Home-based exercise programmes improve physical fitness of healthy older adults

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Review

Home-based exercise programmes improve physical fitness of healthy older adults: A PRISMA-compliant systematic review and meta-analysis with relevance for COVID-19

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ABSTRACT

This systematic review and meta-analysis aimed to examine the effects of home-based exercise programmes on measures of physical-fitness in healthy older adults. Seventeen randomized-controlled trials were included with a total of 1,477 participants. Results indicated small effects of home-based training on muscle strength (between-study standardised-mean-difference [SMD] = 0.30), muscle power (SMD = 0.43), muscular endurance (SMD = 0.28), and balance (SMD = 0.28). We found no statistically significant effects for single-mode strength vs. multimodal training (e.g., combined balance, strength, and flexibility exercises) on measures of muscle strength and balance. Single-mode strength training had moderate effects on muscle strength (SMD = 0.51) and balance (SMD = 0.65) while multimodal training had no statistically significant effects on muscle strength and balance. Irrespective of the training type, >3 weekly sessions produced larger effects on muscle strength (SMD = 0.45) and balance (SMD = 0.37) compared with ≤3 weekly sessions (muscle strength: SMD = 0.28; balance: SMD = 0.24). For session-duration, only ≤30 min per-session produced small effects on muscle strength (SMD = 0.35) and balance (SMD = 0.34). No statistically significant differences were observed between all independently-computed single-training factors. Home-based exercise appears effective to improve components of health- (i.e., muscle strength and muscular endurance) and skill-related (i.e., muscle power, balance) physical-fitness. Therefore, in times of restricted physical activity due to pandemics, home-based exercises constitute an alternative to counteract physical inactivity and preserve/improve the health and fitness of healthy older adults aged 65-to-83 years.

1. Introduction

Physical inactivity (PIN) has adverse effects on health and well-being. The reduction of PIN is a target of global public healthcare. More than one quarter (27.5 %) of the world's population does not meet physical activity (PA) recommendations of at least 150 min of moderate or 75 min of vigorous PA per week (Guthold et al., 2018), issued by the World Health Organization (WHO) (Bull et al., 2020). There is evidence that prevalence rates for PIN increase from ~30 % in 30−44 year olds to ~46 % in adults aged ≥60 years (Hallal et al., 2012). Additionally, compliance to exercise programmes has been reported to be low in older adults (Hawley-Hague et al., 2016; Hill et al., 2011). This may mitigate potential intervention effects on markers of fitness and health (Room et al., 2017). Of note, the WHO has identified PIN as the fourth leading risk factor for global mortality with 6 % of deaths globally (WHO, 2010).

Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) caused the Coronavirus disease 2019 (COVID-19) and elicited a pandemic with severe medical conditions, including death, economic disruptions, and deteriorating health for those not infected by the virus due to forced self-isolation. Months of home confinement can dramatically increase PIN

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(Warren and Skillman, 2020). To shed further light on the effects of forced home confinement associated with the pandemic on PA, China conducted a national cross-sectional study during the early days of the COVID-19 outbreak to gather information on 7-day PA behavior, sedentary screen time, and emotional state using an online questionnaire (Qin et al., 2020). Findings from 12,107 participants aged 18–80 years showed that nearly 60 % of older adults did not meet the required volume of physical activity to confer a health benefit. During non-pandemic periods, only 14 % of Chinese residents do not follow WHO physical activity recommendations (Qin et al., 2020).

COVID-19-related mortality rates dramatically increase as a function of age. Mortality rates amounted to 0–1 %, 8–13 %, and 15–20 % in adults aged 20–59 years, 70–79 years, and ≥80 years, respectively (Onder et al., 2020). Given that older adults are more susceptible to case-fatalities, self-isolation and social distancing have been declared fundamental for infection prevention. Of note, older adults are particularly vulnerable to adverse health effects due to PIN (Cunningham et al., 2020). Social isolation further exacerbates the deterioration of health during the COVID-19 pandemic (Roschel et al., 2020). Long periods of PIN can drastically increase the progression of sarcopenia, frailty, and the development of comorbidities (Bell et al., 2016; Cunningham et al., 2020). Indeed, a reduction of daily steps to ~1500 steps/day over 14 days can decrease lower limbs muscle mass by ~4 % in older adults (Breen et al., 2013). Additionally, there is evidence that 10 days of bed rest resulted in decrements in muscle mass (2 %) and strength (12.5 %) in older adults (Coker et al., 2015). Muscle mass loss weakens the resistance of the body to disease and infections in older adults (Cosquéric et al., 2006). Consequently, periods of enforced mobility restrictions due to pandemics are likely to have a negative impact on medium/long term public health.

The UK National Institute for Health and Clinical Excellence in primary care endorsed the promotion of PA by doctors in clinical settings and recommends PA as a cornerstone of medical disease prevention and treatment (Excellence and Britain, 2006). Further, in a global health initiative, the American College of Sports Medicine promotes exercise as medicine for healthy individuals across the life span and patients suffering from chronic diseases (Lobelo et al., 2014). Extensive evidence exists on the overall positive effects of PA and exercises on markers of health and fitness as well as mobility in older adults, irrespective of sex and health status (Pedersen and Saltin, 2015). Meta-analytical evidence suggests that cycling, low and high doses alike, is associated with a 22 % risk reduction in cardiovascular disease incidents and mortality compared with using passive transport, regardless of sex and age (Nordengen et al., 2019).

During the ongoing COVID-19 pandemic, older adults who are at a disproportionately high risk of viral infections are restricted to their homes to perform PA. Home-based exercise programmes constitute a feasible strategy to reduce the inactivity-induced losses in PA and physical fitness, health- and skill-related components alike, in older adults (Ganz and Latham, 2020; Gentil et al., 2020; Lakicevic et al., 2020; Ravalli and Musumeci, 2020). Indeed, 16 weeks of home-based strength and balance exercises improved physical fitness in 64 years old adults including functionally meaningful changes in muscle power and mobility (Ashari et al., 2016). In addition to recent calls to keep PA levels up even under forced home confinement due to the Corona crisis (Chen et al., 2020; Onder et al., 2020), the WHO has launched a campaign "*be active at home during the COVID-19 outbreak*" to urge people, particularly older adults, to stay physically active (WHO, 2020). However, WHO recommendations did not specify the type and dosage of exercise. While there is experimental evidence in support of the favorable effects of home-based exercise programmes on physical fitness in older adults, this evidence has not yet been comprehensively and systematically assessed. Of note, physical fitness has been defined as a set of attributes that are either health- or (e.g., muscle strength, muscular endurance, cardiorespiratory endurance) or skill-related (e.g., muscle power, balance, speed) and that people have or achieve and are related to the ability to perform physical activity (Caspersen et al., 1985). Therefore, this systematic review with meta-analysis aimed to examine the effects of home-based exercise programmes on measures of health- (i.e., muscle strength, muscular endurance) and skill-related (i.e., muscle power, balance) physical fitness in healthy older adults. We hypothesized that home-based exercise versus no-exercise improves physical fitness in older adults (Ashari et al., 2016; Lacroix et al., 2016). We further hypothesized that multimodal training (combined strength, balance, endurance exercises included in one programme) results in larger physical fitness improvements in healthy older adults compared with single-mode strength training (Jadczak et al., 2018).

2. Methods

This systematic review was conducted according to the Preferred Recording Items for Systematic Review and Meta-analysis (PRISMA) statements (Liberati et al., 2009). This study was registered with the PROSPERO database on July 5th, 2020 (ID: CRD42020182784).

2.1. Literature search

A systematic search was conducted in the electronic databases MEDLINE, Web of Science, Cochrane Library, SPORTDiscuss, and Google Scholar with no date restriction up to December 20th, 2020. Only peer-reviewed randomized-controlled studies written in English were included. Keywords were collected through expert opinion, literature review, and controlled vocabulary (e.g., Medical Subject Headings [MeSH]). The following Boolean search syntax was used: ((exercise OR "neuromuscular training" OR "strength training" OR "resistance training" OR "plyometric training" OR "power training" OR "balance training") AND (residential OR home OR "home-based") AND (fitness OR strength OR power OR balance OR endurance) NOT (rehabilitation OR patients OR disease OR pain OR injury OR "cerebral palsy" OR "multiple sclerosis" OR cancer OR diabetes OR obesity* OR dementia OR arthroplasty)). Search results were screened by three researchers (MH, JH, and HC). Potentially relevant articles were screened for titles, abstracts, and finally full texts. To search for further potentially relevant studies, the reference lists of already published review articles were screened. Of note, studies that used exergaming (virtual reality) as an intervention were excluded. This is because the topic has already been examined extensively in previous systematic reviews (Donath et al., 2016; Molina et al., 2014). An overview of the search process is displayed in Fig. 1.

2.2. Selection criteria

A PICOS (participants, intervention, comparators, study outcomes, and study design) approach was used to rate studies for eligibility (Liberati et al., 2009). The respective inclusion/exclusion criteria were reported in Table 1.

2.3. Study coding and data extraction

All included studies were coded for the variables displayed in Table 2. In case multiple tests were used for the same fitness outcome, protocols with superior criterion validity were prioritized (Higgins et al., 2019). Three independent reviewers (MH, JH, HC) extracted data from the included studies in a standardised template created with Microsoft Excel. In case of disagreement regarding data extraction and study eligibility, co-author OP was consulted for clarification. To calculate between-study effect sizes, baseline and follow-up means and standard deviations were used for health- and skill-related outcome measures of both the intervention and control groups. The characteristics of the included studies are displayed in Table 3.

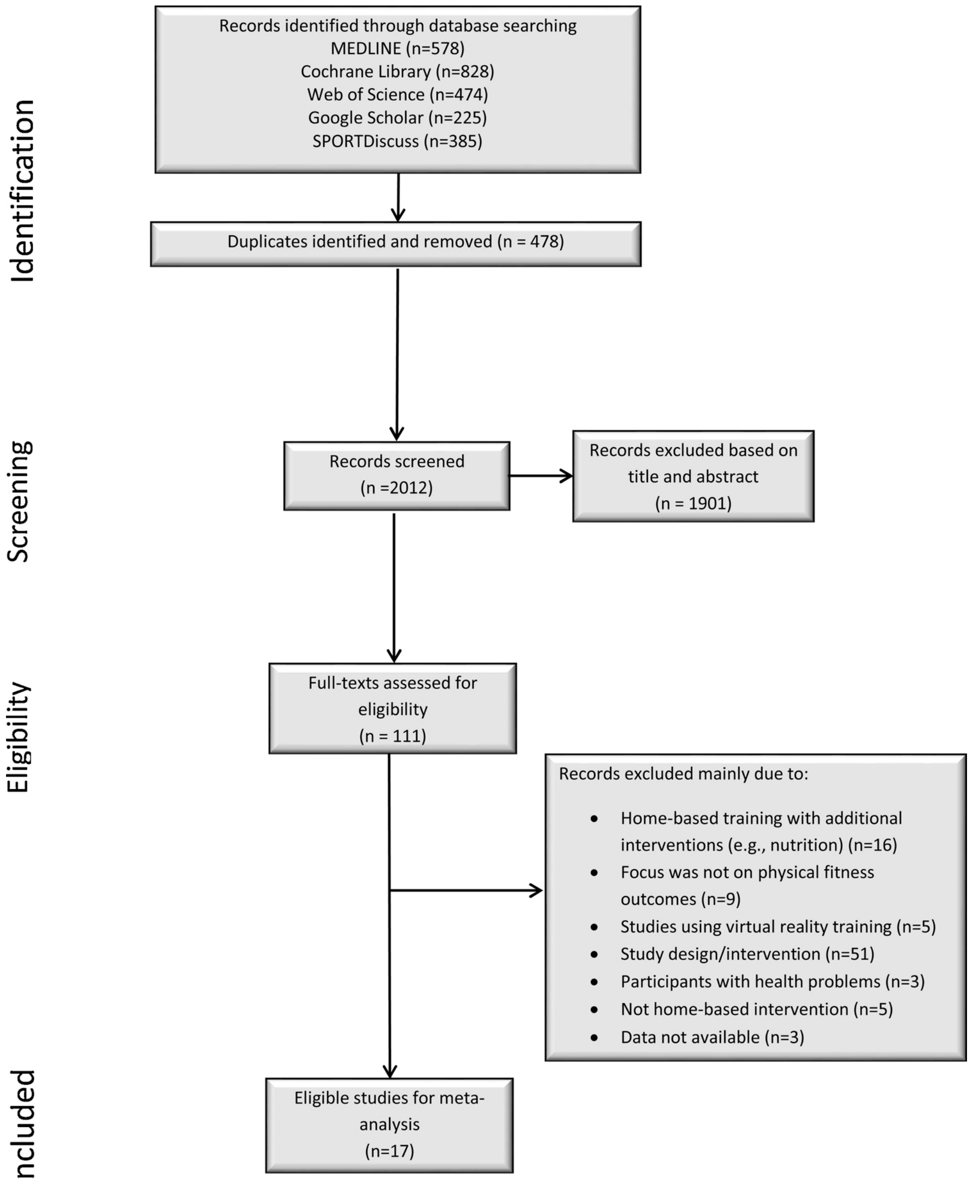

Fig. 1. Flow chart illustrating the selection process for all included and excluded studies.

2.4. *Study quality*

The Physiotherapy Evidence Database (PEDro) scale was used to assess the risk of bias of the included studies. The methodological quality of the included studies was rated on a scale from 0 (high risk of bias) to 10 (low risk of bias). A score of ≥6 represents the threshold for studies with a low risk of bias (Maher et al., 2003) (Table 4).

2.5. *Results analyses and interpretation*

To examine the effectiveness of home-based exercise on health- and skill-related fitness outcomes, weighted between-study standardised mean differences (SMDs) were computed for pre-test and post-test values of each study using the following equation: SMD = (M1 − M2)/S_{pooled}, where M_1 stands for the mean pre/post-value of the intervention group, M_2 for the mean pre/post-value of the control group, and S_{pooled} for the pooled standard deviation. To control for sample size, SMDs were adjusted according to the following equation $\left(1 - \frac{3}{4N-9}\right)$ with N representing the total sample size (Hedges, 1985). Additionally, adjusted SMD values were calculated as the difference between pre-test SMD to post-test SMD (Durlak, 2009). A random-effects model was used to weigh each study and to determine the SMDs which are presented alongside 95 % confidence intervals using Hedges' g estimator. This was realized with the "R" packages "meta" (Balduzzi et al., 2019) and "metafor" (Viechtbauer, 2010). The SMDs were interpreted using the conventions as outlined by Cohen (Cohen, 1988) (SMD < 0.2 "trivial"; 0.2 ≤ SMD < 0.5 "small", 0.5 ≤ SMD < 0.8 "moderate", SMD ≥ 0.8 "large"). Further, a multivariate random-effects meta-regression was conducted to verify if any of the training variables predicted the effects of home-based exercise on measures of physical fitness in healthy older adults using the "R" package "metareg" (Balduzzi et al., 2019). According to the Cochrane Handbook for Systematic Reviews, at least ten studies are needed per covariate to compute meta-regression (Higgins et al., 2019). In addition, independent subgroup analyses were calculated for moderator and single-factor variables. The level of between-study heterogeneity was assessed using the I^2 statistics. This indicates the proportion of effects that are caused by heterogeneity as opposed to chance (Liberati et al., 2009). Low, moderate, and high heterogeneity correspond to I^2 outcomes of 25, 50, and 75 %,

Table 1
Selection criteria.

Category	Inclusion criteria	Exclusion criteria
Population	Healthy older adults (≥65 years), irrespective of sex	Studies investigating individuals with adverse health (e.g., diabetes, hypertension, asthma)
Intervention	Home-based exercise interventions with no or minimal supervision (i.e., <20 % of the training sessions were supervised)	Group-based exercise programmes, exercise interventions not conducted at home, fully supervised exercise interventions conducted at home, home-based exercise programmes delivered with additional interventions (e.g., nutrition), exergaming training
Comparator	Passive control group	Absence of a passive control group
Outcome	Measures of health- (e.g., muscle strength) or skill-related physical fitness (e.g., muscle power, balance)	Lack of baseline and/or follow-up data
Study design	Randomized-controlled trials	Non-randomized controlled trials

Table 2
Testing protocols across the different measures of physical fitness considered for statistical calculations.

Outcome categories	Ranking
Muscle strength	• Maximal isometric force of the knee extensors • Maximal dynamic torque of the knee extensors • Maximal isokinetic knee extensor torque • Maximal isometric force of the plantar flexors
Proxies of muscle power	• Chair rise test, sit-to-stand test
Proxies of muscular endurance	• 30 s chair rise test
Balance	• Timed up and go or 8 foot up and go • Gait speed • Functional reach test

respectively (Higgins et al., 2003). A value above 75 % is rated as being considerably heterogeneous (Deeks et al., 2008). The $\chi2$ (chi-square) statistics were employed to determine whether the differences in the results are due to chance and in such a case, a low p-value, or high $\chi2$ statistic, relative to degrees of freedom would be apparent (Deeks et al., 2008). To generate forest plots, the "R" meta-package was used. The level of significance was set at $p < 0.05$. All analyses were conducted using R (version 4.0.2, 2020) (R-Core Team, 2020).

2.6. Subgroup analyses

The type of home-based exercise programme (i.e., single-mode strength training and multimodal training [balance, strength, endurance]) was considered as a moderator variable. It was not possible to additionally extract data for single-mode balance training given that only one study examined the effects of single-mode balance training (Hinman, 2002).

2.7. Single-factor variables

Single-factor analyses were computed for training duration: ≤8 weeks/>8–16 weeks/>16 weeks; training frequency: ≤3/>3/ sessions/ week; and session duration: ≤30/>30 min.

3. Results

3.1. Study characteristics

The systematic search in five electronic databases identified 111 potentially relevant articles to be included in this study (Fig. 1). Finally, 17 studies were eligible for inclusion comprising 17 experimental groups. The number of participants across the included studies ranged from 9 to 388 with a total of 1,477 (Table 3). One study solely enrolled male participants (Ema et al., 2017), two studies solely enrolled female participants (Niemelä et al., 2011; Vestergaard et al., 2008), and 11 studies included both, males and females (Dondzila et al., 2016; Hinman, 2002; Kahle and Tevald, 2014; Kobayashi et al., 2006; Lacroix et al., 2016; Liu-Ambrose et al., 2008; Maruya et al., 2016; Nelson et al., 2004; Perkin et al., 2019; Tsekoura et al., 2018; Vitale et al., 2020). In three studies, the sex of participants was not specified (Dadgari et al., 2016; Hsieh et al., 2019; Iliffe et al., 2015). Participants' age ranged from 65–83 years with a mean age of 74 ± 4 years.

Minimal supervision of home-based exercise was realized through phone calls, training diaries, and direct visits. Based on findings from 7 studies, between 6 and 17 % of the total number of exercise sessions were supervised (i.e., direct visits) (Dadgari et al., 2016; Ema et al., 2017; Kahle and Tevald, 2014; Kobayashi et al., 2006; Liu-Ambrose et al., 2008; Nelson et al., 2004; Tsekoura et al., 2018). Seven studies used phone calls and/or training diaries (Dondzila et al., 2016; Hsieh et al., 2019; Iliffe et al., 2015; Lacroix et al., 2016; Maruya et al., 2016; Vestergaard et al., 2008; Vitale et al., 2020). Three studies did not provide information on how training was supervised (Hinman, 2002; Niemelä et al., 2011; Perkin et al., 2019). Rates of study compliance were provided in 9 studies (Dondzila et al., 2016; Lacroix et al., 2016; Liu-Ambrose et al., 2008; Maruya et al., 2016; Niemelä et al., 2011; Perkin et al., 2019; Tsekoura et al., 2018; Vestergaard et al., 2008; Vitale et al., 2020). The remaining studies did not include information on the rate of compliance (Dadgari et al., 2016; Ema et al., 2017; Hinman, 2002; Hsieh et al., 2019; Iliffe et al., 2015; Kahle and Tevald, 2014; Kobayashi et al., 2006; Nelson et al., 2004).

Home-based interventions comprised single-mode strength training (Dondzila et al., 2016; Ema et al., 2017; Kahle and Tevald, 2014; Niemelä et al., 2011; Perkin et al., 2019) or single-mode balance training (Hinman, 2002), and multimodal training programmes (i.e., combined strength and balance training) (Dadgari et al., 2016; Hsieh et al., 2019; Iliffe et al., 2015; Kobayashi et al., 2006; Lacroix et al., 2016; Liu-Ambrose et al., 2008; Maruya et al., 2016; Nelson et al., 2004; Shirazi et al., 2007; Tsekoura et al., 2018; Vestergaard et al., 2008; Vitale et al., 2020). Home-based interventions lasted between 4 and 26 weeks. Training frequency ranged between 2–14 sessions per week with a duration of 5–75 min per session. The mean weekly exercise dosage across thirteen studies was 125 min (Dadgari et al., 2016; Hinman, 2002; Hsieh et al., 2019; Kahle and Tevald, 2014; Kobayashi et al., 2006; Lacroix et al., 2016; Liu-Ambrose et al., 2008; Maruya et al., 2016; Niemelä et al., 2011; Perkin et al., 2019; Tsekoura et al., 2018; Vestergaard et al., 2008; Vitale et al., 2020). Four studies did not report information on weekly exercise dosage (Dondzila et al., 2016; Ema et al., 2017; Iliffe et al., 2015; Nelson et al., 2004).

The median PEDro score of the included studies was 6 (range 4–8). Nine out of the 17 included studies reached the cut-off value of 6 (Table 4).

3.2. Effects of home-based exercise on measures of physical fitness

Figs. 2 to 5 show the overall effects of home-based training compared with a passive control on measures of physical fitness. Home-based exercise resulted in small effects on muscle strength (SMD = 0.30 [0.12 to 0.48]; $p < 0.01$, Fig. 2), muscle power (SMD = 0.43 [0.01–0.85]; $p = 0.04$, Fig. 3), balance (SMD = 0.28 [0.07 to 0.48]; $p < 0.01$, Fig. 4) and muscular endurance (SMD = 0.28 [0.14–0.42]; $p < 0.01$, Fig. 5).

3.3. Results of subgroup analyses

The results of the subgroup analyses are displayed in Table 5. Single-mode strength training resulted in moderate effects on muscle strength

Table 3
Characteristics of the included studies.

Study	Population			Characteristics of the home-based training						Rate of compliance
	N	Sex F/M	Age (years)	Description	Training duration (weeks)	Frequency (session/ wk)	Session duration (min)	Intensity	Supervision	
(Dadgari et al., 2016)	IG (160) CG (157)	NA	70.60 ± 5.80 70.06 ± 5.20	Combined strength and balance training	24	3	40–60	progressive NA	Training diary, home visits once a month + family caregivers every session	NA
(Dondzila et al., 2016)	IG (19) CG (19)	15/ 4 12/ 7	73.5±5.6 75.4±6.8	Single-mode strength training	8	2	NA	1–2/10–15	Training log, biweekly calls	at least 80 %
(Ema et al., 2017)	IG (17) CG (17)	0/ 17 0/ 17	73 ± 5	Single-mode strength training	8	3	NA	3 × 10	Laboratory meeting: initial and after 4 weeks	NA
(Hinman et al., 2002)	IG2 (30) CG (30)	7/ 23 12/ 18	72.6 70.1	Single-mode balance training	4	3	20	NA	NA	NA
(Hsieh et al., 2019)	IG1 (79) CG (80)	33/ 46 29/ 51	72.0±6.0 72.5±5.5	Multimodal training (i.e., strength, flexibility, balance, endurance)	24	3–7	5–60	NA	Training log	NA
(Iliffe et al., 2015)	IG1 (178) CG (210)	NA	72.8±5.8 73.1±6.2	Combined strength and balance training	24	3	NA	NA	Training log	NA
(Kahle and Tevald, 2014)	IG (12) CG (12)	8/4 8/4	76.5±6.9 75.6±3.6	Single-mode strength training	6	3	20–35	NA progressive	Training log; one session each 3 weeks	NA
(Kobayashi et al., 2006)	IG (81) CG (56)	49/ 32 29/ 27	70.6±4.3 72.1±4.0	Multimodal training (i.e., strength, balance, stretching)	12	3	45	NA	Six times in total	NA
(Lacroix et al., 2016)	IG (22) CG (22)	14/ 8 13/ 9	73.1±3.6 72.7±3.8	Combined strength and balance training	12	3	45	12–16 on a perceived exertion rating scale; progressive	Biweekly phone calls	97 %
(Liu-Ambrose et al., 2008)	IG (28) CG (24)	22/ 9 19/ 8	81.4±6.2 83.1±6.3	Combined strength and balance training	24	3	30	NA	5 visits in 24 weeks	25 % completed exercise programme 3 or more times per week 57 % completed the programme 2 or more times 68 % at least once per week
(Maruya et al., 2016)	IG (34) CG (18)	19/ 15 10/ 8	69.2 ± 5.6 68.5 ± 6.2	Multimodal training (i.e., strength, balance, and walking)	24	7	20–30 min walking + lower limb strength exercises	NA	Reviewing daily training log	70–90 %
(Nelson et al., 2004)	IG (34) CG (38)	27/ 7 30/ 8	77.7±5.3 77.8 ± 5.3	Combined strength and balance training	24	3	NA	7–8 on a 10 Borg-Scale	Six times during the 1st month after that one time per month	NA
(Niemelä et al., 2011)	IG (26) CG (25)	51/ 0	79.8±.4 80.7±3.9	Single-mode strength training	6	10 (2/day 5/wk)	15	NA	NA	86 % at least 10 times per week 14 % 8 times per week
(Perkin et al., 2019)	IG (10) CG (10)	7/3 7/3	70 ± 4 74 ± 5	Single-mode strength training	4	14 (2/day, 7/wk)	9 min (5 × 1 min exercise + 4 × 1 min rest)	NA	NA	98 %
(Tsekoura et al., 2018)	IG1 (18)	15/ 3	71.2 ± 6.5 72.9±8.3	Multimodal training (i.e.,	12	3	40–60			87.5 %

(continued on next page)

Table 3 (*continued*)

Study	Population			Characteristics of the home-based training						Rate of compliance
	N	Sex F/M	Age (years)	Description	Training duration (weeks)	Frequency (session/ wk)	Session duration (min)	Intensity	Supervision	
	CG (18)	16/ 2		strength, balance and walking)				10–12 on 6–20 Borg-Scale	4 visits of a physiotherapist + 4 calls	
(Vestergaard et al., 2008)	IG (25) CG (28)	53/ 0	81.0±3.3 82.7±3.8	Multimodal training (i.e., strength, balance, flexibility and endurance)	20	3	26	NA	Biweekly calls	89.2 %
(Vitale et al., 2020)	IG (5) CG (4)	6/3	66 ± 4 71 ± 9	Combined strength and balance training	24	4	55	NA	Training log, weekly calls	At least 75 %

N: Number, M: male, F: female, IG: intervention group, CG: control group, NA: not available, RCT: randomized controlled trial, Wk: week.

Table 4
Methodological quality of the included studies based on the physiotherapy evidence database (PEDro) scale.

Study	Eligibility criteria	Randomized allocation	Blinded allocation	Group homogeneity	Blinded subjects	Blinded therapists	Blinded assessor	Drop out <15 %	Intention-to- treat analysis	Between-group comparison	Point estimates and variability	PEDro score
(Liu-Ambrose et al., 2008)	●	●	●	●	○	○	●	○	●	●	●	7
(Dadgari et al., 2016)	●	●	○	●	○	○	●	○	○	●	●	5
(Dondzila et al., 2016)	●	●	○	●	○	○	○	●	●	●	●	6
(Ema et al., 2017)	○	●	●	●	○	○	○	●	○	●	●	5
(Hinman et al., 2002)	●	●	○	●	○	○	○	●	○	●	●	5
(Hsieh et al., 2019)	●	●	○	●	○	○	●	○	●	●	●	6
(Iliffe et al., 2015)	●	●	○	●	○	○	○	○	●	●	●	5
(Kahle and Tevald, 2014)	●	●	●	●	○	○	○	●	●	●	●	7
(Kobayashi et al., 2006)	●	●	○	●	○	○	○	○	○	●	●	4
(Lacroix et al., 2016)	●	●	○	●	○	○	○	●	○	●	●	5
(Maruya et al., 2016)	●	●	○	●	○	○	○	○	○	●	●	4
(Nelson et al., 2004)	●	●	○	●	○	○	●	●	○	●	●	6
(Niemelä et al., 2011)	●	●	●	●	○	○	●	●	●	●	●	8
(Perkin et al., 2019)	●	●	●	●	○	○	○	●	○	●	●	6
(Tsekoura et al., 2018)	●	●	●	●	○	○	○	●	●	●	●	7
(Vestergaard et al., 2008)	●	●	○	●	○	○	○	●	●	●	●	6
(Vitale et al., 2020)	●	●	●	○	○	○	○	○	○	●	●	5

● adds a point on the score, ○ adds no point on the score. The item "eligibility criteria" is not included in the final score.

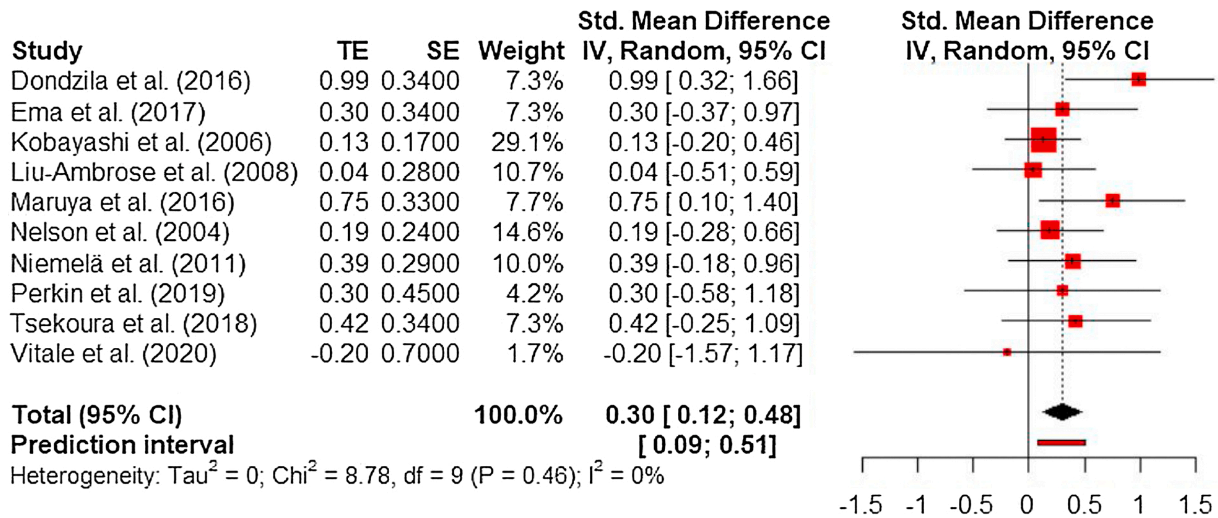

Fig. 2. Effects of home-based training versus passive control on measures of muscle strength in healthy older adults. *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance, *SE* standard error.

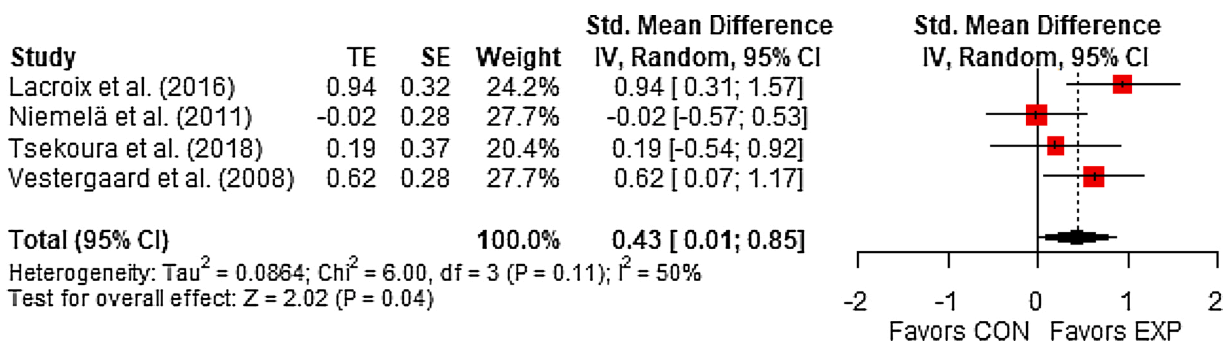

Fig. 3. Effects of home-based training versus passive control on measures of muscle power in healthy older adults. *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance, *SE* standard error.

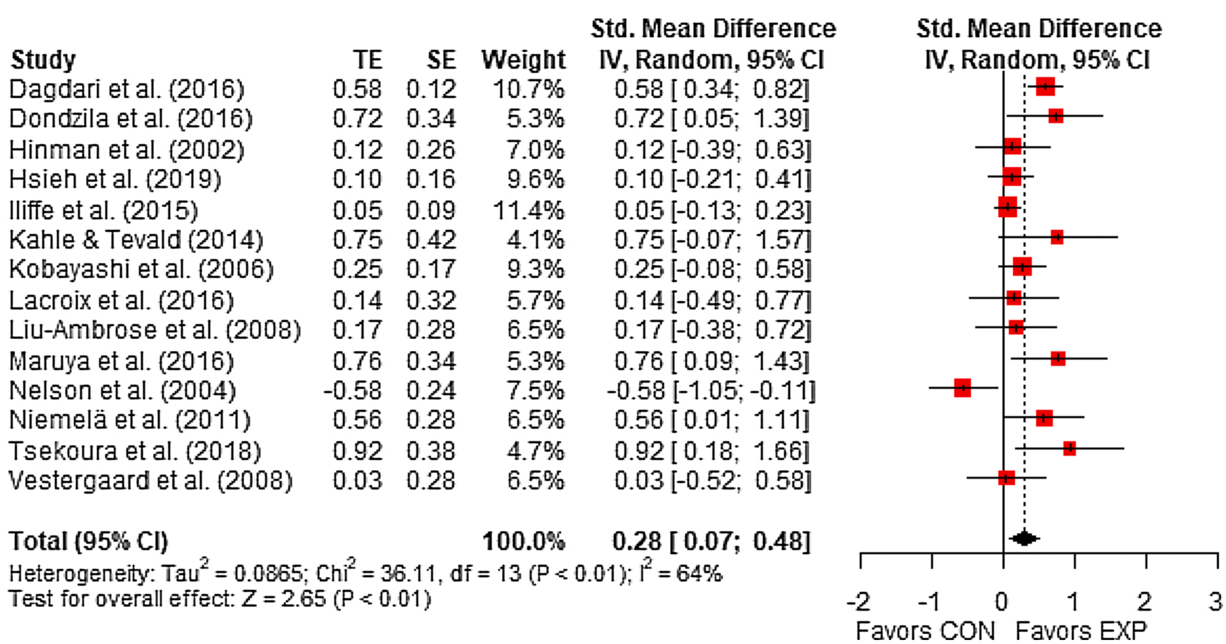

Fig. 4. Effects of home-based training versus passive control on measures of balance in healthy older adults. *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance, *SE* standard error.

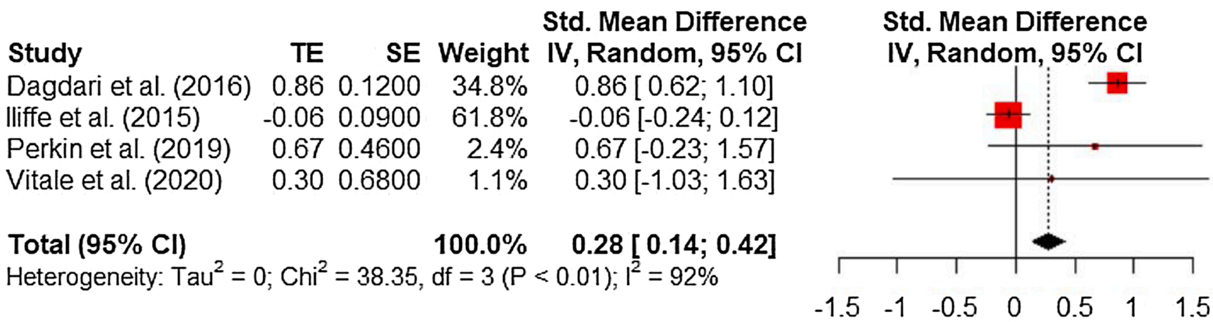

Fig. 5. Effects of home-based training versus passive control on measures of muscular endurance in healthy older adults. *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance, *SE* standard error.

Table 5
Results of overall, subgroup, and single training factor analyses.

	Muscle strength			Muscular power			Balance		
	SMD [CI 95 %]	S (I)	N	SMD [CI 95 %]	S (I)	N	SMD [CI 95 %]	S (I)	N
Overall	**0.30** [0.12; 0.48]	10 (10)	261	**0.43** [0.01; 0.85]	4 (4)	88	**0.28** [0.07; 0.48]	14 (14)	759
Training characteristics									
Training type	P = 0.15			P = 0.07			P = 0.12		
Single-mode strength training	**0.51** [0.17; 0.84]	4 (4)	72	**0.61** [0.19; 1.03]	3 (3)	62	**0.65** [0.27; 1.03]	3 (3)	58
Multimodal training	0.22 [0.00; 0.43]	6 (6)	189	oEG			0.21 [-0.04; 0.47]	10 (10)	671
Training duration (weeks)	P = 0.61			P = 0.21			P = 0.85		
≤ 8	0.28 [-0.02; 0.58]	4 (4)	85	oEG			0.17 [-0.41; 0.74]	4 (4)	100
> 8 – 16	0.19 [-0.11; 0.48]	2 (2)	99	0.59 [-0.15; 1.32]	2 (2)	37	0.38 [-0.08; 0.83]	3 (3)	118
> 16	0.48 [-0.02; 0.98]	4 (4)	77	oEG			**0.29** [0.07; 0.51]	7 (7)	541
Training frequency (session/week)	P = 0.47			P = 0.07			P = 0.56		
≤ 3	**0.28** [0.02; 0.54]	6 (6)	194	**0.61** [0.19; 1.03]	3 (3)	62	0.24 [0.00; 0.49]	11 (11)	628
> 3	**0.45** [0.08; 0.82]	4 (4)	67	oEG			**0.37** [0.01; 0.73]	3 (3)	131
Session duration (min)	P = 0.41			P = 0.56			P = 0.59		
≤ 30	**0.35** [0.03; 0.66]	4 (4)	89	0.30 [-0.33; 0.93]	2 (2)	51	**0.34** [0.08; 0.59]	6 (6)	147
> 30	0.17 [-0.12; 0.46]	3 (3)	104	0.59 [-0.15; 1.32]	2 (2)	37	**0.45** [0.13; 0.76]	4 (4)	271

Bold values stand for significant effect; oEG = only one experimental group; S (I): number of included studies (number of included experimental groups); SMD: weighted mean standardised mean difference; CI: confidence interval; N: total number of subjects in the included experimental groups.

(SMD = 0.51 [0.17; 0.84], $p < 0.05$, 4 studies) while multimodal training induced no statistically significant effects (SMD = 0.22 [0.00; 0.43], $p > 0.05$, 6 studies). For balance performance, the analysis revealed moderate effects for single-mode strength training (SMD = 0.65 [0.27; 1.03], $p < 0.05$, 3 studies) while multimodal training resulted in no statistically significant effects (SMD = 0.21 [-0.04; 0.47], $p > 0.05$, 10 studies). No statistically significant differences were found between the training types, i.e. single-mode strength training versus multimodal training ($p > 0.05$).

3.4. Results of meta-regression analyses

Meta-regression was computed for three training variables (i.e., training frequency, training duration, and session duration) and age in separate analyses. Due to the limited number of identified studies, meta-regression was computed for the outcome measures balance and muscle strength only (Table 6). Irrespective of the training type, none of the training variables predicted the effects of home-based exercise on measures of muscle strength and balance (p = 0.36 to 0.58). Additionally, results showed no significant predictive value of age on the main effects of home-based training on measures of muscle strength and balance in healthy older adults (Z = −1.18 and −0.58; p = 0.23 and 0.56, respectively).

3.5. Results of single training factor analyses

Home-based training programmes lasting ≤8 weeks, >8–16 weeks, or >16 weeks did not produce any statistically significant effects on muscle strength (≤8 weeks: SMD = 0.28 [−0.02; 0.58], $p > 0.05$, 4

Table 6
Results of the random-effects meta-regression which was computed for each training variable separately to predict home-based training effect on measures of balance and muscle strength in healthy older adults.

Covariate	Coefficient	Standard error	95 % CI	*Z* value	*P* value
Balance outcomes (N = 14)					
Frequency (n = 14)	0.1655	0.2585	−0.3411 to 0.6722	0.6404	0.5219
Intercept	0.0758	0.3314	−0.5738 to 0.7253	0.2286	0.8192
Training duration (n = 14)	0.0742	0.1275	−0.1757 to 0.3241	0.5819	0.5606
Intercept	0.1076	0.3119	−0.5037 to 0.7189	0.3450	0.7301
Session duration (n = 10)	0.1059	0.1921	−0.2706 to 0.4823	0.5513	0.5814
Intercept	0.2369	0.3082	−0.3672 to 0.8410	0.7685	0.4422
Muscle strength (N = 10)					
Frequency (n = 10)	0.1943	0.2160	−0.2291 to 0.6178	0.8994	0.3684
Intercept	0.0605	0.2824			
Training duration (n = 10)	0.0886	0.1158	−0.1383 to 0.3156	0.7654	0.4440
Intercept	0.1310	0.2399	−0.3391 to 0.6012	0.5463	0.5848

n: number of studies; CI: Confidence interval.

studies; >8–16 weeks: SMD = 0.19 [−0.11; 0.48], p > 0.05, 2 studies; >16 weeks: SMD = 0.48 [−0.02; 0.98], p > 0.05, 4 studies). For balance, the analysis revealed no statistically significant effects of training lasting ≤8 weeks (SMD = 0.17 [−0.41; 0.74], p > 0.05, 4 studies) or >8–16 weeks (SMD = 0.38 [−0.08; 0.83], p > 0.05, 3 studies). Of note, >16 weeks of training resulted in small effects on balance (SMD = 0.29 [0.07; 0.51], p < 0.05, 7 studies). The differences between the three training durations were not statistically significant for all measures of physical fitness (p > 0.05).

For training frequency, small effects were found for muscle strength for ≤3 weekly sessions (SMD = 0.28 [0.02; 0.54], p < 0.05, 6 studies) and >3 weekly sessions (SMD = 0.45 [0.08; 0.82], p < 0.05, 4 studies). For balance, ≤3 sessions per week resulted in no statistically significant effects (SMD = 0.24 [0.00; 0.49], p > 0.05, 11 studies). However, >3 sessions per week induced small effects on balance (SMD = 0.37 [0.01; 0.73], p < 0.05, 3 studies). No statistically significant differences were noted between the two training frequencies across all measures of physical fitness (p > 0.05).

For session duration, ≤30 min of training resulted in a small effect on muscle strength (SMD = 0.35 [0.03; 0.66], p < 0.05, 4 studies) while no statistically significant effects were observed for >30 min (SMD = 0.17 [−0.12; 0.46], p > 0.05, 3 studies). For muscle power, no statistically significant effects were found for ≤30 min (SMD = 0.30 [−0.33; 0.93], p > 0.05, 2 studies) and >30 min (SMD = 0.59 [−0.15; 1.32], p > 0.05, 2 studies). Considering balance, small effects were noted for ≤30 min (SMD = 0.34 [0.08; 0.59], p < 0.05, 6 studies) and >30 min (SMD = 0.45 [0.13; 0.76], p < 0.05, 4 studies). The differences between the two ranges of session duration were not statistically significant for all measures of physical fitness (p > 0.05).

4. Discussion

The main findings of this study indicated that i) home-based exercise resulted in small effects on components of health- (i.e., muscle strength and muscular endurance) and skill-related (i.e., muscle power and balance) physical fitness in healthy older adults aged 65–83 years, ii) home-based single-mode strength training resulted in moderate effects on muscle strength and balance while multimodal training produced no statistically significant effects on muscle strength and balance in healthy older adults, and iii) results of independently computed single factor analyses for different training variables indicate larger effects of >3 sessions per week and ≤30 min per session on measures of muscle strength and balance compared with ≤3 weekly sessions and >30 min per session in healthy older adults, irrespective of the training type. These results could be used for healthy older adults' training prescription.

4.1. Effects of home-based exercise programmes on measures of physical fitness

Extensive evidence exists on the detrimental effects of PIN in older adults (e.g., increase the progression of sarcopenia and frailty) (Bell et al., 2016; Cunningham et al., 2020; Sallis et al., 2016). Specifically, it has been shown that low muscle strength is a strong indicator of frailty and sarcopenia in older adults (Fried et al., 2001; Morley et al., 2013) and highly associated with limited mobility and increased risk of falls (Rubenstein, 2006). Similarly, improving muscle power and balance is fundamental to mitigate age-related increases in rate and/or risk of falls in older adults (da Rosa Orssatto et al., 2019; Granacher et al., 2011). A recent umbrella review including 24 systematic reviews with meta-analyses demonstrated that being physically inactive is associated with an increased risk of all-cause and cardiovascular mortality, breast and prostate cancer, and recurrent falls in older adults (Cunningham et al., 2020).

The levels of PIN are further exacerbated during the current health crisis caused by the COVID-19 pandemic due to forced social isolation (Roschel et al., 2020). In fact, older adults have been identified as the most vulnerable age-group to get infected by COVID-19 (Heymann and Shindo, 2020), hence the reason why measures of self-quarantine have taken place especially for people older than 65 years (Lakicevic et al., 2020). To cope with such unprecedented circumstances of restricted movements, home exercising appears to be inevitable to reduce inactivity and improve or maintain measures of physical fitness, mobility, and independence in older adults (Ganz and Latham, 2020). Our findings showed that home-based exercise programmes seem effective to improve components of health- (e.g., muscle strength) and skill-related physical fitness (e.g., muscle power, balance) in healthy older adults (SMD = 0.28 to 0.43). These outcomes corroborate previous results (Ema et al., 2017; Hsieh et al., 2019; Kahle and Tevald, 2014; Lacroix et al., 2016; Nelson et al., 2004). For example, the effects of an 8 weeks home-based calf-rise strength training programme vs. passive control was examined on the rate of torque development and balance in healthy men aged 73 years. The calf-rise training but not the control group improved the rate of torque development of plantar flexors that could contribute to improved balance (Ema et al., 2017).

It is difficult to objectively measure exercise compliance during home-based intervention trials. Rates of study compliance were reported in ~50 % of the 17 included studies and the small effects of home-based training on measures of physical fitness could be related to low exercise compliance. Reports from nine studies showed a mean rate of compliance of ~70 %. Of note, the reported data were collected using training logs filled out by the participants. This methodological approach might produce unreliable data because self-reporting can lead to an over-estimation of PA behaviour. Accordingly, the actual exercise dose could have been lower than the reports in the included studies. This may again explain the relatively small training effects. Besides this quantitative aspect, there might be a qualitative component as well that comes into play due to a lack of supervision with home-based exercise. Of note, >80 % of the training sessions across the included studies were unsupervised. This lack of supervision could have resulted in poor technical movement skill competency during the execution of home-based exercises. There is evidence that supervised training has larger effects on components of physical fitness (i.e., muscle strength, balance) compared with unsupervised training in healthy older adults (Lacroix et al., 2017). In this regard, the effects of supervised group-based vs. unsupervised home-based strength and balance training on measures of muscle power and balance in healthy older adults aged 73 years showed larger effects in favor of the supervised programme (Lacroix et al., 2016). Findings from this original research were confirmed by a recent systematic review with meta-analysis which contrasted the effects of supervised vs. unsupervised training on measures of muscle strength and balance in healthy older adults (Lacroix et al., 2017). Taken together, it might be hypothesized that insufficient training volume and/or low technical movement skill competency during the execution of home-based exercises could be responsible for attenuated training-related effects.

To the best of the authors' knowledge, this is the first systematic review with meta-analysis that aggregated data from randomized-controlled trials on the effects of home-based exercise programmes on components of physical fitness in healthy older adults. Overall, the main results of our study are important in that they indicated beneficial effects, although small in magnitude, of home-based exercise programmes on various components of physical fitness in healthy older adults, irrespective of sex. Accordingly, home-based training should be considered as an effective strategy to counteract PIN, more specifically, during times of forced restricted movements such as caused by COVID-19. Indeed, 10 days of bed rest resulted in a significant reduction in muscle mass (2 %), muscle strength (12.5 %), and functional performance (11 %) in older adults (Coker et al., 2015). Moreover, if daily steps are reduced to ~1500 steps over 14 days, this results in a 4 % decline in lower limbs muscle mass in older adults (Breen et al., 2013). Data from 1,005,791 participants who were followed up for 2–18 years indicated that one hour of moderate-to-vigorous PA daily eliminates the increased risk of mortality associated with daily sitting time ≥8 h (Ekelund, 2018; Ekelund et al., 2016). Overall, home-based training is a feasible and effective method to combat PIN and to mitigate the risk of PIN-related health problems in older adults (Cunningham et al., 2020).

4.2. Subgroup analyses

Home-based single-mode strength training moderately improved muscle strength and balance (SMD = 0.51 and 0.65, respectively). Home-based multimodal training did not produce any statistically significant effect on muscle strength and balance. The last updated position stand of the American College of Sports Medicine on exercise and PA in older adults advocated prescribing strength training exercises over endurance exercises (Chodzko-Zajko et al., 2009). A recent umbrella review examining the effects of physical exercise programmes on physical function in pre-frail and frail older adults aged 60 years and older showed that single-mode strength training is effective in improving measures of muscle strength and gait speed (Jadczak et al., 2018). Unlike our findings, the same authors reported higher training-related adaptions in measures of muscle strength and balance following multimodal compared with single-mode strength training. Of note, >80 % of the total home-based training sessions across the included studies were unsupervised. In addition, most of the included studies recruited previously inactive older adults. This makes the execution of a multitude of exercises in multimodal training (e.g., combined strength, balance, and flexibility exercises) a real challenge as high movement skill competency is required to perform the variety of exercises. In contrast, the performance of single-mode strength training allows to focus on one single training type only which may enable older adults to preserve a relatively better quantity (exercise dosage) and/or quality (technical execution) of exercise throughout the programme. This could partly explain the larger training-related adaptations following home-based single-mode strength training compared with multimodal training.

Generally, the main goal of exercise interventions in older adults is to restore or maintain functional independence (Chodzko-Zajko et al., 2009; Paterson et al., 2007) and delay, prevent, or even reverse frailty (Jadczak et al., 2018; Theou et al., 2011). Concurring with the literature (Borde et al., 2015; Cadore et al., 2013; Hortobágyi et al., 2015; Jadczak et al., 2018), the current review showed that home-based single-mode strength training exercises are effective to improve functional capacity, particularly, strength and balance in healthy older adults. Accordingly, healthy older adults are encouraged to regularly engage in home-based single-mode strength training programmes to prevent/delay frailty and, therefore, improve health-related quality of life. Given that the effects of home-based single-mode strength training and multimodal training in healthy older adults were not previously contrasted, future high-quality exploratory studies are needed to substantiate the current findings.

4.3. Results of single factor training variables

Regarding home-based training prorammes' duration, a period of >16 weeks resulted in small effects (SMD = 0.29) on balance. According to an umbrella review, 10 weeks is the minimum duration of a training programme that can be expected to improve older adults' physical fitness (Jadczak et al., 2018) (Table 5). For training frequency, >3 sessions per week seem to be preferable over ≤3 sessions per week to improve muscle strength (SMD = 0.45 vs. 0.28, respectively, both $p < 0.05$) and balance (SMD = 0.37 [$p < 0.05$] vs. 0.24 [$p > 0.05$], respectively), regardless of training type. It has previously been shown that to drive larger functional capacity improvements in older adults, 2–3 multimodal, or single-mode strength training sessions per week are recommended (Cadore et al., 2013). With reference to the recently published position statement of the National Strength and Conditioning Association, exercise programmes should be performed 2-to-3 times per week with older adults (Fragala et al., 2019). Similarly, an umbrella review indicated that 3 weekly sessions of multimodal training appear to be optimal in pre-frail and frail older adults (Jadczak et al., 2018). In fact, it has been suggested that less than 2 training sessions per week are not sufficient to stimulate physical fitness improvements in older adults (Bray et al., 2016). With the potential reduction in the quality (poor movement skill competency) and quantity (insufficient dosage) of home-based exercise due to a lack of supervision and/or exercise compliance, it seems that 2–3 weekly home-based training sessions are not sufficient to stimulate improvements in components of physical fitness in older adults. Overall, unlike fully supervised training interventions (Jadczak et al., 2018), it seems that >3 sessions of home-based training per week are required to induce physical fitness improvements in healthy older adults. Considering session duration, ≤30 min resulted in small effects on muscle strength (SMD = 0.35), and balance (SMD = 0.34). Regarding >30 min, small effects were found for balance only (SMD = 0.45). Results from an earlier systematic review indicated that 45−60 min per training session appear to be optimal for pre-frail older adults (Theou et al., 2011). The same authors showed that 30−45 min per training session seem to be suitable for frail older adults. With reference to the current findings, ≤30 min per session resulted in larger effects on physical fitness compared with >30 min per session in healthy older adults. It is worth noting that the differences between all independently single-training factor analyses were not significant. The reason why our findings have to be interpreted with caution.

4.4. Limitations

While in this meta-analysis, studies were included only if they examined the effects of home-based training in healthy older adults, we cannot rule out that mobility-limited participants or subjects of low, medium, or high fitness levels were enrolled in these studies. Of note, detailed information on mobility status and/or fitness level was not available from the included studies, which is why we were unable to statistically adjust our findings for these potentially moderating factors. Authors from a recent review article postulated that older adults' mobility status may modulate the magnitude of the observed training effects (Brahms et al., 2020). The rather large heterogeneity (I^2 = 0–92 %) amongst the included studies represents another limitation of this meta-analysis, which could undermine the accuracy of the inter-study comparisons. Our methodological approach together with the overall small training-induced effects on measures of health- (i.e., muscle strength and muscular endurance) and skill-related (i.e., muscle power, balance) physical fitness in healthy older adults do not allow us to estimate potential transfer effects of home-based training on markers of health (e.g., blood pressure). Subgroup analyses were conducted independently not interdependently. This means that the main subgroup analyses outcomes should be considered with caution. Finally, only 9 out of the 17 included studies reached the PEDro cut-off score of ≥6 which implies a high risk of bias.

5. Conclusions

Home-based exercise appears effective to improve components of health- (i.e., muscle strength and muscular endurance) and skill-related (i.e., muscle power, balance) physical fitness in healthy older adults aged 65–83 years. Therefore, in times of restricted PA due to pandemics such as COVID-19, home-based exercise constitutes an alternative to counteract PIN and maintain/improve the health and fitness of healthy older adults. The overall small home-based training effects on components of physical fitness in healthy older adults could be due to a low rate of exercise compliance and/or limited technical movement skill competency during the execution of home-based exercises. Home-based single-mode strength training resulted in moderate effects on muscle strength and balance while multimodal training produced no statistically significant effects on muscle strength and balance in healthy older adults. Results of independently computed single factor analysis indicate larger effects for >3 weekly sessions and ≤30 min per session on measures of muscle strength and balance in healthy older adults, irrespective of the training type. A minimum form of exercise supervision for instance through weekly visits and/or phone calls is recommended to improve home-based exercise-related effects on components of physical fitness in healthy older adults. Stakeholders in healthy ageing are encouraged to prescribe home-based training programmes to induce clinically beneficial effects in older cohorts. This is of particular relevance in times of forced isolation during pandemics.

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Declaration of Competing Interest

All authors declare that they have no conflict of interest to be disclosed.

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