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Review

Promotion of muscle-strengthening exercise for public health: a systematic review of real-life interventions in healthy adults

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ABSTRACT

Objectives: Few adults adhere to muscle-strengthening exercise guidelines (≥2 days/week), showing an urgent need to increase this physical activity mode in the general population. We aimed to evaluate the effectiveness of real-life interventions in promoting muscle-strengthening exercise among healthy adults.
Design: A systematic review (PROSPERO CRD42020146423).
Methods: Studies were eligible if they reported behavioral outcomes of a 'real-life' intervention promoting muscle-strengthening exercise in healthy, community-dwelling adults. Study selection, data extraction, and quality assessment were completed, and behavior change techniques were coded.
Results: Sixty-nine unique studies (10 to 3507 participants) were included; 36 were randomized controlled trials. Five studies were rated as strong, 12 as moderate, and 52 as weak. Of the 54 studies providing session attendance, rates ranged between 10 and 100 %, with only seven studies showing rates below 60 %. Only nine studies assessed and reported actual engagement in muscle-strengthening exercise. Most randomized controlled trials (70.0 %) showed an improvement in functional performance. Moderate evidence was found for no change in blood pressure and body-mass index. However, conflicting evidence was found for other outcomes. The most commonly used behavior change techniques (51 were reported) were *instruction on how to perform the behavior* (91.3 %), *behavioral practice/rehearsal* (76.8 %), and *demonstration of the behavior* (76.8 %).
Conclusions: This review suggests that participation in real-life interventions promoting muscle-strengthening exercise is substantial. However, behavioral outcomes related to the actual engagement in muscle-strengthening exercise were hardly reported. As such, from a public health perspective, there is limited evidence on how to best promote muscle-strengthening exercise in healthy populations and more high-quality intervention studies are needed.

Practical implications

- Participation in community-based interventions promoting muscle-strengthening exercise in healthy populations is substantial.
- The most commonly used behavior change techniques were *instruction*, *practice/rehearsal*, and *demonstration*.
- Few studies reported actual engagement in MSE, leaving limited evidence on how to increase uptake and maintenance of MSE.

1. Introduction

Current global physical activity (PA) guidelines for health recommend adults aged 18 years and above to engage in moderate-to-vigorous-intensity aerobic PA for at least 75–150 min/week, and in muscle-strengthening activities involving major muscle groups on two or more days a week.[1] Research on public health surveillance,[2,3] epidemiology,[4,5] and public health promotion[6,7] regarding aerobic PA has been well documented. However, muscle-strengthening exercise

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(MSE) has received comparatively less attention and seems to be the 'forgotten' part of the PA guidelines for public health.[8] Clinical evidence at the meta-analytical level shows that participation in structured, progressive MSE leads to better physical functioning, including strength and performance,[9] improvements in cardio-metabolic health outcomes,[10] and reduced chronic disease risk.[11] However, it was only recently that population-based epidemiological and public health research started to focus on MSE.[12] Emerging observational population-based research shows that MSE is, independently from aerobic PA, associated with various health outcomes, including cardio-metabolic biomarkers,[13] reduced prevalence of chronic health conditions including diabetes, coronary heart disease, hypertension, and depression,[14] lower risk of all-cause[15]/cancer mortality,[16] and lower prevalence of depressive symptom severity.[17–19]

Despite the multiple health benefits of MSE, the number of adults engaging in sufficient MSE is low. Population-based data show that 70–96 % of adults do not meet MSE recommendations.[8,13,14,20–22] From a public health perspective, this suggests a clear need to increase the uptake and adherence of MSE. To do so, there is a need for efficacious programs that successfully translate into "real-life" settings (i.e. beyond controlled laboratory conditions),[23] such as the home environment, the workplace, or other community settings. An understanding of the effectiveness (i.e. degree of beneficial effects under real-world settings[24]) of interventions promoting MSE is crucial for the development of successful PA behavior change programs and policies to improve public health.

Current evidence on the effects of MSE interventions in the general population is limited. Review studies of randomized controlled trials (RCTs) in multiple settings (including clinical trials) showed positive effects on cardio-metabolic outcomes in adults[10] and physical disabilities in older adults.[9] However, few reviews synthesize the effects of real-life (i.e. non-clinical or non-lab based) MSE programs in healthy populations. Review-level evidence on home-based resistance training has shown improved strength and functional ability in older adults.[25,26] Notably, resistance training interventions in older adults have specific age-related objectives, such as enhancing muscle strength to reduce fall risk, indicating that these results cannot be transferred to the general adult population. Also, other types of real-life MSE interventions in healthy adults have not been synthesized. In addition, to our knowledge, no evidence is available for PA-related and/or behavioral outcomes. Therefore, this systematic review aims to summarize the evidence of real-life PA interventions promoting MSE in healthy adult populations. This review will assess interventions in terms of PA behaviors (primary outcome) and health-related outcomes (secondary outcome) and identify behavior change techniques (BCTs) to better understand underlying mechanisms of change.

2. Methods

The PRISMA guidelines were used for conducting this systematic review and meta-analysis. The protocol was registered in PROSPERO CRD42020146423 (April 2020).

2.1. Search strategy for identification of studies

Studies were identified by searching eight electronic databases: CINAHL, Health Source: nursing/academic edition, PsychInfo, PubMed, ScienceDirect, Scopus, SPORTDiscus, and Web of Science. The search strategy developed is presented in Table 1. Details of the strategy for each single database are provided in Supplementary Table S1. The search for studies was conducted on April 21st 2025. The results were downloaded to EndNote and duplicates were removed.

2.2. Inclusion and exclusion criteria

Peer-reviewed studies published in English, Dutch, German, French, Chinese, and Portuguese were included. No restrictions were set regarding publication dates. Participants had to be healthy, community-dwelling adults (mean age ≥18 years). We excluded studies that included the following population subgroups: clinical populations, patient groups, injured or disabled individuals, athletes, pregnant or postpartum women, institutionalized people, and children or adolescents. RCTs, cluster RCTs, cross-over trials, quasi-experiments, comparative and case–control studies were included. Protocol papers, cross-sectional designs, process evaluations, PhD theses, and review articles were excluded. The included studies had to provide a real-life intervention (implemented in "real-life" settings, such as at home, work, and the community) aimed at promoting MSE, excluding clinical trials/lab studies, rehabilitation programs, or interventions only promoting aerobic PA, balance, flexibility or stretching activities. All articles had to report the effects of the intervention on at least one of the following PA behaviors: frequency, duration, or adherence to PA outcomes, whether or not in combination with physical and mental health-related outcomes (e.g. strength, fitness, quality of life, and cognitive outcomes).

2.3. Study selection

After the removal of duplicates, screening was based on the article title and abstract for the inclusion or exclusion of studies, by at least two independent reviewers (EVR, IV, KDC, JS, JvU, SJHB). After that, a full-text screening was conducted by at least two independent reviewers (EVR, IV, KDC, LM, JS, JvU, SJHB). In case of disagreement or doubt, a third reviewer was consulted.

2.4. Data extraction and quality of assessment

The following details were extracted from each paper: study location, study design, participant characteristics (sample size, age, sex), intervention description (e.g. duration, conditions, context, supervised or not), outcomes and measurement methods, and the main study results.

In this systematic review, behavioral outcomes (= primary outcome) refer to indicators of engagement in and changes to PA and/or MSE behaviors. These outcomes encompass both direct measures of behavior change – such as participation in MSE, moderate-to-vigorous intensity PA, walking, daily step counts,

Table 1
Search strategy.[a]

	Search terms
Population	[adult* OR men OR women OR employee* OR aged OR elder* OR senior*]
Type of activity promoted	["Muscle strengthening" OR "Muscle training" OR "Muscle toning" OR "Muscular strengthening" OR "Strength training" OR "Strength or toning" OR "Strength and toning" OR "Strength/toning" OR "Strength / toning" OR "Strength building" OR "Weight training" OR "Weight lifting" OR "Weight bearing training" OR "Weight bearing strengthening" OR "Weight bearing exercise" OR "Resistance training" OR "Circuit training"]
Type of study	[Program OR Programme OR Strateg* OR Intervention OR Promotion OR Education]
Context/setting	[Lifestyle OR Home OR Workplace OR Worksite OR Community OR "Free-living" OR "Real-world"]
Outcomes	[Adher* OR Participation OR Attend* OR Behav* OR "Behav* change" OR Frequency OR Duration OR Outcome? OR Time]
Design/method	[Evaluation OR Effect* OR Randomi* OR Controlled OR Trial OR Test OR "Control group" OR RCT OR Quasi-experiment]

[a] Search blocks were used in AND-combination in the full search.

total PA volume, and the proportion of individuals meeting the aerobic PA and MSE guidelines – and proxy measures of behavior, such as adherence to the intervention protocol (e.g., session attendance).

To ascertain the 'active ingredients' of interventions and better understand underlying mechanisms of change, we coded the BCTs identified in each intervention. Two researchers undertook coding (IV, LM), with another (SJHB) checking and helping resolve discrepancies. BCTs were coded according to the BCT Taxonomy (v1) instructions.[27] BCT coding instructions state that "exercise classes" can generally be assumed to include all three of the BCT instruction, demonstration, and rehearsal, thus we coded these for any indication of group training sessions. In addition, BCTs can only be counted when they are part of a behavior change strategy and not, for example, as part of a data collection procedure. However, the distinction between being employed as a behavior change strategy and as an implicit part of the study design is not always clear. Where BCTs appeared inherent in the design, we left these out of the calculations but noted them separately as "incidental BCTs".

To appraise the methodological quality of the included studies, we used the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies.[28,29] This tool was selected based on its specific relevance to public health research and its capacity to assess a wide range of study designs,[28,30] which aligns with the heterogeneity of studies included in our systematic review. Importantly, the EPHPP tool exhibits acceptable inter-rater reliability – with fair to excellent agreement across domains – and excellent agreement for the global quality rating.[28] Risk of bias assessment was conducted independently by two reviewers for each study (EVR, KDC, LM, JS, JvU). Based on the EPHPP protocol, six components ('selection bias', 'study design', 'confounders', 'blinding', 'data collection methods', and 'withdrawals and dropouts') were rated ('strong' vs 'moderate' vs 'weak'). The overall quality rating was defined for each study based on the following rules as defined in the protocol: '*strong*' when no '*weak*' sub ratings were given, '*moderate*' when only one '*weak*' sub rating was given, and '*weak*' when two or more sub ratings were '*weak*'.

2.5. Data synthesis and analysis

When clinical and/or methodological heterogeneity is substantial, choosing not to pool data across studies is appropriate.[31] Both the clinical heterogeneity and methodological heterogeneity were too extensive within our systematic review to conduct a meta-analysis. For example, the nine studies[32–42] that included explicit behavioral outcomes for MSE (i.e., primary outcome) were a mixture of RCTs and quasi-experimental studies (one or multiple groups); participants ranged from young adults to elderly; intervention duration ranged from 2 weeks to 5 years with exercise sessions performed once weekly up to daily, either supervised or unsupervised, group-based or individualized, using body weight exercises, in- or outdoor gym equipment, or resistance bands; MSE was performed as a single intervention or in combination with moderate-to-vigorous PA and/or flexibility exercises; and behavioral outcomes were highly diverse (e.g., participation in MSE or the proportion of individuals meeting the MSE guidelines). Details of the interventions and all outcomes were therefore reported descriptively. As the study populations, interventions, and settings were also heterogeneous, we summarized the results and described the level of evidence. In accordance with previous systematic reviews on the effectiveness of PA interventions,[43–45] the following rating was used for each outcome: '*no evidence*' (no RCTs available), '*limited evidence*' (one RCT available), '*conflicting evidence*' (inconsistent findings in multiple RCTs), '*moderate evidence*' (generally consistent findings in one high-quality RCT and one or more low-quality RCTs, or in multiple low-quality RCTs), or '*strong evidence*' (generally consistent findings in multiple high-quality RCTs).

3. Results

3.1. Search results and study selection

Fig. 1 presents an overview of the study selection process using the PRISMA flowchart. In total, 76 papers met the inclusion criteria, describing 69 unique studies.[32–42,46–110] All studies were published in English. Some studies were reported in multiple papers, including two papers from the study of Devreede et al.,[60,61] five papers from the study of Jakobsen et al.,[73–77] and three papers from the study of Kamada et al.[34–36] Throughout this systematic review, we refer to the number of studies rather than papers.

3.2. Study characteristics and methodological study quality

The descriptive characteristics and main results of the 69 studies are shown in Table 2. Sixteen studies were from Australia,[38,50,52,53,58,59,65,70–72,79,82,86,104,109,110] 15 from the USA,[33,39–41,47,64,80,83,88,98–103] eight from Japan,[34–36,42,68,87,90,96,107,108] four from Denmark,[57,66,73–77,93] three from the UK,[32,85,95] two from Finland,[46,106] Canada,[37,92] Taiwan,[56,84] China,[55,62] Korea[78,81] and Italy,[54,63 ,61], and one from Iran,[105] Spain,[97] Norway,[69] Sweden,[48] Portugal,[91] Singapore,[89] Germany[51] and Switzerland[67] (in one study the country was not stated[49]). One multi-country study was performed across four countries (i.e., Spain, Germany, UK, Denmark).[94] Two studies were published before 2000, nine between 2000 and 2010, and 58 after 2010. Sample sizes ranged from 10 to 3819 participants, with a total of 18962 participants for all studies included in this systematic review. The mean age of the participants ranged from 19.6 to 79.7 years (average mean age: 57.8 ± 15.9). Thirty-four studies (49.3 %) were conducted in adults aged ≥60 years only (in 31, the mean age was >65 years). Thirteen studies included only females (18.8 %) and three included only males (4.3 %) (overall average proportion of men: 31.2 %).

Thirty-six studies were RCTs (two-groups: n = 25[32,37,38,47,52,55,62,63,66,67,80,82,83,85,86,90,92,95,97,99,103,105–107,109]; three-groups: n = 5[60,61,72,78,94,100]; four-groups: n = 5[34–36,56,65,69,87]; five-groups: n = 1[57]), 12 had a (non-)randomized multiple-groups pre–post design (comparing two[40,51,54,64,71,73–77,81,89,91,96,98] or three[41] intervention conditions) and 21 had a one-group pre–post design.[33,39,42,46,48–50,53,58,59,68,70,79,84,88,93,101,102,104,108,110] In 35 studies, a 'no program' condition was included (Table 2).

The methodological quality of the included studies is presented in Table 3. Overall, four studies were rated as strong,[55,92,94,105] 12 as moderate[32,34–36,39,41,60–62,69,73–77,80,87,97,106] and 53 as weak.[33,37–40,42,46–54,56–59,63–68,70–72,78,79,81–86,88–91,93,95,96,98–104,107–110] In most studies, selection bias and blinding issues resulted in the weak ratings.

3.3. Muscle-strengthening exercise interventions

3.3.1. Intervention characteristics

Details of the intervention characteristics are presented in Table 2. In 25 studies, the intervention focused on MSE only; the other interventions also promoted aerobic activities and/or high-intensity interval training (n = 17), flexibility, balance, mobility, coordination and/or weight-bearing impact activities (n = 15), or a combination of multiple intervention components (n = 12). The majority of the interventions were delivered in community settings (n = 27), such as senior centers, public hospitals or healthcare centers, fitness centers, or outdoor spaces.

The duration of the interventions ranged between two weeks and 2.3 years, with the majority lasting for 10–12 weeks (n = 26). The interventions mostly consisted of three sessions a week (n = 227). In the other interventions, sessions were offered twice a week (n = 19), once a week (n = 7), or in a variety of three to nine sessions weekly

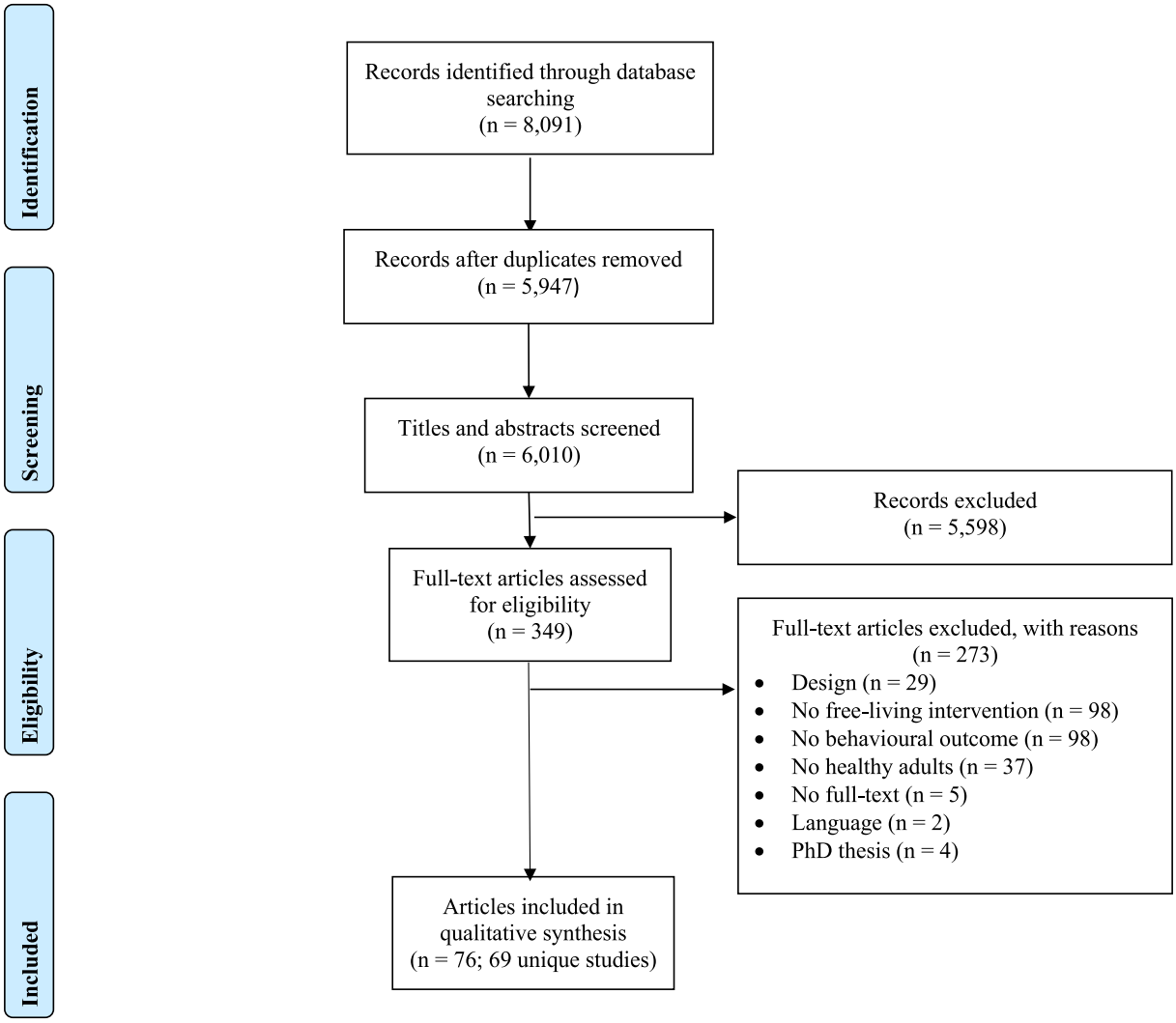

Fig. 1. PRISMA flow diagram of search process and study selection.

(n = 6), or one to four sessions daily (n = 6). In most interventions, the duration of the sessions was 60 min (n = 17); in the other interventions, the duration varied between 1 and 120 min per session. In 19 studies, the program was non-supervised, while it was supervised by at least one person in 33 studies. In 17 studies, supervision was offered in some groups, while not in others, or supervision was offered in only a specific number of weeks.

3.3.2. Behavior change techniques

Of the 93 BCTs listed in the BCT taxonomy,[27] we found the presence of 51 (54.8 %) among the 69 reviewed studies. The majority of these 51 BCTs (n = 36, 70.6 %) were used in five studies or less, while only eight (15.7 %) were used in more than 10 studies. The most commonly used BCTs were *instruction on how to perform the behavior* (used in 63 studies, 91.3 %), *behavioral practice/rehearsal* (53 studies, 76.8 %), and *demonstration of the behavior* (53 studies, 76.8 %) (Supplementary Table S2).

The next most commonly occurring BCTs were used in 12 (17.4 %) to 19 (27.5 %) studies each (Supplementary Table S2). These included *adding objects to the environment* (e.g., providing free training equipment such as resistance bands); *social support (unspecified)* (e.g. encouraging significant others to be supportive); *restructuring the social environment* (e.g., organizing training sessions in the workplace); *feedback on behavior* (e.g., providing feedback about proper execution); and *information about health consequences* (e.g., education sessions on the health effects of strength training). The majority of the incidental BCTs concerned *graded tasks*, *goal setting (behavior)*, and *self-monitoring of behavior*.

The use of a large number of BCTs within a study was not common (Supplementary Table S3). Only 10 out of 69 studies (14.5 %) included 10 or more BCTs.[38,39,41,42,47,53,64,94,101,105] The majority of studies (n = 50, 72.5 %) included five BCTs or less, with most of these (n = 46) not including more than two BCTs beyond *instruction*, *demonstration*, and *practice*, the three BCTs coded for providing a MSE or fitness class. It is noteworthy that the studies that used the most BCTs made explicit efforts to encourage attendance and/or adherence over time, sometimes using theoretical perspectives to frame or guide their interventions, and occasionally including behavior change as an add-on in one of the intervention groups.

Examples of theoretical frameworks used were the Transtheoretical Model of Change with its associated processes of change,[64,105,109] Social Cognitive Theory,[38,40,47,88,94,109] Theory of Planned Behavior,[39] bio-psychosocial framework,[73–77] Health Action Process Approach (HAPA)[38] and Social Marketing Framework.[34–36,42] Four recent studies used the Behavior Change Wheel/COM-B model in their design[53,88,94] or evaluation[51] of the intervention. Several studies that did not use theoretical frameworks nevertheless used various BCTs to try to promote adherence to the intervention,[50,54,69,80,84,106] though less than the studies that did use theoretical frameworks.

Table 2
Main characteristics of the included studies.

Author(s) (year of publication), country	Participants: sample size and description, mean age, proportion males	Study design	Setting	Intervention (I)/control (C) group(s)	Modalities promoted	Duration	Weekly sessions (n)	Duration session	Supervision (yes/no/combi); instructor credentials[a]	Materials
I. Randomized controlled trials (RCTs)										
Arikawa et al. (2011), USA	n = 164 overweight and obese, 36.0 years, 0 %	RCT (2 groups)	Community: YMCA fitness centers	I: Young Women's Christian Association fitness membership, phone and email reminders, incentives, child care, social support C: no intervention	MSE	2 years	2	60–90 min	Combi; certified fitness trainers (months 1–4)	Free weights
Biddle et al. (2022), UK	n = 107 adults 18–75 years, 46.9 years, 12 %	Pilot RCT (2 groups)	Home	I: Active Advent intervention, daily email with a Christmas themed physical activity idea to be completed that day (combination of MSE and MVPA, three levels of difficulty) C: healthy living leaflet	MSE, MVPA	24 days	Daily	Variable	No; research team	Body weight
Brennan et al. (2024), Australia	n = 16 pre-frail adults, 57.9 years, 12 %	RCT (2 groups)	Home	I: progressively overloaded MSE using resistance bands C: control/usual daily living	MSA	6 weeks	3 to 4	2 of 6 exercises per training day	First session supervised; principal investigator	Bands
Chan et al. (2024), China	n = 42 adults 60+ years, I = 68.2 years, 29 %; C: 71.4 years, 19 %	RCT (2 groups)	Community	I: Nintendo Ring Fit Adventure™ program with core exergames C: control/usual care	BAL, MSA	8 weeks	2	60 min	Yes; exercise instructors	Soft balancing board
Chang et al. (2023), Taiwan	n = 72 physically inactive adults 40–70 years, 58.2 years, 11 %	RCT (4 groups)	Community center + home	I_1: AE 30 min I_2: AE 30 min + MSE 10 min I_3: HITT 20 min C: no intervention	MVPA, MSE, HITT	12 weeks	2 community center, 1 home	40–50 min	Combi; professional fitness interveners	Free weights, bands
Dalager et al. (2015), Denmark	n = 537 office workers, 45.8 years, 39 %	RCT (5 groups)	Work	I_1: one 60-min supervised session/week I_2: three 20-min supervised sessions/week I_3: nine 7-min supervised sessions/week I_4: three 20-min sessions/week with minimal supervision (only during initial two weeks) C: no intervention	MSE	20 weeks	1–9	7–60 min	Yes; experienced trainers	Free weights
De Vreede et al. (2005, 2007), The Netherlands	n = 98 elderly, 74.7 years, 0 %	RCT (3 groups)	Home	I_1: resistance group (Fit for Your Life program to strengthen muscle groups important for daily task performance) I_2: function group (core exercised to improve daily tasks) C: no intervention	MSE	12 weeks	3	60 min	Yes; physiotherapist and sports teacher	Free weights
Dun et al. (2022), China	n = 48 community-dwelling older adults, 73 years, 35 %	RCT (2 groups)	Community health center	I: Xiangya Hospital circuit training (X-CircuiT) C: 1-time advice on physical activity without supervised exercise	FLEX, MSE, MVPA	12 weeks	3	46 min	Yes; clinical exercise physiologist	Body weight, bands
Ferrari et al. (2024), Italy	n = 73 adults 60+ years, I = 67.1 years, C = 66.6 years, 50.6 %	RCT (2 groups)	Home	I: video-instructions on tablet + wearable inertial sensor, web-based prescription interface for trainer C: control/regular lifestyle	MSA	6 months	3–5	30–70 min	yes; trainer via interface	chair, ab mat, bands, and bottles of water
Fyfe et al. (2022), Australia	n = 38 community-dwelling older adults, 69.8 years, 37 %	Pilot-RCT (4 groups)	Home	I_1: resistance 'exercise snacks': 1×/day I_2: resistance 'exercise snacks': 2×/day I_3: resistance 'exercise snacks': 3×/day C: no intervention	MSE	4 weeks	Daily	9 min	No; PhysiTrack™ application	Body weight
Gram et al. (2012),	n = 67 construction workers, 43.0 years,	RCT (2 groups)	Work	I: individual program with exercises for neck–shoulder, abdomen–back, hip–knee	MSE, MVPA	12 weeks	3	20 min	Yes; skilled instructors (two of three weekly	Body weight,

Denmark	100 %			C: 1-hour lecture on general health promotion					sessions)	free weights, bands
Hars et al. (2024), Switserland	n = 142 older adults with fall risk, 74.3 years, 8.5 %	RCT (2 groups)	Group-based (setting unclear) + home	I_1: Dalcroze Eurhythmics exercise (music-based multitask exercise) I_2: multicomponent exercise	MSE, BAL, functional exercises	12 months	2	na	Combi; na	na
Heiestad et al. (2016), Norway	n = 143 inactive and overweight, 39.9 years, 0 %	RCT (4 groups)	Community: SATS fitness centers	I_1: BodyPump training (fitness membership with classes including exercises for legs, chest, back, triceps, biceps, shoulder, abdominal and core) I_2: individual PT exercises I_3: non-supervised exercises (instructions 1st and 18th session) C: no intervention All: exercise diary; no financial compensation	MSE	12 weeks	3	45–60 min	Combi; personal trainer	Free weights
Hunter et al. (2021), Australia	n = 85, university employees, 43.2 years, 27 %	RCT (3 groups)	Work	I_1: individually tailored aerobic and resistance program, supervised, onsite exercise facility access (SUP) I_2: individually tailored aerobic and resistance program, unsupervised, onsite exercise facility access (NPS) C: individually tailored aerobic and resistance program, unsupervised, no onsite exercise facility access (CON)	MSE, MVPA	16 weeks	2	na	Combi; I_1 trained undergraduate exercise science students; I_2 gym supervision by one instructor	Free weights
Jamrasi et al. (2024), South Korea	n = 79 older adults 65+ years, 73.9 years, 32 %	RCT (3 groups)	Group-based community center (first 12 weeks) + home (last 12 weeks)	I_1: walking + resistance exercise I_2: walking C: active control (light-intensity stretching)	MSE, walking	12 weeks + 12 week follow-up	2	50 min	First 12 weeks supervised, last 12 weeks unsupervised; na	Bands
Jette et al. (1996), USA	n = 102 elderly, 72.1 years, 63 %	RCT (2 groups)	Home	I: Strong-for-life program with videos and periodic telephone follow-up C: no intervention	MSE	12 weeks	3	30 min	No; trained instructor	Free weights
Kamada et al. (2013, 2015, 2018), Japan	n = 3507 middle-aged and elderly, 60.9 years, 46 %	RCT (4 groups)	Community: city-wide campaign	I_1: muscle-strengthening, flexibility and aerobic activity I_2: muscle-strengthening and flexibility I_3: aerobic activity (mainly walking) All: information delivery (flyers, leaflets, newsletters, posters, banners, audio broadcast), education delivery (medical check-ups and events), support delivery (social, material, professional) C: no intervention	MSE, FLEX, MVPA	5 years	na	na	No; na	Body weight
Keogh et al. (2022), Australia	n = 245 community-dwelling adults receiving Australian Government-funded aged care services, 79.4 years, 21 %	RCT (2 groups)	Senior centers	I: progressive resistance and balance training C: no intervention	MSE, BAL	24 weeks	2	55 min	Yes; accredited exercise physiologists	Gym machines, body weight, boxes
Keshavarz et al. (2023), Canada	n = 60 obese men, 41.7 years, 100 %	RCT (2 groups)	Home	I: online supervised muscle-strengthening circuit program C: online exercise resource for 12-week workout plan	MSE	12 weeks, 46-week follow-up	3	50 min	Combi (24 of 36 sessions supervised online); na	Body weight

(continued on next page)

Table 2 (*continued*)

Author(s) (year of publication), country	Participants: sample size and description, mean age, proportion males	Study design	Setting	Intervention (I)/control (C) group(s)	Modalities promoted	Duration	Weekly sessions (n)	Duration session	Supervision (yes/no/combi); instructor credentials[a]	Materials
Kullman et al. (2020), USA	n = 17 adults, 21.8 years, 47 %	RCT (2 groups)	Exercise facility or home	I_1: Supervised suspension training at exercise facility I_2: Unsupervised home-based suspension training	MSE	8 weeks	2	45-60 min	Combi; TRX certificering study personnel	TRX suspension trainer
Liang et al. (2024), UK	n = 90 older adults with impaired strength and balance, 74.1 years, 29 %	RCT (2 groups)	Home	I: resistance exercise snack and Tai-Chi snack C: control	MSE, BAL	12 weeks	Daily	5 min snack	No; na	Body weight
Lord et al. (1996), Australia	n = 179 elderly, 74.6 years, 0 %	RCT (2 groups)	Community: public hospital and community hall	I: structured exercise classes (fee waived, no classes during school holidays, emphasis on social interaction and enjoyment) C: no intervention	MSE, MVPA, BAL, FLEX	1 year	2	60 min	Yes; three trained instructors	Body weight
Makino et al. (2021), Japan	n = 415 older adults with subjective memory complaints, 72.3 years, 53 %	RCT (4 groups)	Local gyms	I_1: Aerobic exercise training I_2: Resistance exercise training I_3: Aerobic + resistance exercise training C: no intervention	MVPA, MSE	26 weeks	2	60 min	Yes; well-trained fitness instructors	Tubes, body weight
Michishita et al. (2017), Japan	n = 59 white-collar workers, 40.9 years, 68 %	RCT (2 groups)	Work	I: 'Active rest' program with 10 minute lunch fitness C: no intervention	MSE, MVPA	10 weeks	3	10 min	Yes; fitness instructor	Body weight
Mulla et al. (2018), Canada	n = 43 desk-based workers, 43.7 years, 37 %	RCT (2 groups)	Work	I: fitness-center strength classes, follow-up emails to non-attenders C: no intervention	MSE	12 weeks	3	45 min	Yes; certified instructor	Body weight
Olsen et al. (2025), Spain, Germany, UK, Denmark	n = 1360 older adults 65 + years, 75.0 years, 38 %	Multi-country RCT (3 groups)	Group-based community setting + home	I_1: exercise referral scheme I_2: exercise referral scheme + self-management strategies C: control/usual care	AE, MSE, BAL	4 months + follow-up at 22 months	2 group-based sessions	45–60 min	Combi; na	na
Orange et al. (2019), UK	N = 36 aging adults, 53.6 years, 30.6 %	RCT (2 groups)	Home	I: supervised MSE program at lab C: unsupervised MSE program at home with telephone support	MSE	4 week training 12 week detraining	3	I: ±28 min C: ±23 min	Yes; I certified strength and conditioning specialist	Bands
Plotnikoff et al. (2023), Australia	N = 245 adults, 53.4 years, 28 %	Cluster RCT (2 groups)	Community	I: app with outdoor gym workouts C: waitlist control	MSE	10 weeks	2	na	No; researchers	Outdoor fitness equipment
Prieto-Prieto et al. (2022), Spain	n = 44 caregivers of persons with dementia, 60.2 years, 0 %	RCT (2 groups)	Home	I: PA intervention including aerobic, mobility and resistance exercises C: control	MVPA, MSE	9 months	2	60 min	Yes; qualified personal trainer	Body weight, free weights, bands
Rogers et al. (2024), USA	n = 29 office workers and students, 39 years, 31 %	Randomized crossover study (2 groups)	Workplace setting	I: REB (Resistance Exercise Breaks) C: SIT (control, no REB)	MSE	2 weeks	4 REB on days 1 and 2 (i.e., every 2 h), 8 REB on days 3 and 4 (i.e., every 1 h), and 16 REB on day 5 (i.e., every 30 min)	3 min	No; na	Body weight
Rooks et al. (1997), USA	n = 131 elderly, 73.6 years, 45 %	RCT (3 groups)	Community: community center	I_1: resistance training I_2: walking sessions C: no intervention	MSE	10 months	3	60 min	Yes; research assistants and instructor	Free weights
Seguin-Fowler et al. (2021), USA	n = 167 adults 50+ years, 64.8 years, 22 %	RCT (2 groups)	Community locations + home	I: progressive strength training classes C: no intervention	MSE	12 weeks	2 in class, 1 at home	60 min	Combi; experienced health promotion class leaders	Body weight, free weights

Shirazi et al. (2007), Iran	n = 116 mid-aged, 53.2 years, 0 %	RCT (2 groups)	Home	I: exercise education program based on stages of change and transtheoretical model with reminder cards and pamphlet and progressive, individually tailored exercise program C: no intervention	MSE, MVPA	12 weeks	3	20 min	No; na	Bands
Sjogren et al. (2006), Finland	n = 90 office workers, 45.7 years, 27 %	Cross-over RCT (2 groups)	Work	I: individual program of light resistance training with time-out during work day to train C: no intervention	MSE	15 weeks	5	6–8 min	No; physiotherapist	Gym machines
Suzuki et al. (2024), Japan	n = 18 non-elderly hospital workers, 41 years, 5 %	RCT (2 groups)	Home	I: MSE group (sukubara®) C: control	MSE, BAL	12 weeks	3	14.5 min	No; physical therapist	Body weight, foam rubber
Talevski et al. (2023), Australia	n = 162 older adults 60+ years with osteopenia or increased fall/fracture risk, 67.4 years, 27 %	RCT (2 groups)	Community-based fitness centers	I: progressive resistance, weight-bearing impact and balance training C: standard care control	MSE, BAL, weight-bearing impact exercises	18 months	3	60 min	Yes; certified exercise trainers	Gym machines, free weights
II. Multiple-groups pre–post design										
Brandt et al. (2024), Germany	n = 68 military and civilian staff employees, I = 38.2 years, 45.6 %; C: 36.7 years, 41.2 %	2 groups pre–post	Workplace	I: CrossFit® training C: free to attend any other activities offered at the same time	AE, BAL, FLEX, MOB, MSE	12 months	2	60 min	Yes; certified CF level 1 and 2 coaches	na
Capodaglio et al. (2002), Italy	n = 22 elderly, 68.5 years, 100 %	2-groups pre–post	Home	I: upper and lower-body strength training (6 movements), weekly telephone check-ups C: no intervention	MSE	4 months	3	na	No; na	Bands
Fetherman et al. (2011), USA	n = 27 elderly, 69.0 years, 0 %	2-groups pre–post	Home	I_1: strength training only I_2: strength training and behavior change (goal-setting worksheet, one 10-min individual counseling session)	MSE	12 weeks	3	60 min	Combi; undergraduate exercise science students	Free weights
Hunter et al. (2018), Australia	n = 50 university employees, 42.5 years, 20 %	2-groups pre–post	Work	I_1: individual program supervised I_2: individual program unsupervised	MSE, MVPA	8 weeks	1–5	na	Yes; trained undergraduate exercise science students	Free weights
Jakobsen et al. (2015a,b, 2017a,b, 2018), Denmark	n = 200 healthcare workers, 42.3 years, 0 %	2-groups pre–post	Home, work	I_1: group-based strength training at work, 5 group-based motivational coaching sessions (30–45 min with 5–12 participants in each session) during working hours I_2: exercises at home, posters to visually demonstrate the exercises	MSE	10 weeks	5	10 min	Combi; experienced training instructors	Free weights, tubes
Jin et al. (2023), Korea	n = 48 older women 75–84 years, 0 %	Quasi-experiment (2 groups)	Group setting	I: Otago Exercise Program C: no intervention	MSE, BAL, walking	6 months	2	45–55 min	Yes; na	na
Merchant et al. (2021), Singapore	n = 111 older adults 65+ years, 75.9 years, 27 %	Non-randomized experimental study (2 groups)	Community	I: dual-task exercises incorporating resistance, balance, aerobic and cognitive tasks C: no intervention	MVPA, MSE, BAL	3 months	2	60 min	Yes; trainee health coaches	na
Moreira et al. (2022), Portugal	N = 49 computer workers, 36.1 years, 64.1 %	Quasi-experiment (2 groups)	Workplace	I: online workplace exercise program (via MS Teams) C: no intervention	MSE, FLEX	17 weeks	3	15 min	Yes; physiotherapist	Rubber band
Osuka et al. (2017), Japan	n = 127 elderly, 70.7 years, 35 %	2-groups pre–post	Community: public community hall	Walking outside and strength exercises in fitness studio I_1: couple-group I_2: non-couple-group	MSE, MVPA	8 weeks	1	70–100 min	Yes; trained instructors including a physical education teacher and a health fitness	Body weight

(continued on next page)

Table 2 (*continued*)

Author(s) (year of publication), country	Participants: sample size and description, mean age, proportion males	Study design	Setting	Intervention (I)/control (C) group(s)	Modalities promoted	Duration	Weekly sessions (n)	Duration session	Supervision (yes/no/combi); instructor credentials[a]	Materials
									programmer	
Ransdell et al. (2003), USA	n = 34 mothers and daughters, 45.0 years, 0 %	2 groups pre–post	Community (fitness facility) and home	2 classroom sessions (guidelines PA, health related fitness, calculating energy expenditure, goal setting, positive-self talk) I_1: Community-based group at fitness facility. I_2: Home-based group	MSE, MVPA, FLEX	12 weeks	3	60–75 min	Yes; four qualified instructors with degrees in exercise and sport science	Body weight, household items
Rogers et al. (2002), USA	n = 22 African-American elderly, 74.8 years, 0 %	2 groups pre–post	Community: senior center	I: senior center exercise classes C: no intervention	MSE	4 weeks	3	50 min	Yes; exercise science student	Free weights, bands
Schneider et al. (2011), USA	n = 332 elderly, 71.8 years, 24 %	3 groups pre–post	Community: local community facility	I_1: exercise training and cognitive behavioral therapy I_2: exercise training and education C: exercise training only All: $20 at 6-month, $30 at 9-month and $50 at 12-month follow-ups	MSE, FLEX	2 weeks	3	50 min	Yes; research team member with a bachelor's degree in physical education and 15 years of experience working with older adults	Bands
III. 1-group pre–post design										
Aartolahti et al. (2019), Finland	n = 182 older adults 75+ years, 79.7 years, 29 %	1 group pre–post	Gym	Group-based strength and balance training	MSE, BAL	2.3 years	1	75 min	Yes; physiotherapist	Gym machines
Arkkukangas et al. (2020), Sweden	n = 79 adult employees, 45 years, 39 %	1 group pre–post	Workplace	Judo4Balance: breakfall techniques, strength/power exercises, mobility, balance and agility	MSE, MOB, BAL	10 weeks	1	50 min	Yes; qualified judo instructors	Body weight
Ashmead & Bocksmick (2002), na	n = 10 elderly, 68.2 years, 0 %	1-group pre–post	Home	I: upper and lower-body strength training through exercise videos	MSE	10 weeks	3	25 min	No; na	Body weight, free weights, tubes
Bates et al. (2009), Australia	n = 110 elderly, 66.4 years, 15 %	1-group pre–post	Community: centers, church halls, surf lifesaving clubs, hospital recreation halls	I: Staying Active, Staying Strong program with upper and lower-body strength training, education about strength training and falls prevention with handbook	MSE/BAL	10 weeks	1	90 min	Yes; qualified and experienced fitness leaders	Own body, weights
Brown et al. (2024), Australia	n = 74 undergraduate university students, 20.3 (1.4) years, 33.7 %	1 group pre–post	Digital channels and university	I: PEAK Mood, Mind, and Marks program	MVPA, MSE	12 weeks	3 or more	10 min or more	No; na	na
Crespin et al. (2016), USA	n = 2972 university employees, 45.0 years, 68 %	1-group pre–post	Work	I: University of Minnesota's Fitness Rewards Program (monthly $20 credit if participant utilizes fitness center at least 8 times)	MSE/MVPA	Not stated	na	na	No; na	Gym machines
Dalager et al. (2023), Australia	n = 269 office workers,43 years, 38 %	1 group pre–post	Work	I: individualized 1-hour workstation ergonomic assessment, progressive exercise training program	MSE	12 weeks	3	20 min	Combi; 1×/week health professional	Free weights, bands
Daly et al. (2021), Australia	n = 20 older adults 65+ years, 70.4 years, 50 %	1 group pre–post	Home	Multicomponent home exercise program	MSE, BAL, MOB, weight-bearing impact exercises	8 weeks	3	na	No; accredited exercise physiologist using Physitrack app	Body weight, box step, weights, bands
Hasegawa et al. (2019), Japan	n = 14 older adults 65+ years, 78.6 years, 21 %	1 group pre–post	na	Resistance exercises, ergometer cycling	MSE, MVPA	12 weeks	2	60 min	Yes; na	Body weight

Hill et al. (2007), Australia	n = 116 older carers, 64.4 years, 15 %	1-group pre–post	Community: health care services	Program of choice (1 group of Tai Chi, 2 groups of yoga, 8 groups of strength training), refreshments and opportunity for networking and support after each session. Carers had the option of additional respite care to enable participation	MSE, MVPA, BAL	6 months	1–2	60 min	Yes; physical therapist with aged-care experience	na
Jansons et al. (2022), Australia	n = 15 adults 60–89 years, 70.3 years, 40 %	1-group pre–post	Home	Exercise snacks, 4 body weight exercises for upper and lower body and balance exercises	MSE, BAL	12 weeks	2–4× daily	10 min	No; accredited exercise physiologist	Body weight
Liang et al. (2017), Taiwan	n = 58 elderly, 76.9 years, 24 %	1-group pre–post	Community: care stations in centers, churches, temples	I: individual program, 4 educational meetings (1 h), disease- and treatment-related counseling every 2 months	MSE, BAL, FLEX	6 months	2	2 h	Yes; a physical therapist assisted by community volunteers 1×/week, community volunteers without a physical therapist 1×/week	Free weights, bands
Maxwell et al. (2024), USA	n = 19 older adults 50+, 71.4 years, 28 %	1 group pre–post	Home	I: MitoFit intervention: videos on importance mitochondria, didactic instruction about heart rate zones, demo of 5 competencies and exercise plan (including 5 calisthenics exercises)	MSE, walking	4 weeks	na	na	No; research team	Body weight
Nielsen et al. (2025), Denmark	n = 465 hospital employees, 50.0 years, 8 %	1 group pre–post	Outdoor fitness area (or indoor in bad weather)	I: Intelligent Physical Exercise Training	MSE, HIIT	20 weeks	na (on average 1–2 sessions/week)	na	Yes; exercise coaches	Outdoor equipment
Porter et al. (2022), USA	n = 105 adults consuming ≥200 cal per day from sugar sweetened beverage, 41.8 years, 18 %	1 group pre–post	In-group classes + home	I: intervention to increase MVPA and MSE, 3 in-person classes, 1 teach-back call, 11 interactive voice response calls	MVPA, MSE	6 months	na	na	Combi; masters and PhD-level health educators	na
Sciamanna et al. (2021), USA	n = 24 older adults 60+ years, 71.6 years, 67 %	1 group pre–post	Home	Daily push-ups and squats for 30 s	MSE	24 weeks	Daily	1 min	No; emails from the primary care physician	Body weight
Seguin et al. (2012), USA	n = 367 aging women, 63.0 years, 0 %	1 group pre–post	Community: churches, senior centers, public housing, hospitals	I: Strong Women Exercise Program with resistance training + email and online social network, encouragement of regular evaluations	MSE, BAL, FLEX	10 weeks	2	45–60 min	Yes; community leaders	Body weight, free weights
Sharp et al. (2022), Australia	n = 113 firefighters, 43 years, 82 %	1 group pre–post	Onsite training facilities + offside sessions	Gym-based exercise (AE and resistance exercise) and mobility training	MVPA, MSE, MOB	7–20 weeks	10 sessions in total	90–120 min	Combi; professional performance staff	Free weights
Takakura et al. (2015), Japan	n = 65 university students, 19.6 years, 78 %	1 group pre–post	Home	I: individual high-intensity circuit training program	MSE	8 weeks	2–3	7 min	No; senior physical therapy students	Body weight
Tsuzuki et al. (2024), Japan	n = 3819 middle-aged and aged adults, 62 years, 47.8 %	1 group pre–post (high dose vs. low dose)	Community	I: Unnan Kou-un (Happiness in Unnan) Exercise (peer-led MSE program)	MSE	2 years	na (at least once a week)	na	Yes; community exercise leaders	Body weight
Vrantsidis et al. (2014), Australia	n = 35 elderly, 66.4 years, 31 %	1 group pre–post	Community: fitness/leisure centers, health services etc.	I: paid, individual Living Longer Living Stronger strength training program	MSE, BAL, FLEX	8 months	2	1 h	Yes; staff at participating centers	Free weights

AE: aerobic exercise; BAL: balance exercises; combi: combination of supervised and unsupervised; FLEX: flexibility and stretching exercises; HIIT: high-intensity interval training; min: minutes; MOB: mobility exercises; MSE: muscle-strengthening exercise; MVPA: aerobic moderate-to-vigorous physical activity; na: not available; PA: physical activity; RCT: randomized controlled trial.

[a] In unsupervised interventions, instructor credentials refer to the person who designed and/or explained the exercise program to the participants; in supervised interventions, instructor credentials refer to the person who supervised the exercise sessions.

Table 3
Quality assessment of the selected studies.

Author(s), year of publication	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Overall rating
I. Randomized controlled trials							
Arikawa et al., 2011	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Biddle et al., 2022	Weak	Strong	Strong	Strong	Strong	Moderate	**Moderate**
Brennan et al., 2024	Weak	Strong	Strong	Weak	Strong	Moderate	**Weak**
Chan et al., 2024	Moderate	Strong	Strong	Moderate	Strong	Moderate	**Strong**
Chang et al., 2023	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Dalager et al., 2015	Weak	Strong	Strong	Moderate	Strong	Weak	**Weak**
De Vreede et al., 2005; 2007	Weak	Strong	Strong	Moderate	Strong	Moderate	**Moderate**
Dun et al., 2022	Weak	Strong	Strong	Moderate	Strong	Strong	**Moderate**
Ferrari et al., 2024	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Fyfe et al., 2022	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Gram et al., 2012	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Hars et al., 2024	Weak	Strong	Weak	Moderate	Strong	Moderate	**Weak**
Heiestad et al., 2016	Weak	Strong	Strong	Moderate	Strong	Moderate	**Moderate**
Hunter et al., 2021	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Jamrasi et al., 2024	Weak	Strong	Strong	Weak	Strong	Weak	**Weak**
Jette et al., 1996	Weak	Strong	Strong	Moderate	Strong	Strong	**Moderate**
Kamada et al., 2013; 2015; 2018	Strong	Strong	Strong	Weak	Moderate	Moderate	**Moderate**
Keogh et al., 2022	Weak	Strong	Weak	Weak	Strong	Moderate	**Weak**
Keshavarz et al., 2023	Weak	Strong	Weak	Weak	Strong	Moderate	**Weak**
Kullman et al., 2020	Weak	Strong	Strong	Weak	Strong	Weak	**Weak**
Liang et al., 2024	Weak	Strong	Strong	Weak	Weak	Moderate	**Weak**
Lord et al., 1996	Moderate	Strong	Strong	Weak	Weak	Moderate	**Weak**
Makino et al., 2021	Weak	Strong	Strong	Moderate	Strong	Strong	**Moderate**
Michishita et al., 2017	Weak	Strong	Strong	Weak	Weak	Strong	**Weak**
Mulla et al., 2018	Moderate	Strong	Strong	Moderate	Strong	Strong	**Strong**
Olsen et al., 2024	Moderate	Strong	Strong	Moderate	Strong	Moderate	**Strong**
Orange et al., 2019	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
Plotnikoff et al., 2023	Weak	Strong	Strong	Weak	Strong	Moderate	**Weak**
Prieto-Prieto et al., 2022	Weak	Strong	Strong	Moderate	Strong	Strong	**Moderate**
Rogers et al., 2024	Weak	Strong	Strong	Weak	Moderate	Weak	**Weak**
Rooks et al., 1997	Weak	Strong	Strong	Weak	Weak	Strong	**Weak**
Seguin-Fowler et al., 2021	Weak	Strong	Weak	Moderate	Strong	Moderate	**Weak**
Shirazi et al., 2007	Moderate	Strong	Strong	Moderate	Strong	Strong	**Strong**
Sjogren et al., 2006	Moderate	Strong	Strong	Weak	Strong	Strong	**Moderate**
Suzuki et al., 2024	Weak	Strong	Strong	Weak	Moderate	Strong	**Weak**
Talevski et al., 2023	Weak	Strong	Strong	Weak	Strong	Strong	**Weak**
II. Multiple-groups pre–post design							
Brandt et al., 2024	Weak	Moderate	Moderate	Weak	Moderate	Weak	**Weak**
Capodaglio et al., 2002	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Fetherman et al., 2011	Weak	Moderate	Strong	Weak	Strong	Strong	**Weak**
Hunter et al., 2018	Weak	Moderate	Strong	Weak	Strong	Strong	**Weak**
Jakobsen et al., 2015a,b, 2017a,b, 2018	Moderate	Moderate	Strong	Moderate	Weak	Strong	**Moderate**
Jin et al., 2023	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Merchant et al., 2021	Weak	Moderate	Strong	Weak	Strong	Moderate	**Weak**
Moreira et al., 2022	Weak	Moderate	Strong	Weak	Strong	Weak	**Weak**
Osuka et al., 2017	Weak	Moderate	Strong	Weak	Strong	Strong	**Weak**
Ransdell et al., 2003	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Rogers et al., 2002	Weak	Moderate	Strong	Weak	Weak	Strong	**Weak**
Schneider et al., 2011	Weak	Moderate	Strong	Moderate	Strong	Strong	**Moderate**
III. 1-groups pre–post design							
Aartolathi et al., 2020	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Arkkukangas et al., 2020	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Ashmead & Bocksmick, 2002	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Bates et al., 2009	Weak	Moderate	Weak	Weak	Weak	Weak	**Weak**
Brown et al., 2024	Weak	Moderate	Weak	Weak	Moderate	Weak	**Weak**
Crespin et al., 2016	Weak	Moderate	Strong	Weak	Strong	Moderate	**Weak**
Dalager et al., 2023	Weak	Moderate	Weak	Weak	Moderate	Moderate	**Weak**
Daly et al., 2021	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Hasegawa et al., 2019	Weak	Moderate	Weak	Weak	Moderate	Moderate	**Weak**
Hill et al., 2007	Moderate	Moderate	Weak	Weak	Strong	Moderate	**Weak**
Jansons et al., 2022	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Liang et al., 2017	Moderate	Moderate	Weak	Weak	Strong	Strong	**Weak**
Maxwell et al., 2024	Weak	Moderate	Weak	Weak	Moderate	Moderate	**Weak**
Nielsen et al., 2025	Weak	Moderate	Weak	Weak	Strong	Weak	**Weak**
Porter et al., 2022	Weak	Moderate	Strong	Moderate	Strong	Moderate	**Moderate**
Sciamanna et al., 2021	Weak	Weak	Weak	Weak	Weak	Strong	**Weak**
Seguin et al., 2012	Moderate	Moderate	Weak	Weak	Weak	Weak	**Weak**
Sharp et al., 2023	Weak	Moderate	Weak	Weak	Moderate	Weak	**Weak**
Takakura et al., 2015	Weak	Moderate	Weak	Weak	Strong	Strong	**Weak**
Tsuzuki et al., 2024	Moderate	Moderate	Weak	Weak	Strong	Strong	**Weak**
Vrantsidis et al., 2014	Weak	Moderate	Moderate	Weak	Weak	Moderate	**Weak**

3.4. Outcomes of the interventions

Six studies reported behavioral outcomes only,[32,33,42,47,72,88] while others additionally reported on other fitness/functional/physical, general health, psychosocial and/or cognitive health outcomes (Supplementary Table S4 and Table 4).

3.4.1. Behavioral outcomes

Behavioral outcomes mainly included self-reported session adherence/compliance (n = 54). Session attendance rates ranged between 10 and 100 %, with only seven studies showing rates below 60 %.[46,57,81,89,91,94,109] In nine studies, adherence to specific attendance thresholds was presented (Supplementary Table S4).[50,53,62,66,97,103,104,108,109] Only two studies reported compliance with the number of exercises, sets, repetitions and/or level of exercise.[59,85]

Other behavioral outcomes were based on questionnaire data or accelerometry. There were measures of general PA and MSE outcomes (e.g. differences in weekly days or duration of exercise between conditions), showing significant improvements for participation in MSE and mixed findings for moderate-to-vigorous intensity PA, walking, daily step counts, or total PA levels. Only nine studies included explicit behavioral outcomes for MSE, such as participation in MSE (days/week, h/week, min/week) and/or the proportion of individuals meeting the MSE guidelines.[32–42] Moderate evidence was found for increased participation in MSE, with eight out of nine studies (and three out of four RCT's) reporting an increase (Supplementary Table S4 and Table 4).[32,33,37–42]

3.4.2. Fitness/functional/physical outcomes

Muscle strength (n = 39), muscle endurance (n = 7), aerobic fitness (n = 17), balance (n = 23), flexibility (n = 11), and a variety of other functionality measures (n = 35) were additionally reported. Regardless of the study design, *strength measures* improved in 48.7 % of the studies, did not change in 25.6 %, and showed mixed results in 25.6 %. RCT findings (n = 19) showed conflicting evidence for muscular strength. *Muscle endurance* improved in all studies measuring this construct (n = 7); however, there was limited evidence to draw strong conclusions (only three RCTs). In terms of *aerobic fitness*, *balance outcomes* and *flexibility measures*, conflicting evidence was found based on few RCTs. The majority of RCTs showed an improvement in *other functionality measures* (e.g., gait, sit-to-stand, stair climbing) (Supplementary Table S4 and Table 4).

3.4.3. Body composition and general physical health outcomes

Twenty-nine studies included measures of body composition and/or general physical health outcomes, with the majority reporting on a range of measures (Supplementary Table S4 and Table 4). There was moderate evidence for no change in blood pressure (3 RCTs), and conflicting evidence for pain-related outcomes (3 RCTs). For body composition, in 75.8 % of the studies, no changes were reported, while waist circumference or the waist–hip ratio improved in three out of five studies. The evidence for no change in BMI is moderate (6 RCTs). However, four RCTs were of low and two of moderate methodological quality. Both fat mass and fat-free mass showed conflicting findings.

3.4.4. Psychosocial, cognitive and work-related outcomes

A variety of psychosocial (e.g. self-efficacy) (n = 13), mental health-related (n = 11), quality-of-life (n = 11), cognition (n = 7), and work-related (n = 5) measures were reported. Of all psychosocial measures, in more than half of the studies (57.4 %) no change was reported, while 19.1 % showed an improvement, and 21.3 % had mixed findings. For mental health-related measures, quality-of-life variables and work-related measures, in 70.4 % of the studies 'no changes' were reported. There was conflicting evidence regarding mental health outcomes (6 RCTs), work-related outcomes (4 RCTs), and quality of life outcomes (5 RCTs) (Supplementary Table S4 and Table 4).

3.4.5. BCTs and behavioral outcomes

The use of BCTs in the nine studies that measured MSE behavior change (Table 4) was varied, with some studies using very few[32,33,37] and others using a considerable number[38,39,41,42] of BCTs (Supplementary Table S3). The use of theoretical frameworks to guide the intervention in these nine studies was also varied, though six out of the nine studies did make use of a theoretical framework.[34–36,38–42] There is not enough information to compare more successful with less successful interventions to say much about the effectiveness of certain BCTs over others.

4. Discussion

To the best of our knowledge, this systematic review is the first to provide an overview of community-based interventions aiming to promote MSE in the general population. The 69 unique studies (36 RCTs) meeting the inclusion criteria differed from each other in terms of methodological quality, intervention characteristics, and the reported outcomes. Overall, mostly proxy measures of behavioral outcomes, that is adherence to the intervention, were reported, suggesting that participation in the intervention was substantial (>60 % in 62 out of 69 studies). However, measures of actual behavioral (change) outcomes, such as MSE levels, were reported in only nine out of 69 studies, showing moderate evidence for improvement. Overall, the evidence regarding the effectiveness on the other reported outcomes was mainly conflicting.

Table 4
Intervention effects.

Intervention effects on activity behaviours

		NUMBER OF STUDIES									
OUTCOMES	**STUDY DESIGN**	1	2	3	4	5	6	7	8	9	10
Physical Activity (n=27)	RCT	Biddle (n=107)	*Hunter 2021* (n=85)	*Keshavarz (n=60)*	**Shirazi (n=116)**	Makino (n=415)	*Michishita (n=59)*	*Rogers (n=29)*	De Vreede (n=98)	Kamada (n=3,507)	*Liang 2024 (n=90)*
		11. Lord (n=179	*12. Suzuki (n=18)*	*13. Plotnikoff (n= 245)*	*14. Seguin-Fowler (n=167)*						
	(non-)RT	*Ransdell (n=34)*	*Hunter 2018 (n=50)*	Schneider (n=332)							
	1-group pre-post	*Crespin (n=2,972)*	*Daly (n=20)*	*Hasegawa (n=14)*	*Hill (n=116)*	*Maxwell (n=19)*	Porter (n=105)	*Brown (n=74)*	*Tsuzuki (n=3819)*	*Nielsen (n=465)*	*Vrantsidis (n=35)*
Muscle strengthening (n=9)	RCT	Biddle (n=107	*Keshavarz (n=60)*	*Plotnikoff (n=245)*	Kamada (n=3,507)						
	(non-)RT	*Ransdell (n=34)*	Schneider (n=332)								
	1-group pre-post	*Crespin (n=2,972)*	Porter (n=105)	*Tsuzuki (n=3819)*							

Intervention effects on fitness/functional/physical outcomes

OUTCOMES	STUDY DESIGN	NUMBER OF STUDIES 1	2	3	4	5	6	7	8	9	10
Muscle strength (n=39)	RCT	*Brennan (n=16)*	*Dalager 2015 (n=537)*	Dun (n=48)	*Ferrari (n=73)*	*Jamrasi (n=79)*	*Lord (n=179)*	*Plotnikoff (n=245)*	Prieto-Prieto (n=44)	**Shirazi (n=116)**	*Suzuki (18)*
		11. De Vreede (n=98)	*12. Gram (n=67)*	13. Jette (n=102)	*14. Keogh (n=245)*	15. Makino (n=415)	*16. Orange (n=36)*	*17. Rooks (n=131)*	*18. Liang 2024 (n=90)*	**19. Mulla (n=43)**	
	(non-)RT	*Brandt (n=68)*	*Jin (n=48)*	*Capadaglio (n=22)*	*Fetherman (n=27)*	*Hunter* 2018 (n=50)	Jakobsen (n=200)	*Merchant (n=111)*	*Ransdell (n=34)*	*Rogers (n=22)*	Schneider (n=332)
	1-group pre-post	*Bates (n=110)*	*Hasegawa (n=14)*	*Hill (n=116)*	*Liang 2017 (n=58)*	*Seguin (n=367)*	*Takakura (n=65)*	*Vrantsidis (n=35)*	*Aartolahti (n=182)*	*Ashmead (n=101)*	*Sharp (n=113)*
Muscle endurance (n=7)	RCT	*Dalager 2015 (n=537)*	*Jamrasi (n=90)*	Prieto-Prieto (n=44)							
	(non-)RT	*Ransdell (n=34)*	*Rogers (n=22)*								
	1-group pre-post	*Ashmead (n=101)*	*Sciamanna (n=24)*								
Aerobic fitness (n=17)	RCT	Dun (n=48)	*Gram (n=67)*	Prieto-Prieto (n=44)	*Jamrasi (n=79)*	**Mulla** (n=43)	*Keshavarz (n=60)*	*Plotnikoff (n=245)*			
	(non-)RT	*Fetherman (n=27)*	*Hunter 2018 (n=50)*	*Ransdell (n=34)*	Schneider (n=332)						
	1-group pre-post	*Bates (n=110)*	*Liang 2017 (n=58)*	*Nielsen (n=465)*	*Seguin (n=367)*	*Vrantsidis (n=35)*	*Takakura (n=65)*				
Balance (n=23)	RCT	**Chan (n=42)**	Dun (n=48)	*Hars (n=142)*	*Liang 2024 (n=90)*	*Rooks (n=131)*	**Shirazi (n=116)**	*Suzuki (n=18)*	De Vreede (n=98)	*Ferrari (n=73)*	*Fyfe (n=38)*
		11. Makino (n=415)									
	(non-)RT	*Rogers (n=22)*	*Fetherman (n=27)*	*Capodaglio (n=22)*	Schneider (n=332)	*Sharp (n=113)*					
	1-group pre-post	*Arkkukangas* (n=79)	*Bates (n=110)*	*Hill (n=116)*	*Liang 2017 (n=58)*	*Seguin (n=367)*	*Vrantsidis (n=35)*	*Aartolahti (n=182)*			
Flexibility (n=11)	RCT	Dun (n=48)	*Liang (n=90)*	Prieto-Prieto (n=44)	*Seguin-Fowler (n=167)*						
	(non-)RT	*Fetherman (n=27)*	*Ransdell (n=34)*	*Rogers (n=22)*	Schneider (n=332)						
	1-group pre-post	*Seguin (n=367)*	*Bates (n=110)*	*Liang 2017 (n=58)*							
Other functional outcomes (n=35)	RCT	Dun: agility (n=48)	*Ferrari: gait (n=73)*	*Hars: gait, TUG, SPPB, STS (n=142)*	*Jamrasi: STS, TUG (n=79)*	*Liang 2024: SPPB, STS (n=90)*	*Lord: sway (n=179)*	**Mulla: SC (n=43)**	*Keogh: SPPB (n=245)*	*Kullman: FMS (n=17)*	Makino: STS, gait, TUG (n=415)
		12. Orange: gait, TUG, STS, SC (n=36)	*12. Plotnikoff (n=245)*	13. Prieto-Prieto: STS (n=44)	*14. Rooks: SC, ReT, PP (n=131)*	*15. Brennan: frailty, gait (n=16)*	**16. Chan: FES, TUG, STS (n=42)**	17. De Vreede: DF (n=98)	**18. Olsen: SPPB, SF-LLFDI, (I)ADL (n=1360)**	*19. Seguin-Fowler: TUG, AC, STS, ST (n=167)*	*20. Fyfe: STS (n=38)*
	(non-)RT	*Brandt: FMS (n=68)*	*Jin: gait, STS, TUG, SPPB (n=48)*	*Capadaglio: gait (n=22)*	*Merchant: gait, SPPB (n=111)*						
	1-group pre-post	*Arkkukangas* : SPSS (n=79)	*Ashmead: ability (n=101)*	*Bates: ability (n=110)*	*Hasegawa: STS, gait, frailty, step test (n=14)*	*Vrantsidis: FPT (n=35)*	*Aartolahti: STS, gait, TUG (n=116)*	*Hill: gait (n=116)*	*Liang 2017: gait + EMS (n=58)*	*Daly: SPPB (n=20)*	*Jansons: STS (n=15)*
		11. Sharp (n=113)									

Given the potentially far-reaching implications of regular MSE for individuals and public health,[1] there is a need for more high-quality intervention studies assessing this behavior/these activities and their outcomes to know what works to promote this mode of PA and improve physical and mental health.

A key finding is that, despite the need to promote MSE in the prevention of chronic diseases,[12] limited interventional research is available on how to promote this type of PA in healthy populations. Since only nine studies (including two RCTs of low and two of moderate quality) assessed and reported on the engagement in MSE, we were unable to make strong conclusions regarding the effectiveness to change behavior.

Regarding the fitness, functional and physical outcomes, an interesting finding was the conflicting evidence on muscle strength. One would expect that MSE interventions improve strength if done regularly. For example, meta-analytic evidence shows that community and workplace PA (promoting more than MSE, such as walking) results in improved muscle strength in adults aged 40–65 years[111] and meaningful but small improvements in handgrip strength in community-dwelling adults aged 60 years or older.[112] However, despite the substantial adherence rates and intervention durations, improvements in muscle strength were only found in ten of 19 RCTs in the present systematic review. It should however be noted that – in addition to the positive effects across all muscle strength outcomes in these ten RCTs – there also were seven RCTs reporting beneficial effects on several but not all included tests for muscle strength. Only two RCTs reported no significant effects. Furthermore, the RCTs with mixed or null findings were primarily based on measures of handgrip strength which may exhibit low responsiveness to training interventions.[113] According to the principle of training specificity, outcomes are typically more pronounced when the testing conditions closely resemble the training activities.[114,115] This suggests that

Intervention effects on body composition and general physical health outcomes

OUTCOMES	STUDY DESIGN	NUMBER OF STUDIES 1	2	3	4	5	6	7	8	9	10
BMI (n=14)	RCT	*Chang (n=72)*	Dun (n=48)	*Gram (n=67)*	*Keshavarz (n=60)*	*Michishita (n=59)*	Prieto-Prieto (44)				
	(non-)RT	*Fetherman (n=27)*	*Hunter 2018 (n=50)*	*Rogers (n=22)*							
	1-group pre-post	*Bates (n=110)*	*Hasegawa (n14)*	*Sharp (n=113)*	*Vrantsidis (n=35)*	*Nielsen (n=465)*					
Waist / waist hip ratio (n=5)	RCT	Prieto-Prieto (n=44)	*Chang (n=72)*	*Keshavarz (n=246)*							
	(non-)RT	*Hunter 2018 (n=50)*	*Nielsen (n=465)*								
Fat mass (n=7)	RCT	Dun (n=48)	*Chang (n=72)*	*Ferrari (n=73)*	*Keogh (n=245)*	*Keshavarz (n=60)*	*Plotnikoff (n=245)*				
	(non-)RT	*Ransdell (n=34)*									
Fat-free mass (n=7)	RCT	Dun (n=48)	*Kullman (n=17)*	*Suzuki (n=18)*	*Jamrasi (n=79)*	*Keogh (n=245)*	*Keshavarz (n=60)*	*Plotnikoff (n=245)*			
Blood pressure (n=5)	RCT	*Gram (n=67)*	*Michishita (n=59)*	*Keshavarz (n=60)*							
	(non-)RT	*Ransdell (n=34)*									
	1-group pre-post	*Nielsen (n=465)*									
Cholesterol (n=2)	RCT	*Chang (n=72)*	*Keshavarz (n=60)*								
Glucose (n=1)	RCT	*Keshavarz (n=60)*									
Pain-related (n=6)	RCT	*Dalager 2015 (n=537)*	Jette (n=102)	Kamada (n=3,507)							
	(non-)RT	*Brandt (n=68)*	Jakobsen (n=200)	*Moreira (n=49)*							
	1-group pre-post	*Nielsen (n=465)*	*Dalager 2023 (n=269)*								

suboptimal or non-specific measurement methodologies may have contributed to the lack of consistent findings. In addition, insufficient exercise dose and progression may have influenced the heterogeneity of results. Adhering to the intended dose and progression has previously been identified as a major challenge in real-life interventions among community-dwelling older adults, especially when no supervision is provided and limited equipment is available.[25,116] Although supervision may potentially influence compliance, we were unable to confirm such an influence. The majority of the intervention programs within the RCTs in our systematic review (i.e., 13 out of 19) were supervised. More specifically, six out of ten RCTs with positive findings, six out of seven RCTs with mixed findings and one out of two RCTs with null findings were supervised. Furthermore, a mixture of training equipment was used across papers with either positive, mixed or null findings (e.g., body weight only, free weights, bands, tubes, boxes and machines). As only two studies in our systematic review reported compliance with the exercise dose, we can only speculate on the underlying reasons for mixed findings on muscle strength. In contrast to our finding on muscle strength, all present studies, although only three RCTs, reported improvements in muscle endurance. This is similar to meta-analytic findings showing positive effects on muscle endurance in workplace physical exercise training[117] and community and workplace PA programs in 40–65 year-old adults.[111]

Further, conflicting evidence was found for aerobic fitness, balance and flexibility, while moderate evidence was found for improvements in functional outcomes measured through a variety of tests. As the only (pilot) RCT that reported null findings in functional outcomes in our systematic review provided unsupervised exercise in a home-based context, our results are in line with recent meta-analytic findings showing improvements in physical function in older adults (≥60 years) after supervised versus unsupervised exercise.[118]

Regarding body composition outcomes, our results showed moderate evidence of no change in BMI and conflicting evidence for the waist/waist–hip ratio, fat mass, and fat-free mass. These results are in contrast with expectations as regular participation in MSE is expected to result in improved body composition, in particular lean body mass.[119] Null findings on lean body mass in the four studies of our systematic review might partly be explained by the use of whole-body assessments[37,38,82] rather than muscle-specific measurements, which may overlook specific hypertrophic changes that regional assessments can more accurately detect.[120] Also, greater muscle hypertrophy is typically reached with progressively higher weekly training volumes,[121] while exercise dose and progression were not described in sufficient detail to interpret the findings. Similar to body composition outcomes, meta-analytic data suggest that MSE improves cardiometabolic health markers, although the quality of the evidence is rather low.[10] In this review, limited information was available on cardiometabolic health outcomes, so we can neither confirm nor contradict the existing evidence.

The conflicting level of evidence for the psychosocial, cognitive and work-related outcomes in this review is also in contrast to the meta-analytic evidence (based on RCTs) showing that the promotion of resistance training supports, for example, the improvement of health-related quality of life in mid-aged to older adults (i.e., 59.9 to 82.1 years).[122] However, these findings should not be extrapolated to the general adult population, given the age-specific nature of the evidence. It is possible that the volume and intensity of MSE in our included studies were insufficient to improve the outcomes. In addition, little is known about the perceived quality of experience during the interventions, which is also important for psychosocial outcomes.

Designing effective community-based MSE programs requires balancing accessibility, which may initially be more important from a

Intervention effects on psychosocial and cognitive health outcomes and work-related outcomes.

OUTCOMES	STUDY DESIGN	NUMBER OF STUDIES 1	2	3	4	5	6	7	8	9	10
Cognition (n=7)	RCT	*Keogh (n=245)*	*Hars (n=142)*	*Jamrasi (n=79)*	**Chan (n=42)**	Makino (n=245)					
	(non-)RT	*Merchant (n=111)*									
	1-group pre-post	*Brown (n=74)*									
Mental health (n=11)	RCT	*Michishita (n=59)*	*Keogh (n=245))*	Sjogren (n=90)	Jette (n=102)	**Mulla (n=43)**	*Plotnikoff (n=245)*				
	(non-)RT	Jakobsen (n=200)	*Moreira (n=49)*								
	1-group pre-post	*Hill (n=116)*	*Nielsen (n=465)*	*Vrantsidis (n=35)*							
Quality of life (n=11)	RCT	Jette (n=102)	De Vreede (n=98)	Heiestad (n=143)	*Keogh (n=245)*	*Talevski (n=162)*					
	(non-)RT	*Fetherman (n=27)*									
	1-group pre-post	*Nielsen (n=465)*	*Bates (n=110)*	*Hill (n=116)*	*Jansons (n=15)*	*Vrantsidis (n=35)*					
Work-related (n=5)	RCT	*Michishita (n=59)*	*Dalager 2015 (n=537)*	**Mulla (n=43)**	Sjogren (n=90)						
	(non-)RT	Jakobsen (n=200)									
Other psychosocial outcomes (n=13)	RCT	Heiestad (n=143)	*Michishita (n=59)*	*Rogers (n=29)*	**Shirazi (n=116)**	Kamada (n=3,507)	*Dalager 2015 (n=537)*	Sjogren (n=90)			
	(non-)RT	*Brandt (n=68)*	*Merchant (n=111*	*Moreira (n=49)*							
	1-group pre-post	*Nielsen (n=465)*	*Brown (n=74)*	Porter (n=105)							

Green box = significant improvement in the outcome as reported in the individual papers; Blue box = combination of improvement and no change; gray box = no change; Orange box = significant deterioration in the outcome. AC: arm curl test; EMS: elderly mobility scale; FES: falls efficacy scale; FMS: functional movement screen; FPT: physical performance tests; PP: pen pick-up; RCT: randomized controlled trial; RT: randomized trial; ReT: reaction time; SC: stair climb; ST: step test; STS: sit to stand; TUG: timed-up-and-go. The overall quality rating, as described in Table 3, was indicated as follows: Bold = strong; Normal = moderate; Cursive = weak.

public health perspective, with sufficient training stimulus to elicit meaningful physiological adaptations, which is essential from a structured exercise perspective. Current international guidelines for healthy adults – and by extension older adults – recommend performing MSE at least twice weekly using moderate-to-high loads (i.e., ≥60 % of the one-repetition maximum (1-RM)) to maximize gains in muscle mass and strength.[114,123] While the use of lower loads (i.e., <60 % 1-RM) has been identified as less effective for strength development, comparable hypertrophic responses can be achieved if exercises are performed to volitional failure.[124] Although the inclusion of specific MSE guidelines underscores the importance of MSE for public health, it is a major challenge to 'translate' the 'optimal dose and progression' of these training guidelines to clear public health messages. The absence of specific guidelines for dosing and progression, however, is likely to limit impact. For optimal impact for both individuals and society, public health guidelines and initiatives should provide details on training dose and progression, and on how to operationalize them, to align with the international training guidelines. If not, underdosing is likely. The considerable heterogeneity in program design and the absence of detailed data on adherence to the training dose in the studies included in this systematic review preclude adequate dose–response analyses, limiting our ability to confirm or rule out the presence of underdosing. In addition to the challenge of achieving appropriate training stimuli and progression in community-based settings, many community programs lack the equipment, individualization, and progression needed for sustained benefits.[25] Despite these challenges, there is a clear need for the promotion of adequate MSE, with sufficient stimulus, from a public health perspective.

Besides examining the outcomes, we also coded the BCTs used during the interventions.[27] The most commonly used BCTs were *instruction on how to perform the behavior*, *demonstration of the behavior*, and *behavioral practice/rehearsal*, as MSE requires learning to use weight training equipment or body weight exercises in conjunction with new motor skills. These BCTs are commonly employed in interventions to improve strength training participation.[125] When it comes to *instruction* as an intervention component, however, merely assessing its presence or absence would appear to be too general to ascertain its function in affecting behavior change. The role of many specific aspects of delivery (e.g. mode, instructor credentials, frequency) needs to be considered. The indication of presence versus absence of *demonstration* would also seem too generalized to tease out any behavior change effects on MSE, and more specific aspects (e.g. mode, characteristics) may need to be assessed or manipulated. Finally, *practice/rehearsal* is a vital aspect of muscle-strengthening skill acquisition, and only assessing its presence or absence may not do justice to the variety of factors (e.g. supervision, peer support, intensity) that may affect how *practice/rehearsal* influences behavior change. *Social support*, *adding objects to the environment*, *restructuring the social environment*, *feedback on behavior*, and *information about health consequences* were also somewhat commonly used, which is in line with the findings of Ma et al.[125] The latter study also indicated that goal setting, self-monitoring of behavior, and using a credible source were common BCTs, which were less common in the included studies of our systematic review. While we cannot make firm suggestions regarding effective behavioral change, a recent review on mediators of resistance training behavior showed that interventions that incorporated a greater number of BCT clusters appeared to have a

more positive impact on behavior; however, no specific BCT cluster emerged as particularly crucial.[126] The number of BCTs used did not seem to be of great relevance in our systematic review, as some studies showed improvements in MSE behavior with only a minimal number of BCTs. It may be that the choice of relevant BCTs for a given population and context is more important than the number of BCTs.[127] The delivery of the BCTs, including their frequency and intensity (rather than mere presence), and how well participants engage with the techniques, may also be important issues. As 70–96 % of adults do not meet MSE recommendations,[8,13,14,20–22] there is an urgent need to embed evidence-based behavior change techniques into public health efforts to effectively motivate, support, and reinforce MSE participation.

4.1. Directions for future research

The inclusion of MSE in the WHO guidelines is a clear indication of its importance for individual and public health. However, much work remains to be done to increase our understanding of the promotion of MSE in healthy populations. Overall, well-designed, controlled trials of high quality, assessing MSE and clearly reporting the (active) components of the interventions are needed to examine true behavior change. At this stage, there is no evidence on the most effective intervention strategies for particular population groups. Strain and colleagues[8] highlighted three key groups for intervention, that is, women, particularly in the youngest age groups; those over the age of 75; and those already undertaking some but not sufficient MSE. Our results show that 18.8 % of the studies included women only, 49.3 % of the interventions were done in adults aged over 60, and only 7.2 % of the studies included a sample with a mean age over 75 years. As such, from a public health perspective, more interventions are needed in women and older adults.

Overall, including explicit assessments of MSE behavior pre- and post-interventions should be encouraged in all studies aiming to examine MSE, even if a study's main focus is on health outcomes. Ideally, follow-up assessments of engagement in MSE behavior at different points in time post-intervention would be included. Self-enacted change techniques should also be considered and documented.[128]

Deliberate inclusion and explicit assessment of the effectiveness of behavior change support strategies in future studies is also encouraged. While the BCT taxonomy[27] provides a useful range of techniques to consider, more specific work on the role of strategies that are particularly relevant to MSE behavior (for particular populations) is needed.[128] Features that deserve attention include location (e.g. home, fitness club, work/school, community center); aspects of instruction (e.g. ratio of instructor-to-participant; length, duration, and frequency of instruction sessions); aspects of demonstration (e.g. mode; characteristics of the demonstrator); education about health consequences and injury risks; the provision of equipment to encourage home practice; the use of psychological support strategies (e.g. goal setting and action planning, decision balance, self-monitoring, feedback on outcomes); and social support. We found that studies that frame the intervention in behavior change and/or social theories appear to include more psychologically-orientated BCTs, and this may help in the design of future studies.

Apart from considering these aspects in the design of interventions, some way of assessing the impact of these features on MSE behavior is encouraged. Studies may systematically vary aspects of delivery to test their importance to adherence and/or health outcomes. Few studies so far have varied psychological behavior change strategies as an intervention arm, controlling for the effectiveness of adding specific psychological behavior change support.

4.2. Strengths and limitations

The key strength of this study is that it appears to be the first review to synthesize the existing peer-reviewed evidence on real-life interventions promoting MSE in healthy populations. In addition, we used a comprehensive search strategy across multiple databases and all screening, quality assessment and data extraction were done by two independent reviewers. Finally, the identification of BCTs using the BCT Taxonomy v1[27] may provide important information on the intervention strategies, which could be informative for future intervention development and implementation. Nevertheless, other factors should be considered when trying to link BCTs to intervention effectiveness. The present review is also subject to some limitations. The main limitation is that no meta-analyses were conducted due to the high heterogeneity of the intervention characteristics, reported outcome variables, and measurement methods between the included studies. Hence, we analyzed the data in a descriptive narrative way. Secondly, the methodological quality of the included studies was, in general, weak. Moreover, as we only identified published articles, the possibility of publication bias cannot be excluded.

5. Conclusion

This systematic review of 69 community-based interventions promoting MSE in healthy populations showed a lack of uniformity in intervention elements and reported outcomes. Behavioral outcomes related to the actual engagement in MSE were hardly reported. As such, from a public health promotion perspective, at this stage, there is limited evidence on how to best increase the uptake and maintenance of this mode of PA. More well-designed intervention studies are needed on how to promote MSE in healthy populations.

Consent for publication

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Confirmation of ethical compliance

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CRediT authorship contribution statement

Evelien Van Roie: Methodology, Investigation, Data curation, Visualization, Writing – original draft. **Jannique van Uffelen:** Methodology, Investigation, Visualization, Writing – review & editing. **Jan Seghers:** Methodology, Investigation, Writing – review & editing. **Larry Myers:** Methodology, Investigation, Writing – review & editing. **Ineke Vergeer:** Methodology, Investigation, Writing – review & editing. **Stuart J.H. Biddle:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Katrien De Cocker:** Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing – original draft.

Declaration of interest statement

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2025.09.005.

Data availability

All data generated or analyzed during this study are included in this published article and its Supplementary files.

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