



## Minimally supervised home-based resistance training and muscle function in older adults: A meta-analysis



Ofer Kis<sup>a,b</sup>, Assaf Buch<sup>b,c,d,\*</sup>, Naftali Stern<sup>b,c</sup>, Daniel S. Moran<sup>a</sup>

<sup>a</sup> The Faculty of Health Sciences, Ariel University, Ariel, Israel

<sup>b</sup> Institute of Endocrinology, Metabolism and Hypertension, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel

<sup>c</sup> The Sackler Faculty of Medicine, Tel Aviv University, Israel

<sup>d</sup> Robert H Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel

### ARTICLE INFO

#### Keywords:

Minimally supervised home-based resistance training  
Lower body strength  
Upper body strength  
Timed get up and go test

### ABSTRACT

In an attempt to define feasible means to improve compliance with current recommendations on resistance training in older subjects, published evidence on the efficacy and safety of minimally supervised home-based resistance training (MSHBRT) on muscle strength and functionality was systematically evaluated in this population segment for the first time. We performed a meta-analysis using the following data sources: MEDLINE (Ovid), EMBASE and Cochrane, with a total of 1160 subjects with a mean age of  $72 \pm 6.3$  years. MSHBRT modestly increased lower body strength (MD 0.6 Kg, 95% CI, 0.16–1.04) in a diverse population of older adults including subjects with significant age-related diseases. Although earlier evidence indicates that larger increments in muscle performance and function can be attained through more intense and directly supervised resistance training, MSHBRT may comprise a useful and inexpensive method to preserve and even enhance lower body muscle strength in older adults.

### 1. Background

The increase in longevity over the past several decades has expectedly resulted in increased incidence of late-life chronic diseases; which can challenge mobility and the ability to perform activities of daily life (Dugoff, Canudas-Romo, Buttorff, Leff, & Anderson, 2014), increasing the burden on an already thinly stretched healthcare system (Cesari et al., 2016).

To effectively address these trends, resistance training (RT) comprises a potentially important measure to reduce sarcopenia and functional disability (Cruz-Jentoft et al., 2014; Papa, Dong, & Hassan, 2017), both prevalent conditions in older adults (Da Silva Alexandre, de Oliveira Duarte, Ferreira Santos, Wong, & Lebrão, 2014). Still only ~22% of older adults in the United States actually comply with muscle-strengthening guidelines (Centers for Disease Control and Prevention (CDC) (2013)). To retard frailty, new and low-cost strategies such as home-based exercises (Kirkland & Peterson, 2009) have been implemented, increasing both muscle strength and function. Such programs diminish the need for transportation and facilities, thus reducing

potential barriers to exercise (Schutzer & Graves, 2004). In order to increase adherence to such programs, phone calls and internet-based strategies have been successfully used (Geraedts, Zijlstra, Bulstra, Stevens, & Zijlstra, 2013).

Two studies have partially addressed the subject of the rate of supervision of RT on outcome measures: the first is a review with high supervision rates (up to 66%) (Thiebaud, Funk, & Abe, 2014), whilst the second is a meta-analysis (Lacroix, Hortobágyi, Beurskens, & Granacher, 2017) with mildly supervised rates (up to 33%), that included healthy subjects exclusively as well as non-RT studies (aerobic exercises and Tai Chi).

Whether MSHBRT is beneficial in healthy older subjects, and in comparison, to those with age-related diseases, is presently unknown. Hence, the effect of a truly minimally supervised ( $\leq 15\%$  of RT sessions) home-based RT on both populations remains to be assessed.

The primary aim of this meta-analysis was to evaluate for the first time, the effect of a MSHBRT programs in diverse populations of older adults with respect to upper body strength (UBS), lower body strength (LBS) and functional ability ["Timed up and go test" (TUG)]. Secondary

*Abbreviations:* AEs, adverse events; HBRT, home-based resistance training; LBS, lower body strength; MD, mean differences; MSHBRT, (minimally supervised HBRT); RCT, randomized control trials; RPE, rating of perceived exertion; RT, resistance training; TUG, timed up and go test; UBS, upper body strength

\* Corresponding author at: The Institute of Endocrinology, Metabolism and Hypertension, Tel Aviv-Sourasky Medical Center, 6 Weizmann St., Tel-Aviv 64239, Israel.

E-mail addresses: [oferkis58@gmail.com](mailto:oferkis58@gmail.com) (O. Kis), [buchasaf@gmail.com](mailto:buchasaf@gmail.com) (A. Buch), [naftalis@tlvmc.gov.il](mailto:naftalis@tlvmc.gov.il) (N. Stern), [Dani.Moran@sheba.health.gov.il](mailto:Dani.Moran@sheba.health.gov.il) (D.S. Moran).

<https://doi.org/10.1016/j.archger.2019.103909>

Received 20 March 2019; Received in revised form 11 June 2019; Accepted 5 July 2019

Available online 08 July 2019

0167-4943/ © 2019 Elsevier B.V. All rights reserved.

aims were to evaluate the effect of these programs in relation to the health status of the participants within the trials, as well as the level of contact with participating patients, exercise intensity, exercise volume and total program duration.

## 2. Material and methods

This meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement 11 (Liberati et al., 2009) and the Cochrane Handbook for Systematic Reviews (Higgins & Green, 2011).

### 2.1. Search strategy

We systematically searched the following electronic databases up to Dec 2018: MEDLINE (Ovid), EMBASE and Cochrane. The search was comprised of the following exercise-related terms: home based; unsupervised; minimally-supervised; autonomous; weight; lift or bear; training; resistance or strength; all with limitations to older adults. We did not limit the search by language, only one abstract was not in English (excluded -could not be found). Contact with researchers (via e-mail and/or Research Gate) was made in case the article was not available. Reference lists of the included trials were also searched manually. The same was applied to the search for systematic reviews and meta-analyses. For full search strategy please see Supplementary Text S1.

### 2.2. Eligibility criteria

A priori criteria were developed based on the "Participants, Intervention, Comparison, Outcomes and Setting" approach (PICOS) (Liberati et al., 2009). Randomized control trials (RCT) reporting a minimal direct supervision/home visit by a trainer or researcher ( $\leq 15\%$  of exercise sessions), with participants being older adults ( $\geq 60$  years by range or mean  $\geq 60$  years with  $SD \leq 10$ ). Studies were eligible for both men and women with any medical condition and a moderate background of physical activity ( $\leq 3$  times a week of moderate exercise, excluding RT). The intervention had to be structured in such a manner, so that patients were engaged in a planned, individualized program of RT lasting  $\geq 8$  weeks; at least once weekly, performed at any intensity, with any equipment (i.e., weights, bands, body weight, weighted vests), without concurrent aerobic workout, unless a parallel aerobic workout was performed in the control group also. Eligible intervention studies were included only if a control group (follow up or counseling, but no active workout) was also part of the report. To be included, studies had to report at least one of the following outcomes: measured LBS (e.g., RM1, isokinetic/ isometric knee extension/ flexion) and/ or UBS (grip strength), and/ or TUG. We were unable to analyze additional outcomes of interest such as sarcopenia/ frailty and/ or other specific functional tests and/ or anthropometric data as they were not reported sufficiently in the studies that qualified to be included in this meta-analysis. We refrained from including other clinical strength or function tests to keep the unity of the measures as much as possible. Duplicate publications or sub-studies of included trials were excluded, such that only the article with the most definitive and extractable information was used.

### 2.3. Data extraction

Titles, abstracts and then relevant complete articles' texts were evaluated for the eligibility criteria by the primary study's investigator (not blinded to authors, institutions, or manuscript journals) who is an expert in the field of physical exercise. Based on eligibility criteria "first no" response was documented as the main reason for excluding the study. A second investigator who is a methodologist reviewed the full articles that were excluded to verify their exclusion justification (no disagreement occurred at this stage). The included articles were

retrieved by both investigators together and data extraction sheet was formed. See also Supplementary Text S2.

### 2.4. Risk of Bias in individual studies

Risk of bias was evaluated according to the "Cochrane collaboration's tool for assessing risk of bias" (Higgins, Altman, & Sterne, 2011) and followed by the PRISMA statement 11 (Liberati et al., 2009). Quality assessment was independently performed by the two reviewers and disagreements were designated to be solved by consensus or by a third reviewer. For further explanation on risk of bias assessment please see Supplementary Text S3.

### 2.5. Data analyses

#### 2.5.1. Summary measures

All outcomes in this meta-analysis are continuous (presented as means  $\pm$  standard deviations [SD]). Adverse events (AEs) were considered as any clinical event, sign or symptom that goes in an unwanted direction (Friedman, Furberg, DeMets, Reboussin, & Granger, 2010). AEs were counted in each study and in both groups and stratified by their severity: serious AEs (hospitalization or any serious episode such as cardiac episodes or surgery) or other AEs (such as musculoskeletal disturbance). The primary outcome was the difference in muscle strength (in kg) between intervention and control (LBS and UBS assessed separately). Also, differences in TUG (in seconds) were evaluated. Mean differences (MDs) were calculated for each outcome (for more information, please see Supplementary Text S4).

#### 2.5.2. Synthesis of results

The main analysis includes all eligible RCTs and was performed using Review manager 5.3 (Review Manager (RevMan) (2014)). An  $\alpha$  value  $< .05$  was considered statistically significant. Heterogeneity was explored utilizing the statistical test of homogeneity, P values and  $I^2$  statistic, with values higher than 50% considered as indicative of high heterogeneity. Random effects methods were used due to variability in some factors across studies and because random-effects models yield more-conservative estimates over fixed-effect in the setting of between-studies heterogeneity.

### 2.6. Risk of bias across studies

Publication bias was detected using funnel plot of each trial's effect size against the standard error. The symmetry of each funnel plot was assessed visually and by the Begg and Egger Tests. A significant publication bias was considered if the P value was less than .10 (Egger, Davey Smith, Schneider, & Minder, 1997). Selective reporting bias was assessed within each study (as mentioned in "risk of bias in individual studies"). Studies were not excluded from the analysis based on publication bias, as publication bias is difficult to exclude or verify from the results, when only a few studies are available (Liberati et al., 2009).

### 2.7. Additional analyses

**Sensitivity analysis** was performed with the inclusion of studies which presented relatively lower risk of bias, as evaluated in the validity assessment. We included only studies with less than 3 components of "unknown risk of bias" (excluding the "other bias component"). This was done to assess if the overall effect was biased in the main analysis which included all studies. Finally, we excluded the studies reporting on DVD-recorded instruction (Jette et al., 1996, 1999) as opposed to personal, face-to-face instruction, in order to assess if the modality of exercise instruction was associated with effect on the outcomes (relevant for LBS and TUG only). **Sub-analyses** were performed to assess whether the effect of intervention was mediated or attributed to workout intensity [studies with high or medium intensity vs. studies

with low intensity; defined either by rating of perceived exertion (RPE) (Borg scale 6-20: low,  $\leq 9$ ; medium/high,  $\geq 10$ ) (Tiggemann et al., 2016) or by adjectives describing effort (i.e.: hard, maximizing effort). We also analyzed the data according to program duration (low duration vs. high duration;  $\leq 3$  vs.  $> 3$  months respectively). In addition, we analyzed the effect of the level of contact (low vs. high contact; less than 1 contact/ month vs.  $\geq 1$  contact/ month, respectively; all defined as phone call or meeting with the trainer). Since balance exercise can increase muscle strength and functionality, thus confounding attempts to discern the direct effects of RT per se (Avelar et al., 2016), we performed a sub-analysis that compared studies that combined RT and balance exercises vs. studies that included only RT. Furthermore, we assessed the total weekly exercise volume performed by the subjects and evaluated its effect on the outcome measured (low vs. high volume, defined as  $\leq 30$  vs.  $> 30$  sets per week, respectively). Finally, we sub-analyzed the data according to health status of the participants in the surveyed trials.

### 3. Results

#### 3.1. Study selection

A total of 787 articles were identified using the three search engines, of which 434 were excluded by the contents of the abstract. Full texts of 112 articles were retrieved after the preliminary eligibility screening, with additional identification of 5 eligible articles using their references lists. In 32 of the identified studies we detected a potential carryover effect, in which the intervention was carried out after another intervention, raising the possibility of interaction. These specific studies were therefore excluded. Eventually, a total of 12 articles were found eligible for inclusion in the meta-analysis (Allen et al., 2010; Clegg, Barber, Young, Iliffe, & Forster, 2014; Clemson et al., 2012; Jette et al., 1996, 1999; Kamide, Shiba, & Shibata, 2009; Kanemaru et al., 2010;

Lacroix et al., 2016; Nelson et al., 2004; Sosnoff, Finlayson, McAuley, Morrison, & Motl, 2014; Østerås et al., 2014; Vuorenmaa et al., 2014) (Fig. 1).

#### 3.2. Study characteristics

Included studies had a total of 1160 subjects, with 578 subjects in the MSHBRT group and 582 in the control group. Most studies (9/12) included subjects with diverse health conditions ( $n = 963$ ; 83%). The health conditions included frailty [7%] (Clegg et al., 2014), functional limitations and overweight [25%] (Jette et al., 1999; Nelson et al., 2004), frequent falls [18%] (Clemson et al., 2012), hand osteoarthritis and overweight [11%] (Østerås et al., 2014), knee arthroplasty and obesity [9%] (Vuorenmaa et al., 2014), osteoporosis [6%] (Kanemaru et al., 2010), multiple sclerosis [2%] (Sosnoff et al., 2014), Parkinson disease [4%] (Allen et al., 2010) including additional health conditions (Table 1); while the rest were healthy older adults. All 12 studies were in the form of RCTs. Except for one control group that performed sham gentle exercise (Clemson et al., 2012), all other groups maintained their habitual lifestyle. The major characteristics of all studies are summarized in Table 1. The average age across studies was  $72 \pm 6.5$  years in the RT group and  $72 \pm 6$  years in the control group. The overall F/M ratio was 2.25, compiled from two female-based trials (Kamide et al., 2009; Kanemaru et al., 2010) and 10 mixed female/male studies. Most studies were progressive resistance training programs (PRT) (75%) using mostly body weight and elastic band exercises, and 50% included some type of balance exercises as well. None of the studies included structured aerobic type of activity, except for a single study prescribing a single exercise (stepping in place) with a negligible amount of aerobic work (Clegg et al., 2014). The modes of intensity and contact level were as follows: four studies reporting low intensity; six studies reporting medium/high intensity (two did not report the intensity level). Within our definition of minimally supervised, five studies had "high" level of

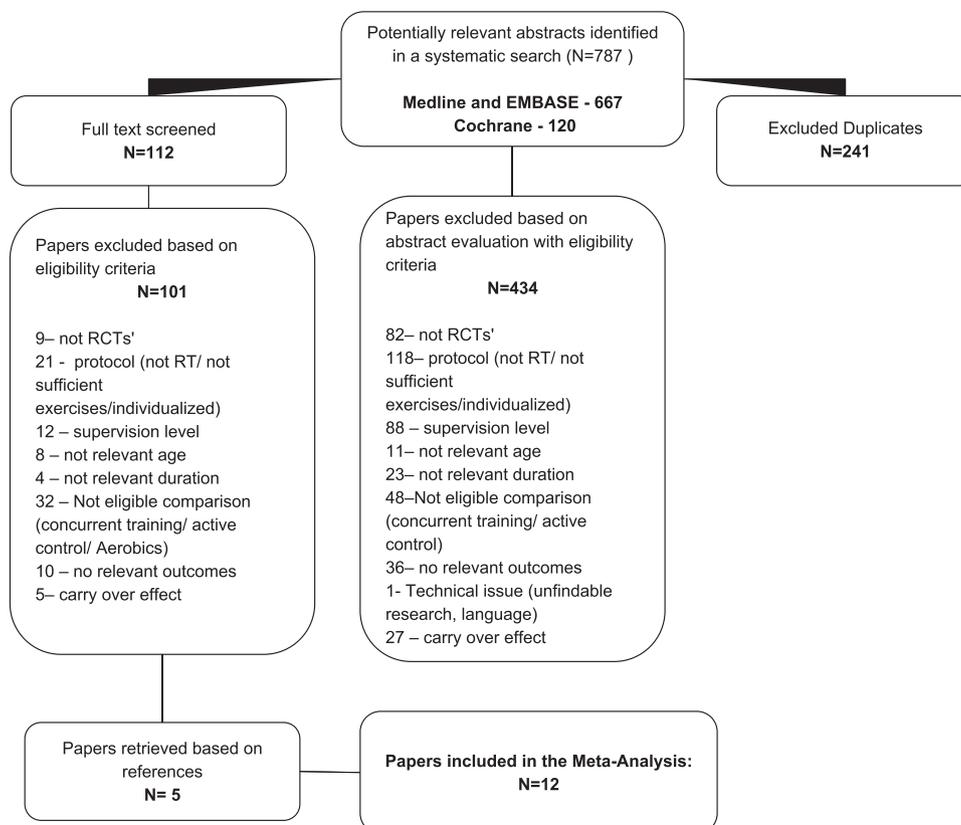


Fig. 1. Flow of screening process.

**Table 1**  
Summary of main characteristics of the included studies.

Source; country	Population Age (years)	MSHBRT -N (% females)	Control -N (%females)	Total Sessions*	Intensity <sup>†</sup> (RPE/effort level)	Contact level <sup>‡</sup>	Adherence (% in MSHBRT) MSHBRT; % in control) Compliance to workout (% in MSHBRT)	Volume <sup>§</sup>	Description of RT exercises (MSHBRT) <sup>  </sup>
Jette et al. (1996). <i>Journal of the American Geriatrics Society</i> ; Boston, USA	Non-disabled MSHBRT, 71; control, 73.2	45 (54.8)	51 (70.6); Follow up	3*12-15	Low	Moderate	MSHBRT, 84 Control, 98 MSHBRT, 58	High	10 exercises Description NR B+; PRT+
Jette et al. (1999). <i>American journal of public health</i> ; Boston, USA	Functional Limitations MSHBRT, 75.4; control, 74.6	107 (72.9)	108 (82.4); Follow up	3*24	Low	Moderate	MSHBRT, 93 Control, 93 MSHBRT, 89	High	11 exercises Description NR B+; PRT+
Clegg et al. (2014). <i>Age and Aging</i> ; Bradford, UK	Frail MSHBRT, 79.4; control, 78	45 (73)	39 (69); Follow up	5(3/day) +24	Low	High	MSHBRT, 70 Control, 77 MSHBRT, 46	High	1) chair rise 2) wall press-up 3) single leg calf raise 4) leg back and side raise B+; PRT+
Kamide et al. (2009). <i>Journal of physiological anthropology</i> ; Kanagawa, Japan	Older women MSHBRT, 71; control, 70.9	28 (100)	29 (100)	3*24	Medium/high	Low	MSHBRT, 82.2 Control, 93.1 MSHBRT, 82.6	Low	4 exercises Description NR B+; PRT-
Nelson et al. (2004). <i>The journals of gerontology. Series A, Biological sciences and medical sciences</i> ; Boston, USA	Functional limitations Overweight MSHBRT, 77.7; control, 77.8	34 (27)	38 (30); Follow up	3*24	Medium/high	High	MSHBRT, 94.2 Control, 100 MSHBRT, 82	High	1) chair stand 2) knee extension 3) standing hip extension 4) standing hip abduction 5) overhead press 6) biceps curl 7) triceps extension B+; PRT+
Sosnoff et al. (2014). <i>Clinical Rehabilitation</i> ; Virginia, USA	Multiple Sclerosis MSHBRT, 60.1; control, 60.1	13 (23)	14 (21); Follow up	3*12	Medium/high	High	MSHBRT, 77 Control, 85.8	Low	1) squat 2) leg abduction 3) abdominal crunch 4) seated twist B+; PRT+
Kanemaru et al. (2010). <i>Archives of gerontology and geriatrics</i> ; Tokyo, Japan	Osteoporotic Women MSHBRT, 74.7; control, 74.3	37 (100)	32 (100)	7*52	Low	Low	MSHBRT, 68 Control, 100	NR	NR B+; PRT-
Lacroix et al. (2016). <i>Gerontology</i> ; Poitsdam, Germany	Healthy MSHBRT, 73.1; control, 72.2	22 (63)	22 (59)	3*12	Medium/high	High	MSHBRT, NR Control, 91 MSHBRT, 97.4	High	1) squats 2) plank 3) standing side leg - lifts 4) calf raise 5) standing trunk extensions B+; PRT+
Clemson et al. (2012). <i>BMJ (Clinical research ed.)</i> ; Sydney, Australia	Older with falls Stroke 13% Chronic Illness 57% MSHBRT, 84.03; control 83.47	105 (54.3)	105 (55.2)	3*48	Medium/high	Low	MSHBRT, 53 Control, 53 MSHBRT, 35	NR	1) standing and walking on toes 2) standing and walking on heels 3) walking up stairs 4) sit to stand B+; PRT+
Vuorenmaa et al. (2014). <i>Journal of rehabilitation medicine</i> ; Jyväskylä, Finland	Primary total knee arthroplasty Obesity CVD 22% Diabetes 17% Pulmonary Disease 11% MSHBRT, 69; control, 69	53 (57)	55 (65)	3*48	NR	Low	MSHBRT, 96 Control, 96 MSHBRT, 49	Low	1) chair raises 2) step up 3) isometric knee extension 4) isometric knee flexion 5) wall slide 6) toe raises B+; PRT+
Østerås et al. (2014). <i>Osteoarthritis Cartilage</i> ; Oslo, Norway	Hand osteoarthritis Overweight Chronic diseases 34% MSHBRT, 67; control, 65	65 (89)	65 (91)	3*12 <sup>e</sup>	Medium/high	High	MSHBRT, 97 Control, 97 MSHBRT, 88	Low	1) shoulder extension 2) biceps curl 3) shoulder flexion 4) make an "O-sign 5) roll into a fist 6) thumb abduction/extension 7) grip strength B+; PRT-

(continued on next page)

Table 1 (continued)

Source; country	Population Age (years)	MSHBRT -N (% females)	Control -N (%females)	Total Sessions *	Intensity † (RPE/effort level)	Contact level ‡	Adherence (% in MSHBRT; % in control) Compliance to workout (% in MSHBRT)	Volume §	Description of RT exercises (MSHBRT)
Allen et al. (2010) Movement Disorders Sydney, Australia	Parkinson's Disease MSHBRT, 66; control, 68	24 (46%)	24 (46%)	3 *24	NR	Low	MSHBRT, 88 Control, 100 MSHBRT, 70	NR	NR

Abbreviations: MSHBRT, Minimally Supervised Home-Based Resistance Training; NR, Not Reported; RPE, Rate of Perceived Exertion. \*- calculated as: frequency (times per week) × duration (weeks); †- calculated as: (Borg table 6–20): Low, ≤ 9; Medium/high, ≥ 10; ‡- calculated as meetings with trainer or phone calls with subjects per month: Low, < one contact; High, ≥ one contact; §- calculated as number of sets of exercises per week: Low, ≤ 30; High, ≥ 31; ||- if balance exercise performed B+, if not, B-; if program was increased progressively, PRT+, if not, PRT-.

contact; two and five with moderate and low level, respectively. Overall compliance (% completed workouts) in the MSHBRT group was 69.5 ± 20.3% (n = 11). Adherence (defined as % subjects that participated in the intervention and control groups until the end of the study) averaged at 85 ± 13.4% in the MSHBRT groups and 90.3 ± 13.6% in the control groups. Total workout sessions ranged from 36 up to 364 with a mean of 100 ± 92 sessions. The number of reported instructional sessions during the first month of intervention was up to six home visits (Nelson et al., 2004). Two studies incorporated instructions through DVD's (Jette et al., 1996, 1999).

AEs recorded in the MSHBRT group included four major events: one hip fracture (Kanemaru et al., 2010), one surgery for an inguinal hernia (Clemson et al., 2012) and two falls that resulted in admissions to hospital (Clegg et al., 2014). Minor events included falls (n = 7) (Clegg et al., 2014), a pelvic stress fracture (Clemson et al., 2012), musculoskeletal complains (Jette et al., 1999), pain during exercise (n = 5) (Vuorenmaa et al., 2014), neck (n = 5) and finger pain (n = 3) (Østerås et al., 2014), joint pain (n = 3) and medication modification (increased L-dopa dose; n = 2) (Allen et al., 2010). AEs which were likely unrelated to MSHBRT were bruises (n = 1) and one food poisoning (Nelson et al., 2004). Adverse events in the control groups included: a) major events: four admissions to hospital (Clegg et al., 2014) and one broken foot due to a fall (Sosnoff et al., 2014), b) minor events: one food poisoning (Nelson et al., 2004), medication modification (increased L-dopa dose; n = 7) (Allen et al., 2010). There was no statistical difference when the proportions of major and minor (or unrelated) events were compared between the MSHBRT and the control group (chi-square = 0.8102; p = 0.368).

### 3.3. Quality (risk of bias) and publication bias assessment

While all 12 eligible studies were RCTs, two did not provide information on the method of randomization (unclear risk of bias). Six of the RCTs did not provide information on allocation concealment. Four of the studies did not report information regarding the blinding of outcome assessments. Following our pre-defined scoring method, incomplete data was observed in four studies that had attrition rates higher than 5% (in one or both groups) and were thus viewed as “unclear risk of bias”. No selective reporting was observed and concern with other bias was found in eight studies (Fig. 2).

### 3.4. Effect of MSHBRT on muscle strength

In the main analysis, data on the effect of MSHBRT on LBS was based on nine studies with 806 subjects. Groups receiving MSHBRT had significantly greater gains in LBS than groups receiving no RT, P = 0.008 (MD, 0.6 Kg; 95% CI, 0.16–1.04; I<sup>2</sup>, 0%; p for heterogeneity = 0.4) (Fig. 3). The pooled effect of MSHBRT on UBS (4 studies with 302 subjects) was not significant and non-superior to the effect of no RT, p = 0.29 (MD, 0.42; 95% CI, -0.35-1.19; I<sup>2</sup>, 0%; p for heterogeneity = 0.79) (Fig. 4).

Sub-analyses on the effects of several features of the MSHBRT on LBS yielded the following results: larger increase in LBS for a) high workout intensity ((0.65 Kg; p = 0.11); b) long program duration (0.75 Kg; p = 0.006); c) high contact level (0.51 Kg; p = 0.15); and d) high program volume (0.62 Kg; p = 0.09). The subgroups differences between high vs low intensity, program duration, level of contact and program volume were not significant (p > 0.1) for all subgroup differences. Sub-analyses by health status showed that the effect of MSHBRT on LBS was more profound in studies with unhealthy participants (MD, 0.78 Kg; 95% CI, 0.09–1.48; I<sup>2</sup>, 25%; p for heterogeneity = 0.23) than studies with healthy participants (MD, 0.43 Kg; 95% CI, -0.34-1.2; I<sup>2</sup>, 0%; p for heterogeneity = 0.73). Finally, subgroup analysis revealed no difference in LBS comparing studies with the inclusion of balance training vs. studies without balance training (only RT), (p = 0.76 for subgroup differences). (Supplementary Figure S1a-f).



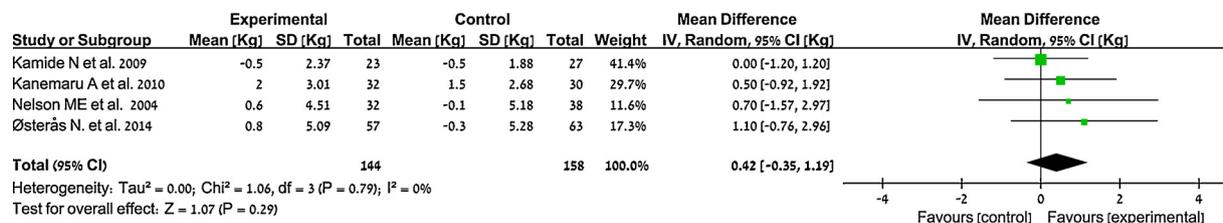


Fig. 4. Mean difference of upper body strength in the experimental group vs. control: main analysis.

CI indicates confidence interval. Mean differences in lower body strength (kg) (a) and mean difference in upper body strength (b) of individual studies included in the meta-analysis of MSHBRT group vs. control (no intervention) in older adults. Weights are from random-effects analysis. Abbreviations: minimally supervised home-based resistance training, MSHBRT.

4. Discussion

To the best of our knowledge, this is the first meta-analysis on HBRT programs performed with truly minimal levels of supervision in older populations with a high rate of concomitant diseases. In all, the results clearly indicate that MSHBRT can modestly increase lower body muscle strength in a diverse population of older subjects, including subjects with an array of age-related common diseases.

Previous reviews have shown favorable effects on muscle strength and function but were based either on relatively high (≤67%) (Thiebaud et al., 2014), (≤33%) (Lacroix et al., 2017) supervision rates or were not solely RT programs (Lacroix et al., 2017). In contrast, our analysis incorporated only RT studies with mostly (83%) subjects suffering from health conditions frequently observed in older populations while being minimally supervised.

4.1. Muscle strength

4.1.1. Lower body strength (LBS)

The low yet significant 0.6 – 0.78 Kg increase in LBS can delay the annual rate decline in muscle strength observed in older adults by ~1-2 years (Frontera et al., 2000; Goodpaster et al., 2006) potentially moving them away from cut-points associated with increased risk for mobility disability (Hicks et al., 2012). The low increase in LBS concurs with the review from Thiebaud et al. (2014), and can be attributed to the low direct supervision rates performed throughout the studies (Lacroix et al., 2017), as well as very low training volume (Kamide et al., 2009; Sosnoff et al., 2014) and exercise intensity (Jette et al., 1996; Kanemaru et al., 2010) seen in some programs, since both factors appear critical for increasing muscle strength (Borde, Hortobágyi, & Granacher, 2015; Peterson, Rhea, Sen, & Gordon, 2010; Raymond, Bramley-Tzerefos, Jeffs, Winter, & Holland, 2013). Concordant with this concept is our finding that although sub-group differences between longer vs shorter duration programs were not significant, longer programs can increase strength even further (Borde et al., 2015).

In the absence of practical barriers, clinicians seeking larger increases in strength levels should probably prefer the use of longer

duration, gym based supervised RT programs (Thiebaud et al., 2014), or circuit resistance training (Buch et al., 2017).

Our analysis revealed that combining both RT and balance exercise showed a non-significant increase in LBS compared to performing only RT. This concurs with Joshua et al. (2014), who found that adding balance exercise to RT had no added value at all, albeit this may be the result of a reduced balance exercise volume in both his combined RT and balance groups.

4.1.2. Upper body strength (UBS)

Of interest is also the finding that MSHBRT had no significant effect on UBS. The failure of MSHBRT to increase UBS may be related to the lower training intensity afforded using elastic bands-base exercise (home) compared to supervised gym-based weight machines training (Colado & Triplett, 2008). Lower MSHBRT intensity could also reflect the previously reported preference of older subjects to intuitively select low intensity RT (Elsangedy et al., 2013) while not under direct supervision. Finally, as UBS is normally assessed by isometric grip test, improvement due to dynamic exercises in MSHBRT such as employed in most studies, could have been missed by this mode of testing (Martins et al., 2015), or the relative low number of studies analyzed.

4.2. Timed “up and go” (TUG)

The borderline significant improvement of 0.62 sec MSHBRT had on TUG, is a change which is quantitatively similar to the 0.69 sec improvement found in Liu's systematic review of gym based supervised RT in older adults (Liu & Latham, 2009). Such improvement, however, may be too small to translate into a clear functional benefit in some populations with various health conditions, as only larger changes in TUG were considered as indicative of a significant clinical improvement (knee osteoarthritis 1.10 sec) (Alghadir, Anwer, & Brismée, 2015) (COPD 1.84 sec) (Marques, Cruz, Quina, Regêncio, & Jácome, 2016). Although the subgroup differences between high vs low intensity were not significant, our sub-analysis revealed that RT intensity was associated with a larger TUG outcome. This can be attributed to the magnifying effect higher intensity has on LBS (Borde et al., 2015) and its

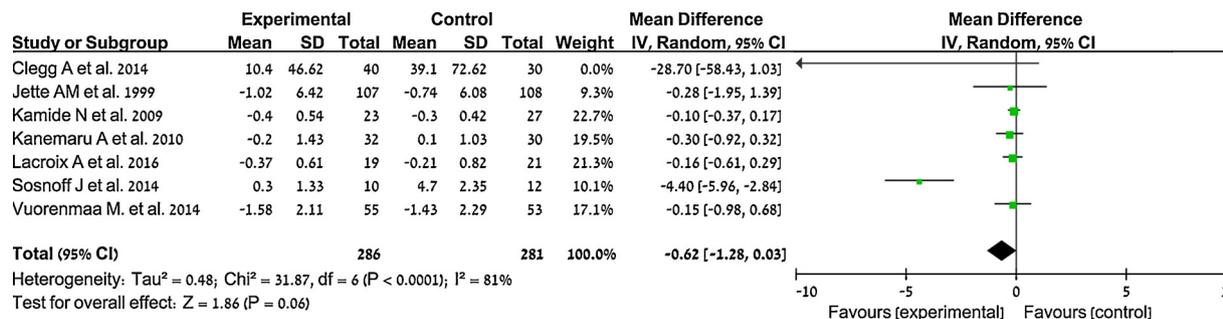


Fig. 5. Mean difference in "Timed up and go test" (sec) in the experimental group vs. control: main analysis.

CI indicates confidence interval. Mean difference in "Timed up and go test" (sec) of individual studies included in the meta-analysis of MSHBRT group vs. control (no intervention) in older adults. Weights are from random-effects analysis. Abbreviations: minimally supervised home based resistance training, MSHBRT.

correlation to TUG (Benavent-Caballer et al., 2016).

#### 4.3. Level of contact

The level of contact with the participants did not impart an added effect on both LBS and UBS. Since this report is the first to focus on the effect of minimal supervision rates in RT on physical outcomes in older subjects, our results cannot be directly compared to reviews focusing on RT interventions without information on their contact level. Unlike our findings, in a meta-analysis on fall prevention by Simek, McPhate, and Haines (2012) and the study on exercise by Marios, Smart, and Dalton (2012), it was found that subjects had much higher adherence rates to programs with more frequent phone contacts (once a week). In contrast, physiotherapy studies have found that adding supervised booster sessions did not affect the clinical outcome (Bennell, Kyriakides, Hodges, & Hinman, 2014), and patient's comorbidities and motivation, rather than the degree of supervision were related to the final results (Papalia et al., 2013).

While evidence suggests that larger increments in muscle performance and function can be attained by more intense RT applied under direct supervision (Thiebaud et al., 2014), the "second best" choice reviewed here, adds new dimensions of depth and broad applicability to the implementation of RT.

#### 4.4. Health status

To our knowledge, this is the first meta-analysis showing that MSHBRT is an effective means to improve LBS in older subjects with a wide range of health problems, including functional limitations, frequent falls, osteoarthritis, osteoporosis and neurodegenerative diseases. In fact, the improvement seen with MSHBRT in subjects with impaired health was entirely comparable to that seen in healthy individuals. Since the adverse events rate was not larger than in the control group (non-exercising subjects), this information should be reassuring to physicians seeking ways to improve LBS through MSHBRT.

#### 4.5. Adherence rate

A favorable finding of our analysis is that the adherence rates ( $85 \pm 13.4\%$ ), including subjects with various disease conditions, approached levels found in technology-based interventions (Valenzuela, Okubo, Woodbury, Lord, & Delbaere, 2018).

A finding of importance as high attrition rates can significantly bias the intervention's outcomes (van Reijen, Vriend, van Mechelen, Finch, & Verhagen, 2016).

#### 4.6. Adverse events

Program safety and the overall rate of AEs are of crucial importance due to the inherent risks of performing HBRT with minimal direct supervision. Most of the reported AEs were classified as minor and musculoskeletal related, an observation shared by many supervised studies monitoring such events (Liu & Latham, 2009, 2011). Unfortunately, some trials did not provide any information on AEs (Jette et al., 1996; Kamide et al., 2009), a phenomenon shared by many RT studies (Liu & Latham, 2009, 2011). Due to underreporting of AEs in the literature, it is difficult to compare the frequency and type of events in our analysis to supervised studies. Since MSHBRT was not linked to excess in the severity and number of AEs relative to the control group, it is reasonable to conclude that it comprises a safe mode of RT.

#### 4.7. Study limitations

This study has several limitations. The analysis is based on a relatively low number of studies and subjects. Unfortunately, data in this field of research, particularly in older populations is limited.

Nevertheless, given the low adherence to exercise in older adults and the biased nature of studies in this field (mostly supervised, which do not, necessarily, reflect "real-life"), we considered that there was a real need to conduct the analyses included herein. The sub-analyses are based on the comparisons of mean differences across studies (and not within the single studies) and were performed each time for different potential confounder. Therefore, we cannot ensure the true and sole effect of the level of contact or intensity level. Also, we cannot exclude the effect of publication bias on the precision of two of the outcomes (UBS and TUG and in subgroup analyses for LBS). Finally, the changes in strength and TUG are small in absolute terms. It may suggest that better methods of RT training outside of the gym are needed, with better portable or home-based equipment and better implementation of remote monitoring such as video-conferencing, phone calls and others.

## 5. Conclusion

A minimally supervised HBRT is a safe, effective and low-cost exercise option to increase lower body muscle strength in healthy older adults as well as in older subjects with a variety of health conditions. As such, MSHBRT offers a "real world" achievable interventional treatment modality in older adults; both for its roll in increasing lower body muscle strength and as a possible facilitator of increasing functional abilities.

The results of our study should be interpreted in context of the understanding that higher increase in muscle strength, including upper body strength and functional abilities, can be achieved through gym based, mostly supervised programs, relative to MSHBRT. Nevertheless, the high adherence rates, along with the relatively low rate of adverse events and very low number of home visits make MSHBRT an attractive, viable and, from a public health perspective, a feasible addition to either supervised home or gym-based RT training.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.archger.2019.103909>.

## References

- Allen, N. E., Canning, S. G., Sherrington, C., Lord, S. R., Latt, M. D., Close, J. C., ... Fung, V. S. (2010). The effects of an exercise program on fall risk factors in people with Parkinson's disease: A randomized controlled trial. *Movement disorders: official journal of the Movement Disorder Society*, 25(9), 1217–1225.
- Alghadir, A., Anwer, S., & Brismée, J.-M. (2015). The reliability and minimal detectable change of timed up and go test in individuals with grade 1–3 knee osteoarthritis. *BMC Musculoskeletal Disorders*, 16(174).
- Avelar, B. P., Costa, J. N., Safons, M. P., Dutra, M. T., Bottaro, M., Gobbi, S., ... Lima, R. M. (2016). Balance Exercises Circuit improves muscle strength, balance, and functional performance in older women. *Age (Dordrecht, Netherlands)*, 38(1).
- Benavent-Caballer, V., Sendin-Magdalena, A., Lisón, J. F., Rosado-Calatayud, P., Amer-Cuenca, J. J., Salvador-Coloma, P., ... Segura-Ortí, E. (2016). Physical factors underlying the timed "up and go" test in older adults. *Geriatric Nursing (New York, NY)*, 37(2), 122–127.
- Bennell, K. L., Kyriakides, M., Hodges, P. W., & Hinman, R. S. (2014). Effects of two physiotherapy booster sessions on outcomes with home exercise in people with knee osteoarthritis: A randomized controlled trial. *Arthritis Care & Research*, 66(11), 1680–1687.
- Borde, R., Hortobágyi, T., & Granacher, U. (2015). Dose-Response relationships of resistance training in healthy old adults: A systematic review and meta-analysis. *Sports Medicine (Auckland, NZ)*, 45(12), 1693–1720.
- Buch, A., Kis, O., Carmeli, E., Keinan-Boker, L., Berner, Y., Barer, Y., ... Stern, N. (2017). Circuit resistance training is an effective means to enhance muscle strength in older and middle aged adults: A systematic review and meta-analysis. *Ageing Research Reviews*, 37, 16–27.
- Centers for Disease Control and Prevention (CDC) (2013). Adult participation in aerobic and muscle-strengthening physical activities-United States, 2011. *MMWR Morbidity and Mortality Weekly Report*, 62(17), 326–330.
- Cesari, M., Marzetti, E., Thiem, U., Pérez-Zepeda, M. U., Abellan Van Kan, G., Landi, F., ... Bernabei, R. (2016). The geriatric management of frailty as paradigm of "The end of the disease era". *European Journal of Internal Medicine*, 31, 11–14.
- Clegg, A., Barber, S., Young, J., Iliffe, S., & Forster, A. (2014). The Home-based Older People's Exercise (HOPE) trial: A pilot randomised controlled trial of a home-based

- exercise intervention for older people with frailty. *Age and Ageing*, 43(5), 687–695.
- Clemson, L., Fiatarone Singh, M. A., Bundy, A., Cumming, R. G., Manollaras, K., O'Loughlin, P., ... Black, D. (2012). Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): Randomised parallel trial. *BMJ (Clinical Research Ed)*, 345.
- Colado, J. C., & Triplett, N. T. (2008). Effects of a short-term resistance program using elastic bands versus weight machines for sedentary middle-aged women. *Journal of Strength and Conditioning Research*, 22(5), 1441–1448.
- Cruz-Jentoft, A. J., Landi, F., Schneider, S. M., Zúñiga, C., Arai, H., Boirie, Y., ... Cederholm, T. (2014). Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). *Age and Ageing*, 43(6), 748–759.
- Da Silva Alexandre, T., de Oliveira Duarte, Y. A., Ferreira Santos, J. L., Wong, R., & Lebrão, M. L. (2014). Sarcopenia according to the European working group on sarcopenia in older people (EWGSOP) versus Dynapenia as a risk factor for disability in the elderly. *The Journal of Nutrition, Health & Aging*, 18(5), 547–553.
- Dugoff, E. H., Canudas-Romo, V., Buttorff, C., Leff, B., & Anderson, G. F. (2014). Multiple chronic conditions and life expectancy: A life table analysis. *Medical Care*, 52(8), 688–694.
- Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ (Clinical Research Ed)*, 315(7109), 629–634.
- Elsangedy, H. M., Krause, M. P., Krinski, K., Alves, R. C., Hsin Nery Chao, C., & Da Silva, S. G. (2013). Is the self-selected resistance exercise intensity by older women consistent with the American College of Sports Medicine guidelines to improve muscular fitness? *Journal of Strength and Conditioning Research*, 27(7), 1877–1884.
- Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., & Granger, C. B. (2010). *Fundamentals of clinical trials* (4th ed.). New York, NY: Springer.
- Frontera, W. R., Hughes, V. A., Fielding, R. A., Fiatarone, M. A., Evans, W. J., & Roubenoff, R. (2000). Aging of skeletal muscle: A 12-yr longitudinal study. *Journal of Applied Physiology (Bethesda, Md. :1985)*, 88(4), 1321–1326.
- Geraedts, H., Zijlstra, A., Bulstra, S. K., Stevens, M., & Zijlstra, W. (2013). Effects of remote feedback in home-based physical activity interventions for older adults: A systematic review. *Patient Education and Counseling*, 91(1), 14–24.
- Goodpaster, B. H., Park, S. W., Harris, T. B., Kritchevsky, S. B., Nevitt, M., Schwartz, A. V., ... Newman, A. B. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: The health, aging and body composition study. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, 61(10), 1059–1064.
- Hicks, G. E., Shardell, M., Alley, D. E., Miller, R. R., Bandinelli, S., Guralnik, J., ... Ferrucci, L. (2012). Absolute strength and loss of strength as predictors of mobility decline in older adults: The InCHIANTI study. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, 67A(1), 66–73.
- Higgins, J. P., Altman, D. G., & Sterne, J. A. (2011). *Chapter 8: Assessing risk of bias in included studies. in: Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 (updated March 2011)*. Retrieved from: [www.handbook.cochrane.org](http://www.handbook.cochrane.org).
- Higgins, J., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions version 5.1.0 (updated March 2011)*. Retrieved from: [www.cochrane-handbook.org](http://www.cochrane-handbook.org).
- Jette, A. M., Harris, B. A., Sleeper, L., Lachman, M. E., Heislein, D., Giorgetti, M., ... Levenson, C. (1996). A home-based exercise program for nondisabled older adults. *Journal of the American Geriatrics Society*, 44(6), 644–649.
- Jette, A. M., Lachman, M., Giorgetti, M. M., Assmann, S. F., Harris, B. A., Levenson, C., ... Krebs, D. (1999). Exercise—It's never too late: The strong-for-life program. *American Journal of Public Health*, 89(1), 66–72.
- Joshua, A. M., D'Souza, V., Unnikrishnan, B., Mithra, P., Kamath, A., Acharya, V., ... Venugopal, A. (2014). Effectiveness of progressive resistance strength training versus traditional balance exercise in improving balance among the elderly - a randomised controlled trial. *Journal of Clinical and Diagnostic Research: JCDR*, 8(3), 98–102.
- Kamide, N., Shiba, Y., & Shibata, H. (2009). Effects on balance, falls, and bone mineral density of a home-based exercise program without home visits in community-dwelling elderly women: A randomized controlled trial. *Journal of Physiological Anthropology*, 28(3), 115–122.
- Kanemaru, A., Arahata, K., Ohta, T., Katoh, T., Tobimatsu, H., & Horiuchi, T. (2010). The efficacy of home-based muscle training for the elderly osteoporotic women: The effects of daily muscle training on quality of life (QoL). *Archives of Gerontology and Geriatrics*, 51(2), 169–172.
- Kirkland, J. L., & Peterson, C. (2009). Healthspan, translation, and new outcomes for animal studies of aging. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, 64A(2), 209–212.
- Lacroix, A., Kressig, R. W., Muehlbauer, T., Gschwind, Y. J., Pfenninger, B., Bruegger, O., ... Granacher, U. (2016). Effects of a supervised versus an unsupervised combined balance and strength training program on balance and muscle power in healthy older adults: A randomized controlled trial. *Gerontology*, 62(3), 275–288.
- Lacroix, A., Hortobágyi, T., Beurskens, R., & Granacher, U. (2017). Effects of supervised vs. unsupervised training programs on balance and muscle strength in older adults: A systematic review and meta-analysis. *Sports Medicine*, 47(11), 1–21.
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gotzsche, P. C., Ioannidis, J. P. A., ... Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Annals of Internal Medicine*, 151(4), W65–94.
- Liu, C., & Latham, N. K. (2009). Progressive resistance strength training for improving physical function in older adults. *The Cochrane Database of Systematic Reviews*(3), CD002759.
- Liu, C.-J., & Latham, N. (2011). Can progressive resistance strength training reduce physical disability in older adults? A meta-analysis study. *Disability and Rehabilitation*, 33(2), 87–97.
- Marios, T. A., Smart, N., & Dalton, S. (2012). The effect of tele-monitoring on exercise training adherence, functional capacity, quality of life and glycemic control in patients with type II diabetes. *Journal of Sports Science & Medicine*, 11(1), 51–56.
- Marques, A., Cruz, J., Quina, S., Regêncio, M., & Jácome, C. (2016). Reliability, agreement and minimal detectable change of the timed up & go and the 10-meter walk tests in older patients with COPD. *COPD*, 13(3), 279–287.
- Martins, W. R., Safons, M. P., Bottaro, M., Blaszczak, J. C., Diniz, L. R., Fonseca, R. M. C., ... de Oliveira, R. J. (2015). Effects of short term elastic resistance training on muscle mass and strength in untrained older adults: A randomized clinical trial. *BMC Geriatrics*, 15(99).
- Nelson, M. E., Layne, J. E., Bernstein, M. J., Nuernberger, A., Castaneda, C., Kaliton, D., ... Fiatarone Singh, M. A. (2004). The effects of multidimensional home-based exercise on functional performance in elderly people. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, 59(2), 154–160.
- Østerås, N., Hagen, K. B., Grotle, M., Sand-Svartrud, A.-L., Mowinkel, P., & Kjekshus, I. (2014). Limited effects of exercises in people with hand osteoarthritis: Results from a randomized controlled trial. *Osteoarthritis and Cartilage*, 22(9), 1224–1233.
- Papa, E. V., Dong, X., & Hassan, M. (2017). Resistance training for activity limitations in older adults with skeletal muscle function deficits: A systematic review. *Clinical Interventions in Aging*, 12, 955–961.
- Papalia, R., Vasta, S., Tecame, A., D'Adamio, S., Maffulli, N., & Denaro, V. (2013). Home-based vs supervised rehabilitation programs following knee surgery: A systematic review. *British Medical Bulletin*, 108(1), 55–72.
- Peterson, M. D., Rhea, M. R., Sen, A., & Gordon, P. M. (2010). Resistance Exercise for Muscular Strength in Older Adults: A Meta-Analysis. *Ageing Research Reviews*, 9(3), 226–237.
- Raymond, M. J., Bramley-Tzerofos, R. E., Jeffs, K. J., Winter, A., & Holland, A. E. (2013). Systematic review of high-intensity progressive resistance strength training of the lower limb compared with other intensities of strength training in older adults. *Archives of Physical Medicine and Rehabilitation*, 94(8), 1458–1472.
- Review Manager (RevMan) (2014). *Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration*.
- Schutzer, K. A., & Graves, B. S. (2004). Barriers and motivations to exercise in older adults. *Preventive Medicine*, 39(5), 1056–1061.
- Simek, E. M., McPhate, L., & Haines, T. P. (2012). Adherence to and efficacy of home exercise programs to prevent falls: A systematic review and meta-analysis of the impact of exercise program characteristics. *Preventive Medicine*, 55(4), 262–275.
- Sosnoff, J. J., Finlayson, M., McAuley, E., Morrison, S., & Motl, R. W. (2014). Home-based exercise program and fall-risk reduction in older adults with multiple sclerosis: Phase 1 randomized controlled trial. *Clinical Rehabilitation*, 28(3), 254–263.
- Thiebaud, R. S., Funk, M. D., & Abe, T. (2014). Home-based resistance training for older adults: A systematic review. *Geriatrics & Gerontology International*, 14(4), 750–757.
- Tiggemann, C. L., Dias, C. P., Radaelli, R., Massa, J. C., Bortoluzzi, R., Schoenell, M. C. W., ... Krueel, L. F. (2016). Effect of traditional resistance and power training using rated perceived exertion for enhancement of muscle strength, power, and functional performance. *Age (Dordrecht, Netherlands)*, 38(2).
- Valenzuela, T., Okubo, Y., Woodbury, A., Lord, S. R., & Delbaere, K. (2018). Adherence to technology-based exercise programs in older adults: A systematic review. *Journal of Geriatric Physical Therapy*, 41(1), 49–61.
- van Reijen, M., Vriend, I., van Mechelen, W., Finch, C. F., & Verhagen, E. A. (2016). Compliance with sport injury prevention interventions in randomised controlled trials: A systematic review. *Sports Medicine (Auckland, NZ)*, 46, 1125–1139.
- Vuorenmaa, M., Ylinen, J., Piitulainen, K., Salo, P., Kautiainen, H., Pesola, M., ... Hakkinen, A. (2014). Efficacy of a 12-month, monitored home exercise programme compared with normal care commencing 2 months after total knee arthroplasty: A randomized controlled trial. *Journal of Rehabilitation Medicine*, 46(2), 166–172.