
| Test for overall effect: Z = 4.60 (P < 0.00001) | | | | | | | | |
| **Total (95% CI)** | | | **267** | | | **262** | **100.0%** | **1.04 [0.70, 1.38]** |
| Heterogeneity: Tau² = 0.35; Chi² = 52.71, df = 17 (P < 0.0001); I² = 68% | | | | | | | | |
| Test for overall effect: Z = 5.96 (P < 0.00001) | | | | | | | | |
| Test for subgroup differences: Chi² = 0.87, df = 1 (P = 0.35), I² = 0% | | | | | | | | |

Std. Mean Difference IV, Random, 95% CI

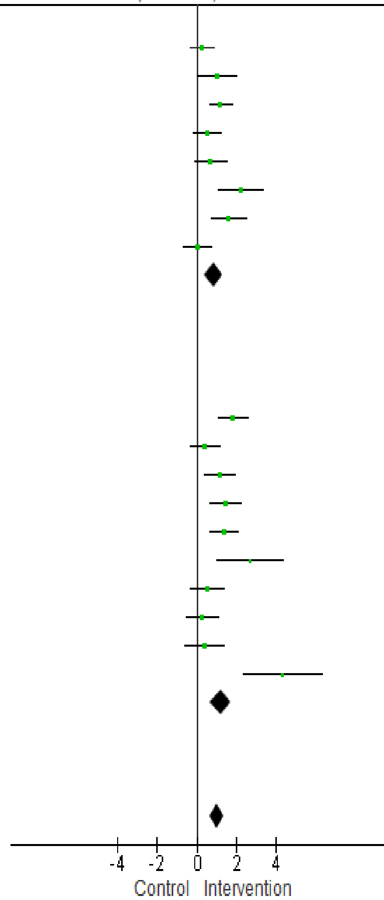
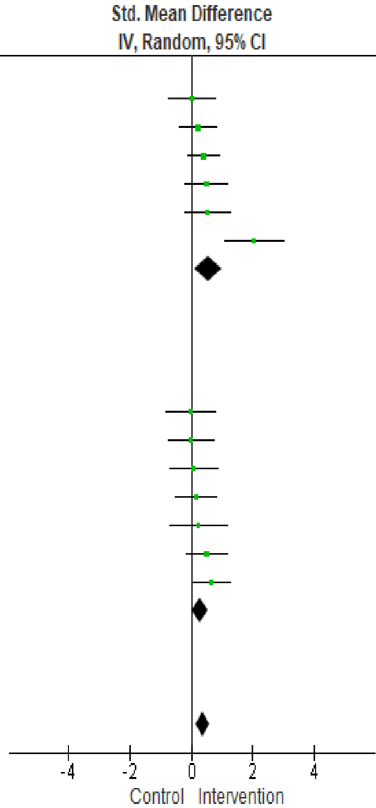


**Table 4.** VO2 peak

| | Intervention | | | Control | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI |
| **3.1.1 Middle-age** | | | | | | | | |
| Laotaris, 2013 | 19.6 | 6.2 | 13 | 19.5 | 4.1 | 14 | 7.1% | 0.02 [-0.74, 0.77] |
| Alshamari, 2023 | 21.5 | 7.3 | 19 | 20.1 | 4.3 | 25 | 9.7% | 0.24 [-0.36, 0.84] |
| Beckers 2008 | 2.1 | 0.7 | 28 | 1.9 | 0.1 | 30 | 11.4% | 0.40 [-0.12, 0.92] |
| Selig, 2004 | 16.9 | 3.8 | 14 | 14.9 | 4 | 19 | 7.8% | 0.50 [-0.20, 1.20] |
| Feiereisen, 2007 | 15.6 | 3.3 | 15 | 14 | 2.4 | 15 | 7.4% | 0.54 [-0.19, 1.27] |
| Senden, 2005 | 20.9 | 4.2 | 17 | 12.8 | 3.2 | 11 | 4.9% | 2.04 [1.09, 3.00] |
| **Subtotal (95% CI)** | | | **106** | | | **114** | **48.3%** | **0.55 [0.11, 1.00]** |
| Heterogeneity: Tau² = 0.18; Chi² = 12.52, df = 5 (P = 0.03); I² = 60% | | | | | | | | |
| Test for overall effect: Z = 2.43 (P = 0.02) | | | | | | | | |
| **3.1.2 Elderly** | | | | | | | | |
| Mandic, 2009a | 17.2 | 6.9 | 12 | 17.3 | 6.4 | 12 | 6.5% | -0.01 [-0.81, 0.79] |
| do Nascimento, 2023 | 18.6 | 5.5 | 13 | 18.6 | 4.8 | 14 | 7.1% | 0.00 [-0.75, 0.75] |
| Mandic, 2009b | 17.2 | 6.9 | 12 | 16.7 | 6.1 | 13 | 6.7% | 0.07 [-0.71, 0.86] |
| Laoutaris, 2021b | 18.8 | 5.4 | 17 | 18 | 4.3 | 18 | 8.5% | 0.16 [-0.50, 0.82] |
| Pu 2001 | 15.08 | 1.62 | 9 | 14.75 | 0.94 | 9 | 5.1% | 0.24 [-0.69, 1.17] |
| Laoutaris. 2021a | 20.4 | 4.9 | 19 | 18 | 4.3 | 18 | 8.6% | 0.51 [-0.15, 1.16] |
| Jonsdottir, 2006 | 17.19 | 4.05 | 22 | 14.76 | 3.02 | 21 | 9.3% | 0.67 [0.05, 1.28] |
| **Subtotal (95% CI)** | | | **104** | | | **105** | **51.7%** | **0.28 [0.00, 0.55]** |
| Heterogeneity: Tau² = 0.00; Chi² = 3.41, df = 6 (P = 0.76); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 1.97 (P = 0.05) | | | | | | | | |
| **Total (95% CI)** | | | **210** | | | **219** | **100.0%** | **0.39 [0.15, 0.62]** |
| Heterogeneity: Tau² = 0.05; Chi² = 17.08, df = 12 (P = 0.15); I² = 30% | | | | | | | | |
| Test for overall effect: Z = 3.22 (P = 0.001) | | | | | | | | |
| Test for subgroup differences: Chi² = 1.07, df = 1 (P = 0.30), I² = 6.8% | | | | | | | | |



# ผลของการฝึกออกกำลังกายด้วยแรงต้านต่อความแข็งแรงของกล้ามเนื้อและอัตราการใช้ออกซิเจนสูงสุดของร่างกายขณะออกกำลังกายในผู้ป่วยวัยกลางคนและสูงอายุที่มีภาวะหัวใจล้มเหลว : การวิเคราะห์อภิมาน

*Loura Caroline Korengkeng, Elisa Anderson, Ailine Yoan Sanger, Denny Maurits Ruku**

**บทคัดย่อ:** มาตรการการช่วยเหลือโดยใช้การฝึกออกกำลังกายด้วยแรงต้านสำหรับผู้ที่เป็นโรคหัวใจล้มเหลวที่ผ่านมามีจำนวนมาก แต่ประสิทธิผลโดยรวมของการฝึกออกกำลังกายด้วยแรงต้านในการเพิ่มความแข็งแรงของกล้ามเนื้อและอัตราการใช้ออกซิเจนสูงสุดของร่างกายขณะออกกำลังกายตามอายุนั้น ยังไม่สามารถสรุปได้ การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาประสิทธิผลของการฝึกออกกำลังกายด้วยแรงต้านต่อความแข็งแรงของกล้ามเนื้อและอัตราการใช้ออกซิเจนสูงสุดของร่างกายขณะออกกำลังกาย ในผู้ที่มีภาวะหัวใจล้มเหลวโดยพิจารณาตามอายุ ในการทบทวนงานวิจัยครั้งนี้ ผู้ศึกษาสืบค้นงานวิจัยจาก 5 ฐานข้อมูล ได้แก่ Embase, CINHAL, MEDLINE, Cochrane, และ PEDro ตลอดจนสืบค้นข้อมูลเพิ่มเติมจาก Google Scholar ในช่วงปี ค.ศ. 2000 ถึง 2023 ผู้ศึกษาได้คำนวณผลต่างค่าเฉลี่ยมาตรฐานและช่วงความเชื่อมั่น 95% และตรวจสอบอคติจากการตีพิมพ์ด้วยวิธี Egger'test โดยใช้ซอฟต์แวร์ RevMan 5.4 ส่วนการตรวจสอบคุณภาพของงานวิจัย ใช้เกณฑ์ของ the Critical Appraisal Skills Programme

ผลการศึกษาแสดงให้เห็นว่างานวิจัยเชิงทดลองแบบสุ่มและมีกลุ่มควบคุมทั้งหมด 23 ฉบับ เป็นไปตามเกณฑ์การคัดเลือกซึ่งประกอบด้วยผู้ตอบแบบสอบถาม 830 คน โดย 422 คนอยู่ในกลุ่มทดลอง และ 408 คนอยู่ในกลุ่มควบคุม ในกลุ่มย่อยวัยกลางคน การฝึกออกกำลังกายด้วยแรงต้านได้ผลต่อการเพิ่มความแข็งแรงของกล้ามเนื้อบริเวณแขนส่วนบนและส่วนล่างอย่างมีนัยสำคัญ ในทำนองเดียวกัน การฝึกออกกำลังกายด้วยแรงต้านก็ส่งผลต่อการเพิ่มความแข็งแรงของกล้ามเนื้อบริเวณแขนส่วนบนและส่วนล่างในกลุ่มย่อยวัยสูงอายุเช่นเดียวกัน นอกจากนี้ พบว่าการฝึกออกกำลังกายด้วยแรงต้านเพิ่มอัตราการใช้ออกซิเจนสูงสุดของร่างกายขณะออกกำลังกายอย่างมีนัยสำคัญทั้งในผู้ป่วยวัยกลางคนและสูงอายุที่มีภาวะหัวใจล้มเหลว การฝึกออกกำลังกายด้วยแรงต้าน ถือว่าเป็นวิธีหนึ่งที่มีประสิทธิผลในการเพิ่มความแข็งแรงของกล้ามเนื้อและอัตราการใช้ออกซิเจนสูงสุดของร่างกายขณะออกกำลังกาย ดังนั้น จึงควรแนะนำให้เป็นส่วนหนึ่งของการฟื้นฟูสมรรถภาพสำหรับผู้ที่เป็นโรคหัวใจล้มเหลว นอกจากนี้ ควรพิจารณาองค์ประกอบของโปรแกรมการฝึกออกกำลังกายด้วยแรงต้านที่สามารถเพิ่มได้สูงสุดโดยพิจารณาให้เหมาะสมกับอายุของผู้ป่วยด้วย

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