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Residual Effects of Physical Exercise After Periods of Training Cessation in Older Adults: A Systematic Review With Meta-Analysis and Meta-Regression

Ángel Buendía-Romero[1,2,3] | Tomas Vetrovsky[4] | Alejandro Hernández-Belmonte[5] | Mikel Izquierdo[2,6] | Javier Courel-Ibáñez[7]

[1]GENUD Toledo Research Group, Faculty of Sports Sciences, University of Castilla-La Mancha, Toledo, Spain | [2]Centro de Investigación Biomédica en Red Fragilidad y Envejecimiento Saludable (CIBERFES), Instituto de Salud Carlos III, Madrid, Spain | [3]Grupo Mixto de Fragilidad y Envejecimiento Exitoso UCLM-SESCAM, Universidad de Castilla-La Mancha -Servicio de Salud de Castilla-La Mancha, IDISCAM, Toledo, Spain | [4]Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic | [5]Human Performance and Sports Science Laboratory. Faculty of Sport Sciences, University of Murcia, Murcia, Spain | [6]Navarrabiomed, Complejo Hospitalario de Navarra (CHN), Universidad Pública de Navarra (UPNA), IdiSNA, Pamplona, Spain | [7]Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, Melilla, Spain

Correspondence: Javier Courel-Ibáñez (courel@ugr.es)

Received: 25 September 2024 | **Revised:** 18 December 2024 | **Accepted:** 19 December 2024

Funding: Á.B.-R. is supported by CIBERFES (CB16/10/00477) and Plan Propio de Investigación of the University of Castilla-La Mancha and FEDER funds from the European Union (2022-GRIN-34296) and the Spanish Ministry of Science and Innovation (JDC2023-052593-I). J.C.-I is supported by the Spanish Ministry of Science and Innovation (Grant No. PID2019-108202RA-I00). T.V. is supported by the Cooperatio Program, research area Sport Sciences—Biomedical & Rehabilitation Medicine. A.H.-B. is supported by a predoctoral contract from the Spanish Ministry of Science (Grant No. FPU19/03258) and the Spanish Ministry of Science and Innovation (JDC2023-051020-I). Funding for open access charge: Universidad de Granada / CBUA.

Keywords: deconditioning | functional impairments | long-term effects | physical inactivity

ABSTRACT

We aimed to determine the persisting effects of various exercise modalities and intensities on functional capacity after periods of training cessation in older adults. A comprehensive search was conducted across the Cochrane Library, PubMed/MEDLINE, Scopus, and Web of Science Core Collection up to March 2024 for randomized controlled trials examining residual effects of physical exercise on functional capacity in older adults ≥60 years. The analysis encompassed 15 studies and 21 intervention arms, involving 787 participants. The exercise and training cessation periods ranged from 8 to 43 weeks and 4 to 36 weeks, respectively. Meta-analyses were performed using change scores from before the physical exercise to after the training cessation. The effect sizes (ES) were calculated as the standardized mean differences between the intervention and control groups' change scores. Subgroup analyses and meta-regressions explored the influence of participant characteristics, the magnitude of the effect produced by the initial training program, various exercise modalities (resistance and multicomponent training) and intensities (high and low), and subdomains of functional capacity (agility, balance, standing ability, walking ability, and stair walking). The findings revealed that exercise interventions had a significant effect on preserving functional capacity after training cessation ($ES = 0.87$; $p < 0.01$). This protective effect was consistent across various exercise modalities and intensities ($ES \geq 0.67$; $p \leq 0.04$). The benefits obtained during the training program were positively associated with the residual effects observed after training cessation ($\beta = 0.73$; $p < 0.01$), while age negatively influenced the persisting adaptations ($\beta = -0.07$; $p < 0.01$). Current evidence suggests that exercise-based interventions, irrespective of modality and intensity, are highly effective in preventing functional declines after training cessation among older adults.

1 | Introduction

Functional capacity refers to the ability to perform everyday activities such as walking, rising from a chair, climbing stairs, or maintaining balance [1]. Deficiencies in functional capacity significantly impact autonomy, quality of life, and health-related costs, especially as the population ages and becomes more frail [2–4]. In individuals over 60 years of age, a severe decline in functional capacity is associated with a 50% increase in mortality risk [5]. Conversely, exercise is linked to an extended period of good health and can potentially slow down the progression of age-related illnesses among older individuals [6]. Increasing physical activity levels offers substantial health and economic benefits, with the World Health Organization (WHO) estimating a return of 1.7 € for every 1 € invested in physical activity policies [7]. Therefore, exercise emerges as a highly effective, cost-efficient strategy for preventing, mitigating, and even reversing age-related functional impairments [8, 9].

Each exercise modality induces specific physiological adaptations. Resistance training, involving the use of external loads or body weight, primarily enhances muscle mass and strength [8, 10, 11]. On the other hand, aerobic training, characterized by continuous movements of large muscle groups for an extended period to increase caloric expenditure, improves systemic vascular function and metabolic profile [12, 13]. Interestingly, multicomponent training, which combines resistance, aerobic, and balance exercises, has shown the most promising outcomes in enhancing functional capacity among older adults [8]. Furthermore, training intensity plays a crucial role in eliciting exercise adaptations [14]. Evidence suggests that high-intensity training programs, such as resistance training exceeding 70% of the one-repetition maximum (1RM), yield the greatest improvements in functional capacity among the older population [15].

Preserving adequate functional capacity in older adults poses challenges due to age-related degeneration affecting the musculoskeletal system's ability to execute coordinated movements [16, 17]. Additionally, exercise programs for older individuals are often interrupted due to falls, illness, or hospitalizations [18], resulting in partial or complete loss of the adaptations previously gained [19]. Training cessation, combined with aging-related degeneration, leads to impairments in muscle structure [17] and function [20]. Among others, older adults experience decreases in neural activity [21], lean mass [22], muscle strength, and power [20]. All these factors combined contribute to difficulties in carrying out activities of daily living [23]. Older individuals with better physical conditions before the interruption tend to experience a lesser decline in functional capacity during periods of training cessation [24]. Consequently, exercise may have a residual effect, enabling the retention of positive changes generated by physical exercise even after training cessation [25–27]. Nevertheless, it remains unclear if the residual effects are produced after different exercise modalities and intensities.

This systematic review and meta-analysis aimed to summarize the available evidence on the persisting effects of various exercise modalities and intensities on functional capacity after periods of training cessation in older adults.

2 | Methods

This systematic review and meta-analysis were conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and Cochrane Collaboration guidelines [28]. The original protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42021235092) and published elsewhere [29].

2.1 | Study Selection

The PICOS (Population, Intervention, Comparators, Outcomes, Study design) approach for the eligibility of studies was used to determine the inclusion and exclusion criteria.

Participants: People ≥ 60 years (considered as older adults according to the WHO [30]) who have completed a physical training program followed by an exercise cessation phase. No restrictions for maximum age, diseases, gender, socio-economic status, ethnicity, or geographical area were set.

Intervention: Training cessation periods that took place immediately after an exercise intervention. A training cessation period was defined as any follow-up phase without active and voluntary physical activity (e.g., hospitalization or usual daily activity). No duration restriction was set for either the exercise program or the training cessation period.

Comparator: A control group not conducting a previous training intervention but being evaluated before and after a time interval identical to the experimental group.

Outcome measures: Subdomains of functional capacity (i.e., standing ability, walking ability, agility, gait speed, balance, and stair walking) measured by validated physical assessments (e.g., sit-to-stand, timed up and go [TUG], 6-min walk, or static balance tests). Data from questionnaires were not considered.

Studies: Randomized controlled trials (RCTs) including at least one control group and one experimental group (which underwent a training and subsequent detraining period). Studies without primary data (e.g., reviews), investigations published in non-peer-reviewed journals, and behavioral interventions were excluded.

2.2 | Search Strategy

A search from the earliest record up to and including March 2024 was performed using the electronic databases Cochrane Library, PubMed/MEDLINE, Scopus, and Web of Science Core Collection. The systematic search strategy (Table S1), which was adapted for each database, included the following combination of keywords: "elder," "elderly," "older adults," "detraining," "training cessation," "exercise interruption," "deconditioning," "retraining," and "physical restraint." Moreover, the search strategy was complemented with a screening of the references and citations of studies included.

2.3 | Data Extraction

Metadata was imported to Mendeley (v1.19.6, Elsevier, London, UK) and processed in Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA). After the automatic and manual removal of duplicates, two researchers (Á.B.-R. and J.C.-I.) independently screened the titles and abstracts, considering eligibility criteria (first-stage screening). Full texts of the remaining studies were subjected to a second-stage screening. Full-text studies not finally considered for the quantitative and qualitative analyses were also recorded to justify their non-inclusion based on the eligibility criteria. Any discrepancy between Á.B.-R. and J.C.-I. during the study selection process was solved by a discussion with another researcher of the current study (T.V).

Data extracted for each study were: (1) study characteristics (total sample number, sex, age, weight, height, body composition), (2) training configuration (modality, volume, intensity, duration, exercises), (3) characteristics of the training cessation period (type of inactivity and duration), and (4) changes before and after the intervention. For quantitative analyses (meta-analyses), authors collected the mean differences with standard deviation (SD). Scores from pre-training, post-training, and training cessation period were used for statistical analyses. Otherwise, missing numerical data were obtained from figures using the reliable WebPlotDigitizer software [31]. Missing SD was estimated from standard errors using the following formula [28, 32]:

$$SD = \sqrt{n} \bullet (\text{upper limit} - \text{lower limit of } 95\% \text{ confidence interval}) / 3.92$$

The low and high intensity was defined for aerobic training based on the percentage of maximal heart rate (77%), heart-rate reserve (60%), and rate of perceived exertion (RPE, 15/20) [14]. Resistance training intensity was categorized as low or high intensity based on %1RM (69%1RM) [14] and RPE (13/20 or 7/10) [33, 34]. Power training (i.e., resistance at a maximal intended velocity in the concentric phase) was considered high-intensity when participants conducted each repetition as fast as possible against $\geq$60%1RM [14]. When the intensity of aerobic and resistance training progressively increased during an intervention, the average intensity was used for classification. Multicomponent training was classified as high-intensity when the programs comprising it were categorized as high-intensity. If a study had two groups performing a different training modality, these intervention arms were coded as a separate study.

2.4 | Quality Assessment and Certainty of Evidence

The Cochrane tool for assessing the risk of bias in randomized trials (RoB 2 tool) was implemented [35]. A high risk of bias was considered when the score was $\geq$5 points. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was used to rate the certainty of the evidence, graded as High, Moderate, Low, or Very Low based on the presence or extent of study limitations, inconsistency of the effect, imprecision, and publication bias [36]. The RoB2 and GRADE tools were independently implemented by two researchers (Á.B.-R and J.C.-I.), including a third one (T.V.) when there was a discrepancy.

2.5 | Data Synthesis and Analysis

The effect sizes (ES) were calculated as the standardized mean differences (Hedges' g) [37] between the intervention and control groups' change scores from pre-training to the end of the training cessation period. Meta-analyses were performed using robust variance estimation (RVE) with small-sample corrections [38, 39]. RVE is a form of random-effects meta-regression for multilevel data structures, which allows for multiple effect sizes from the same study to be included in a meta-analysis, even when information on the covariance of these effect sizes is unavailable. Instead, RVE estimates the variance of meta-regression coefficient estimates using the observed residuals. It does not require distributional assumptions and does not make any requirements on the weights [38, 39]. Observations were weighted by the inverse of the sampling variance. Subgroup analyses were performed when the number of interventions was $\geq$5, as recommended by Cochrane [28], to explore the effects of different training modalities, intensities, and subdomains of functional capacity. The pooled ES were considered significant at $p \leq 0.05$ and rated as small (0.20–0.49), moderate (0.50–0.79), or large ($\geq$0.80) [40]. The heterogeneity of results across studies was evaluated using the I [2] (the percentage of total variation attributed to between-study heterogeneity), which was interpreted as small (<25%), moderate (25%–50%), or high (>50%) [41]. Potential effect moderators (participants' age, training modality and intensity, training duration, duration of the cessation period, and training effect) were explored with univariable and multivariable meta-regression models. The training effect was calculated as the standardized mean difference between the intervention and control groups' change scores from pre-training to post-training. Finally, the presence of publication bias was assessed using a visual inspection of the funnel plots and a random-effects version of Egger's regression test. All analyses were performed using the *metafor* and *robumeta* packages in R (The R Foundation for Statistical Computing, Vienna, Austria).

3 | Results

3.1 | Literature Selection

Initially, a total of 3383 articles were retrieved through the database search. Following this, duplicate papers ($n=1312$) were removed either automatically or manually. Subsequently, the remaining 2071 titles and abstracts were screened based on the predefined inclusion criteria, constituting the first-stage screening. From this screening, 43 full-text articles were assessed in detail during the second-stage screening. Finally, 15 articles were selected for qualitative analysis and 14 for quantitative analysis (Figure 1).

3.2 | Study Characteristics

We analyzed 15 RCTs (Table 1) involving 787 older adults (553 women) with a mean age ranging from 64 to 92 years old

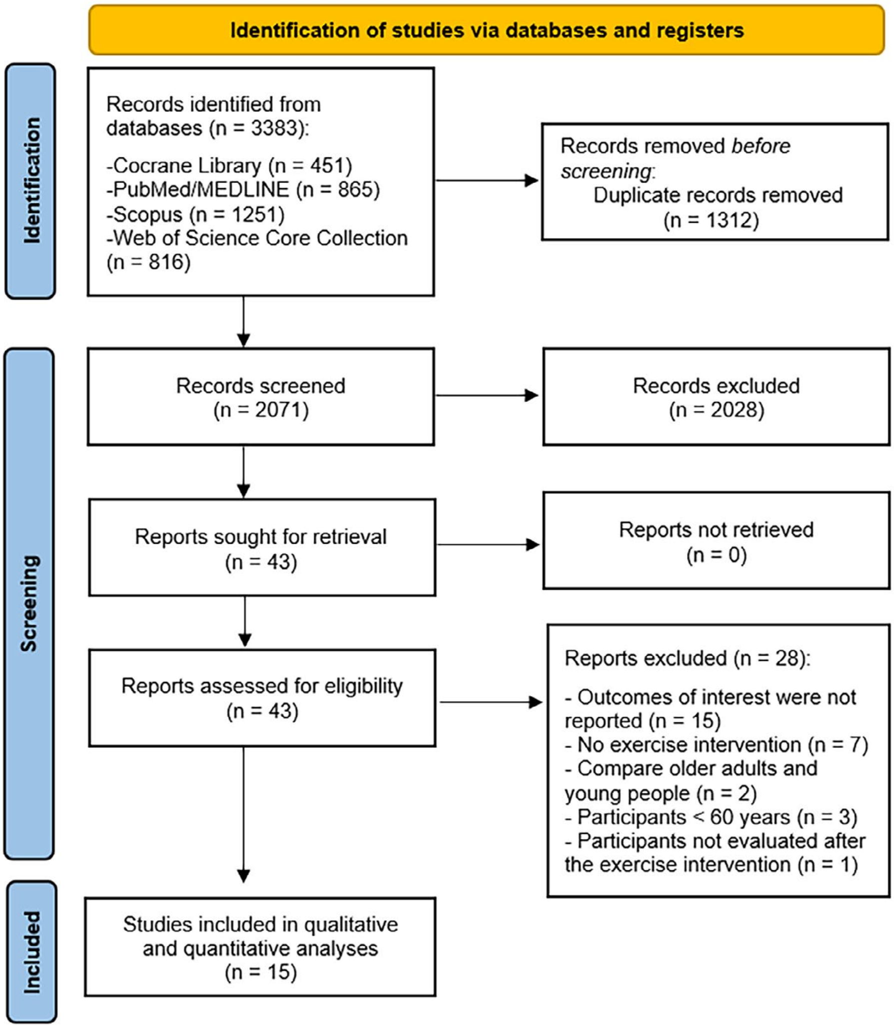

FIGURE 1 | Flowchart illustrating the different phases of the search and study selection, according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statements.

at baseline [42–56]. Seven studies recruited both male and female participants [42, 44, 50, 51, 53, 55, 56], six recruited only females [43, 45, 46, 48, 52, 54], and two studies specifically analyzed a male-only population [47, 49]. In seven studies, participants with chronic diseases such as type 2 diabetes or special physical conditions like prefrailty, institutionalization, or a VO_{2max} < 20 mL/kg/min were included [43, 44, 47, 51, 53, 55, 56]. The participants' demographics were 79.4% Europeans [44–50, 52, 53, 55, 56], 11.8% Americans [42, 43], and 8.8% Asians [51, 54]. The mean duration of the exercise programs was 16 weeks (range 8–43 weeks). Weekly training frequency examined included 2 times per week [44–49, 53, 55, 56], 3 times per week [42, 43, 50–52] and 5 times per week [54]. The exercise cessation period varied between 4 and 36 weeks, with a mean duration of 11 weeks. One study had a follow-up period of 240 weeks [46]. During this period, all participants were instructed to avoid any type of regular exercise and to carry on with their normal daily activities. No injuries, illnesses, surgeries, or physical restraints were reported in the included studies.

Qualitative analysis included 21 intervention arms from 15 RCTs. Eleven interventions conducted multicomponent training [42, 45, 46, 48, 50, 51, 53, 55], nine on resistance training [42–44, 47, 49, 52, 56], and one on aerobic training [54]. Seven experimental groups performed high-intensity training [42, 47, 50, 55, 56], 12 conducted low-intensity training [43–49, 51–53, 56], and two did not control the intensity [46, 54]. Quantitative analysis included 21 exercise interventions from 15 RCTs and 24 outcomes, [42–53, 55, 56] grouped in standing ability [42–45, 48–52, 55, 56], agility [42, 43, 45, 47, 49–51, 53, 56], gait speed [43, 46, 47, 53, 55, 56], static balance [42, 46, 50, 54, 56], stair walking [47, 50, 51, 53], and walking ability [45, 48].

3.3 | Meta-Analysis

Forest plots are depicted in Figures S1–S11. Overall, there was a medium and significant protective effect on functional capacity in favor of the training groups (ES = 0.88 [CI: 0.47 to 1.29], $p < 0.01$, $I^2 = 81\%$). Results from subgroup analyses are shown in Table 2. Results for individual subdomains of functional capacity independently revealed positive and significant effects on agility, walking ability, standing ability, and stair walking (ES ≥ 0.61; $p < 0.05$; $I^2 = 0\%–85\%$), as well as positive

TABLE 1 | Characteristics of studies included.

Study	Sample at baseline	Training intervention	Adherence ratio	Exercise cessation	Outcomes
Ansai et al. 2016 [42]	MT group ($n=23$) RT group ($n=23$) C group ($n=23$) 82.4 ± 2.4 y 68.1% females, healthy older adults	16 wk., 3 d/wk.; supervised High- intensity MT 13 min AT, 3 min interval training from 60% to 85% HRR 20 min RT, 4 exercises, 3 set of 15 rep, intensity 14–17 RPE (6–20) 10 min balance, static and dynamic exercise increasing difficult level High-intensity RT 6 exercises. 3 sets of 10-12RM 2-s concentric and 4-s eccentric phase	MT: 34.7% RT: 56.5%	6 wk	Standing ability: STS 5 reps (stopwatch) Agility: Dual-task TUG (stopwatch) Balance (stopwatch): Dominant-leg balance No dominant-leg balance Tandem balance
Bezerra-Melo et al. 2022 [43]	RT group ($n=12$) C group ($n=12$) 66.5 ± 5.9 y 100% females with type 2 diabetes	12 wk, 3 d/wk., supervised Low-intensity RT 8–18 exercises, 1 set of 10 rep 11–12 RPE (6–20)	No reported	4 wk	Standing ability: STS 5 reps (stopwatch) Agility: RCHo (stopwatch) Gait speed: 10 m (stopwatch)
Caldo-Silva et al. 2021 [44]	RT group ($n=12$) C group ($n=15$) 84.9 ± 4.7 y, institutionalized older adults	16 wk., 2 d/wk. supervised Low-intensity RT 9 exercises, 2–3 set of 10–20 rep, intensity 4–6 RPE (0–10)	70%	8 wk	Standing ability: STS 5 reps (stopwatch)
Carvalho et al. 2009 [45]	MT group ($n=32$) C group ($n=25$) 69 ± 3.5 y 100% females, healthy older adults	32 wk., 2 d/wk. supervised Low-intensity MT AT, 20-25 min walking, jogging, or dancing to intensity 12–14 RPE (6–20) RT, 12 exercise, 1-3set of 8–15 reps to 12–16 RPE (6–20) 10 min balance, static and dynamic exercise increasing difficult level	91%	12 wk	Standing ability: STS 30 s (stopwatch) Agility: TUG (stopwatch) Walking ability: 6-min walk test (meters)

(Continues)

TABLE 1 | (Continued)

Study	Sample at baseline	Training intervention	Adherence ratio	Exercise cessation	Outcomes
Englund et al. 2009 [46]	MT group ($n = 18$) C group ($n = 16$) 72.4 ± 3.7 y 100% females, healthy older adults	43 wk., 2 d/wk., supervised Self-paced intensity MT AT, 10 min walking or jogging RT, 4 exercise, 2 set of 8–12 reps Balance, 5 min static and dynamic exercise increasing difficult level	No reported	240 wk	Balance: Dominant-leg balance (stopwatch) Gait speed 30 m (stopwatch)
Fatouros et al. 2005 [47]	High-intensity RT group ($n = 20$) Low-intensity RT group ($n = 18$) C group ($n = 14$) 71.2 ± 4.1 y 100% males, sedentary older adults (VO_{2max} < 20 mL/kg/min)	24 wk., 2 d/wk., supervised 8 exercises, 2–3 set Low-intensity RT: 14–16 reps 50%–55%1RM 3 min rest High-intensity RT: 6–8 reps 80%–85%1RM 6 min rest 2–3 s concentric phase, 2–3 s eccentric phase and 2–4 s pause between reps	No reported	36 wk	Agility: TUG (photocells) Stair walking (photocells) Walking up 8 stairs Walking down 8 stairs Gait speed: 15 m (photocells)
González-Ravé et al. 2020 [48]	MT group ($n = 12$) MT with extra aquagym session group ($n = 12$) MT with extra hypertrophy session group ($n = 12$) C group ($n = 12$) 65.7 ± 4.5 y 100% females, healthy older adults	10 wk., 1–2 d/wk., supervised Low-intensity MT AT, 40 min with continuous (60%–70% HRE) and intermittent exertion (70%–80% HRE). RT, 8–10 exercises, 3 set of 12–15 reps 60%–70%1RM with moderate execution speed. Balance, static, and dynamic exercise increasing difficult level 3–5 set of 2-3 min /30s Hypertrophy session: 8 exercises, 2–3 set of 8–12 reps 70%–80%1RM /1–3 min of rest Aquagym session: 8 exercises, 3set of 20 reps 7-8RPE (6–20)/30 s –2 min of rest	No reported	4 wk	Standing ability: STS 30 s (stopwatch) Walking ability: 6-min walk test (meters) Jumping ability: CMJ (contact barriers) Abalakov (contact barriers)

(Continues)

TABLE 1 | (Continued)

Study	Sample at baseline	Training intervention	Adherence ratio	Exercise cessation	Outcomes
Kalapotharakos et al. 2010 [49]	RT group ($n=8$) C groups ($n=7$) 82.4 ± 2.6 y 100% males, community-dwelling older adults	8 wk., 2 d/wk., supervised Low-intensity RT 6 exercises, 3 set of 10 reps 70% 3RM/30–90 s rest	90%	6 wk	Standing ability: STS 5 reps (stopwatch) Agility: TUG (stopwatch) Walking ability: 6-min walk test (meters)
Lacroix et al. 2015 [50]	MT supervised group ($n=22$) MT unsupervised group ($n=22$) C group ($n=22$) 72.83 ± 3.7 y 62.12% females, healthy older adults	12 wk., 3 d/wk. High-intensity MT RT, 5 exercise, 3 set of 8–15 reps 12–16 RPE (6–20)/1–2 min rest Balance, static, and dynamic exercise, 4 set of 20–60 s/30 s rest	Supervised: 91.7% Unsupervised: 97.4%	12 wk	Standing ability: STS 5 reps (stopwatch) Agility: TUG (stopwatch) Balance: Eyes closed (force plate) Stair walking (stopwatch): Walking up 8 stairs Walking down 8 stairs
Park & Lee 2015 [51]	MT group ($n=24$) C group ($n=13$) 54% females, older adults with type 2 diabetes	12 wk., 3 d/wk. supervised Low-intensity MT RT, 6 exercises, 1–3 set of 10-12reps 45%–75%1RM/1 min rest AT, 1–3 set of 3–5 min cycling or walking at 9–14 RPE (6–20)	No reported	8 wk	Standing ability: STS 30 s (stopwatch) Stair walking: Number of steps in 2 min (stopwatch) Agility: TUG (stopwatch)
Pereira et al. 2012 [52]	RT group ($n=20$) C group ($n=17$) 65.3 ± 2.7 y 100% females, healthy older adults	12 wk., 3 d/wk., supervised Low-intensity RT 6 exercises, 3 set of 4–10 rep, intensity 40-75%RM/2 min rest	91.6%	6 wk	Standing ability: STS 30 s (stopwatch) Jumping ability: CMJ (trigonometric carpet)
Serra-Rexach et al. 2011 [53]	MT group ($n=20$) C group ($n=29$) 92 ± 2 y 80% females, institutionalized older adults	8 wk., 2 d/wk., supervised Low-intensity MT AT, 10-15 min cycling 12–13 RPE (6–20) RT, 6 exercises, 1–3 set of 8–10 rep 30%–70%RM/1-2 min rest	74.6%	4 wk	Agility: TUG (stopwatch) Stair walking Walking up 4 stairs (stopwatch) Gait speed: 8 m (stopwatch)

(Continues)

TABLE 1 | (Continued)

Study	Sample at baseline	Training intervention	Adherence ratio	Exercise cessation	Outcomes
Sun et al. 2018 [54]	AT group ($n=16$) C group ($n=16$) 64.3 ± 3.3 y 100% females, healthy older adults	16 wk., 5 d/wk., supervised Self-paced intensity AT 10 to 40 min brisk walking (breathing accelerated)	80%	8 wk	Balance (foot pressure plate): One leg balance with eyes open One leg balance with eyes closed
Telenius et al. 2015 [55]	MT group ($n=87$) C group ($n=83$) 86.9 ± 7.4 y 73.5% females, institutionalized older adults with dementia	12 wk, 2 d/w, supervised High-intensity MT RT, 2 exercises, 1 set of 12 reps 12RM. Rest no reported Balance, 2 static, or dynamic exercises performed near the limits of maintaining postural stability	75%	12 wk	Standing ability: STS 30 s (stopwatch) Gait speed: 6 m (stopwatch)
Zech et al. 2012 [56]	RT group ($n=24$) RT (power) group ($n=24$) C group ($n=22$) 77.6 ± 6.1 y 70% females, prefrail older adults	12 wk., 2 d/wk., supervised Low-intensity RT: concentric phase with controlled velocity (2–3 s) High-intensity RT (power): concentric phase as rapidly as possible 7 exercises, 2 set of 6–15 rep 10–16 RPE (6–20)/2 min rest	No reported	24 wk	Standing ability: STS 5 reps (stopwatch) Agility: TUG (stopwatch) Balance test (stopwatch): Feet together Semi-tandem Tandem position Gait speed: 6 m (stopwatch)

Abbreviations: AT, aerobic training; C, control; CMJ, countermovement jump; d, day; wk, week; GS, gait speed; HRE, heart rate estimated; HRR, heart rate reserve; MT, multicomponent training; RCHo, standing up, circling two cones 3 m behind the chair in a V shape, as fast as possible; RPE, rate of perceived exertion; RT, resistance training; STS, sit-to-stand test; RM, repetition maximum; TUG, time up and go test.

TABLE 2 | Subgroup meta-analyses for different training modalities, intensities, and subdomains of functional capacity. Effect sizes explain the changes from baseline to after the detraining period in favor of the training group.

Outcomes	*k*	*n*	ES	95% CI	*p*	I^2 (%)
Modalities						
Multicomponent training	11	455	0.89	0.33 to 1.46	<0.001*	83.6
Resistance training	9	233	0.84	0.02 to 1.66	0.045*	81.7
Intensities						
High intensity	7	325	0.67	0.10 to 1.23	0.027*	73.4
Low intensity	12	329	1.06	0.37 to 1.75	0.006*	84.0
Functional capacity subdomains						
Agility	11	328	0.61	0.13 to 1.09	0.018*	68.8
Balance	8	237	0.48	−0.01 to 0.97	0.051	55.0
Gait speed	8	350	0.38	−0.01 to 0.77	0.056	43.0
Stair walking	6	181	1.26	0.09 to 2.42	0.039*	85.0
Walking ability	5	120	0.88	0.01 to 1.75	0.049*	0.0
Standing ability	16	562	1.35	0.77 to 1.94	>0.001*	84.8
Multicomponent training						
Agility	6	206	0.67	−0.24 to 1.59	0.116	80.8
Standing ability	9	381	1.51	0.65 to 2.36	0.004*	87.8
Resistance training						
Agility	5	122	0.48	−0.11 to 1.07	0.087	8.9
Standing ability	7	181	1.16	0.12 to 2.20	0.034*	81.7
Gait speed	5	128	0.64	−0.10 to 1.37	0.073	46.1
High intensity						
Agility	5	152	0.44	−0.05 to 0.92	0.067	0.0
Standing ability	6	298	0.96	0.08 to 1.85	0.038*	79.9
Balance	5	151	0.53	−0.27 to 1.33	0.138	62.0
Low intensity						
Agility	6	176	0.72	−0.24 to 1.69	0.111	79.9
Standing ability	10	264	1.59	0.72 to 2.46	0.002*	82.2
Walking ability	5	120	0.88	0.01 to 1.75	0.049*	0.0

*Significant differences ($p<0.05$).
Abbreviations: CI, confidence interval; ES, effect size (Hedges' g), I^2, heterogeneity; *k*, number of interventions; *n*, total number of participants.

but non-significant effects on gait speed (ES = 0.38, $p=0.06$, $I^2=43\%$) and balance (ES = 0.48, $p=0.05$, $I^2=55\%$). Modalities comparisons found positive effects for both multicomponent and resistance training (ES ≥ 0.84, $p<0.05$, $I^2 \leq 84\%$). Intensities comparisons found positive effects for both high-intensity and low-intensity interventions (ES ≥ 0.67, $p \leq 0.03$, $I^2 \leq 84\%$). The combination of modality and intensity with each functional capacity subdomain indicated large and significant protective effects on standing ability for all training modalities and intensities (ES ≥ 0.96, $p<0.04$, $I^2=80\%–88\%$) and walking ability after low-intensity training (ES = 0.88, $p<0.05$; $I^2=0$) in favor of the exercise groups. The results of the GRADE assessment ranged from very low to moderate quality of evidence (Table S2).

3.4 | Meta-Regression

Univariable meta-regression analysis (Table 3) revealed that the training effect (i.e., change between the pre- and post-exercise intervention) and age significantly influenced the preservation of functional capacity after training cessation. The benefits obtained during the training program were positively associated with the residual effects observed after training cessation

TABLE 3 | Meta-regression analyses for different moderators.

Moderators	Beta	95% CI	p
Sample age (years)	−0.06	−0.10 to −0.02	0.006*
Training effect (ES)	0.66	0.32 to 1.01	0.003*
Exercise modality (ES)[a]	−0.05	−0.97 to 0.87	0.660
Exercise intensity (ES)[b]	0.29	−0.53 to 1.10	0.461
Training duration (weeks)	−0.02	−0.09 to 0.05	0.408
Detraining duration (weeks)	−0.01	−0.03 to 0.02	0.381

Note: Beta coefficients explain the changes in the detraining effect size (ES) either per unit of change in the moderator (for continuous moderators: age, training effect, training, and detraining duration) or between two conditions (for binary moderators: exercise modality and intensity).
Abbreviation: CI, confidence interval.
*Significant differences ($p < 0.05$).
[a]Reference condition: multicomponent training.
[b]Reference condition: high intensity.

($\beta = 0.66$; $p < 0.01$), while age negatively impacted the persisting adaptations ($\beta = -0.06$; $p < 0.01$). However, among the other moderators examined, including training modality, intensity, and duration of training cessation, there were no significant findings observed in either the univariable or multivariable models.

3.5 | Risk of Bias

The risk of bias is summarized in Figure S12. Eleven studies presented "some concerns" [42, 44–52, 54] and four studies "low risk." [43, 53, 55, 56] The funnel is presented in Figure S13. Visual inspection revealed an asymmetrical shape confirmed with Egger's test ($p = 0.004$). This asymmetry was not related to publication bias but a result of large heterogeneity across studies.

4 | Discussion

While the benefits of regular exercise across the lifespan are well-established [57–59], emerging evidence highlights its protective effect during periods of inactivity caused by falls, illness, or hospitalizations. This is particularly important in frail populations such as older adults who commonly suffer from adverse events that force them to interrupt physical activity levels for days, weeks, or even months. However, there is still limited understanding regarding the exercise prescription (i.e., different exercise modalities and intensities) to achieve the residual effects [26, 27]. The objective of this study was to systematically review and analyze the current evidence from 21 different exercise programs, focusing on their ability to counteract deconditioning during training cessation periods in older adults. The findings revealed that engaging in physical training twice a week for over 2 months before a hiatus of at least 1 month can significantly preserve functional capacity, including agility, walking ability, standing ability, and stair walking (Table 2). It is worth noting that positive effects were observed for gait speed and balance, with results close to reaching statistical significance ($p = 0.056$ and $p = 0.051$, respectively). These results reaffirm that exercise programs have long-lasting benefits on several subdomains of functional capacity (with the exception of balance) in older adults, regardless of the duration of training and exercise cessation [60].

The meta-analysis demonstrated that functional capacity was preserved (large effect size) regardless of the exercise modality and intensity (Table 2, Figures S2–S5). The evidence favors multicomponent as the preferred modality for enhancing functional capacity in older adults [61]. However, considering that functional capacity is strongly influenced by individual strength levels [62], it is expected that both modalities would lead to improvements in agility, walking ability, standing ability and stair walking. This study revealed that the functional adaptations achieved through either resistance or multicomponent training are similarly retained following a period of training cessation. Notably, due to substantial heterogeneity among interventions, a dose–response relationship could not be identified. Therefore, further exploration is needed to understand the time-dependent relationship between exercise duration and the length of the inactivity period, specifically regarding the regression of functional capacity adaptations.

Exercise-induced strength adaptations primarily depend on the intensity and volume of training performed within each set [63]. The understanding of these parameters has improved, leading to a re-evaluation of traditional beliefs that advocated for high loads (>85% of 1RM) and reaching muscular failure [64–66]. Current approaches emphasize the use of technology-based training methods to individualize intensity and manage fatigue on a daily or weekly basis to optimize recovery while maximizing performance gains [67]. This paradigm has proven successful in both high-level sports settings [68] and clinical environments, where it has been employed to assist resistance training with older adults [69]. Recognizing the significance of exercise intensity, our study analyzed the interventions based on this factor. However, contrary to our expectations, we did not observe a substantial influence of exercise intensity on the preservation of functional capacity following periods of inactivity. This unexpected finding raises questions about the effectiveness of the methods used to ensure that participants were working at the intended intensity. It is worth emphasizing that a significant portion of the reviewed interventions (57%) relied on self-rated perceived exertion scales, such as the RPE scale (Table 1). Although self-rated scales are easily accessible [70], their accuracy may be biased by individuals' training experience, with less-experienced individuals tending to underreport (and consequently underestimate) intensity, especially at light and moderate levels that do not approach muscular failure [71]. Supporting the limitations of self-rated tools, the largest and longest randomized controlled trial on exercise for older adults [72] found no differences in overall mortality rates among three self-directed interventions (national guidelines vs. high-intensity exercise vs. moderate-intensity exercise), aligning with findings from supervised interventions employing objective monitoring methods. Therefore, to enhance the precision of exercise interventions in older adults, it would be advisable to combine self-rated assessments with objective tools to better control intensity and manage fatigue [71].

Despite the well-established healing effects of exercise, its improper implementation can have detrimental consequences [73]. Nowadays, various accessible methodologies are being employed in both healthy [74] and unhealthy [75] older adult populations to facilitate exercise monitoring and enhance the quality of interventions. Resistance training interventions, for instance, can benefit from the use of force sensors [76, 77] or linear transducers [69] to accurately adjust intensity and volume. In aerobic training, intensity levels can be supervised using heart rate monitors [78] in combination with RPE measurements for more precise monitoring. Additionally, velocity parameters can be implemented for walking interventions [79], while power meters can be utilized for cycling interventions [75] to monitor external load. Therefore, the above-mentioned approaches should complement the implementation of effective and tailored interventions.

The meta-regression analyses showed a significant influence of moderators on the residual effects of physical exercise on functional capacity (Table 3). The benefits obtained during the training program (i.e., the change between the pre- and post-exercise intervention) were positively associated with the residual effects observed after training cessation. This influence of the training effect, and consequently, greater functional capacity is consistent with previous studies analyzing the residual adaptations of exercise training on functional capacity after short and long detraining periods [25, 60]. This finding supports the fact that individuals with higher fitness levels may experience less functional decline compared to those with lower physical condition [24]. On the other hand, the age of participants negatively influenced the residual effects of exercise training, which indicates that older adults with higher age reported lower residual effects. This finding would agree with previous studies analyzing the effects of the exercise cessation period, where the oldest participants (i.e., ≥ 74 years) reported no residual effect on walking ability, while younger participants (i.e., ≤ 73 years) showed long-lasting benefits in this capacity [80, 81]. Hence, it is of vital importance to maintain regular physical exercise or reduce as much as possible exercise cessation periods in the oldest population. Among the characteristics of participants influencing the residual effects of exercise training, institutionalization could play a significant role. Despite the inclusion of 15 studies in this systematic review, only 3 RCTs with institutionalized older adults were included in the meta-analysis [44, 53, 55], which is limited to conducting subgroup analyses according to Cochrane guidelines [28]. However, the subgroup meta-analysis for agility (Figure S6) and standing ability (Figure S9) reported the lowest effect sizes in studies with institutionalized participants compared to community-dwelling older adults. While these results may suggest that institutionalized older adults report lower residual effects, these findings should be interpreted with caution due to the limited number of studies and lack of subgroup meta-analysis for this condition. Therefore, future studies analyzing the potential influence of institutionalization on the residual effects are needed.

The adherence rate to exercise programs is a critical factor in ensuring their effectiveness [82]. However, only 11 out of 21 training programs (52%) reported adherence rates, with an average of 77% (Table 1). Overall, adherence to all exercise programs was high, regardless of the training modality, with rates of 77% for resistance and multicomponent training. Interestingly, low-intensity training reported a higher adherence rate (83%) compared to high-intensity training (71%). Although these results may suggest that low-intensity training is a preferable strategy for improving adherence, these findings should be interpreted with caution due to the limited number of interventions examining adherence and the potential inaccuracies in intensity monitoring. Reporting adherence rates should be a standard practice for exercise-based interventions involving older adults to evaluate the effectiveness of exercise programs and promote the physical health and safety of this population [83] Furthermore, these adherence rates can provide valuable insights into the barriers that hinder older adults from participating in exercise interventions and help in devising long-term strategies to enhance engagement.

5 | Study Limitations

This research is not exempt from limitations. First, some of the examined outcomes showed moderate to high levels of heterogeneity. Second, the lack of consensus on the assessment methods limits the ability to compare studies and interpret findings. Third, we had to estimate results from studies that only reported them graphically or lacked some specific statistic (e.g., SD). Finally, we categorized exercise intensity dichotomously according to established cut-off values due to the several methods of monitoring intensity in the studies included.

6 | Perspectives

This study adds new evidence to the existing literature as the first systematic review and meta-analysis focused on the preservation of functional capacity after training cessation in older adults. The key results indicate that exercise-based interventions, regardless of modality (resistance or multicomponent training) or intensity (high or low), exhibit residual effects that preserve functional capacity even after training cessation. Older adults with greater exercise-related benefits prior to training cessation showed better long-lasting effects, while those of greater age experienced a lower preservation of functional capacity. These findings advocate for the implementation of tailored interventions that prioritize exercise modalities and intensities that optimize adherence and maximize the enhancement of functional capacity in older adults, especially in the oldest population.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. T. J. Wang, "Concept Analysis of Functional Status," *International Journal of Nursing Studies* 41, no. 4 (2004): 457–462, https://doi.org/10.1016/j.ijnurstu.2003.09.004.

2. A. J. Cruz-Jentoft, G. Bahat, J. Bauer, et al., "Sarcopenia: Revised European Consensus on Definition and Diagnosis," *Age and Ageing* 48, no. 1 (2019): 16–31, https://doi.org/10.1093/ageing/afy169.

3. S. K. Inouye, P. N. Peduzzi, J. T. Robison, J. S. Hughes, R. I. Horwitz, and J. Concato, "Importance of Functional Measures in Predicting Mortality Among Older Hospitalized Patients," *Journal of the American Medical Association* 279, no. 15 (1998): 1187–1198, https://doi.org/10.1001/jama.279.15.1187.

4. I. Baltasar-Fernandez, J. Alcazar, A. Mañas, et al., "Relative Sit-To-Stand Power Cut-Off Points and Their Association With Negatives Outcomes in Older Adults," *Scientific Reports* 11, no. 1 (2021): 1–10, https://doi.org/10.1038/s41598-021-98871-3.

5. E. Tonet, A. Ariza-Solé, M. Serenelli, et al., "The Impact of Sex and Physical Performance on Long-Term Mortality in Older Patients With Myocardial Infarction," *BMC Medicine* 20, no. 1 (2022): 1–9, https://doi.org/10.1186/s12916-021-02211-1.

6. P. L. Valenzuela, J. S. Morales, A. Castillo-García, et al., "Effects of Exercise Interventions on the Functional Status of Acutely Hospitalised Older Adults: A Systematic Review and Meta-Analysis," *Ageing Research Reviews* 61 (2020): 101076, https://doi.org/10.1016/j.arr.2020.101076.

7. World Health Organization (WHO), "Global Status Report on Physical Activity 2022." (2023).

8. M. S. Fragala, E. L. Cadore, S. Dorgo, et al., "Resistance Training for Older Adults: Position Statement From the National Strength and Conditioning Association," *Journal of Strength and Conditioning Research* 33, no. 8 (2019): 2019–2052, https://doi.org/10.1519/jsc.0000000000003230.

9. M. Izquierdo, R. A. Merchant, J. E. Morley, et al., "International Exercise Recommendations in Older Adults (ICFSR): Expert Consensus Guidelines," *Journal of Nutrition, Health & Aging* 25, no. 7 (2021): 824–853, https://doi.org/10.1007/s12603-021-1665-8.

10. K. Talar, A. Hern, T. Vetrovsky, et al., "Benefits of Resistance Training in Early and Late Stages of Frailty and Sarcopenia: A Systematic Review and Meta-Analysis of Randomized Controlled Studies," *Journal of Clinical Medicine* 10, no. 8 (2021): 1630, https://doi.org/10.3390/jcm10081630.

11. D. L. Marques, H. P. Neiva, D. A. Marinho, and M. C. Marques, "Manipulating the Resistance Training Volume in Middle-Aged and Older Adults: A Systematic Review With Meta-Analysis of the Effects on Muscle Strength and Size, Muscle Quality, and Functional Capacity," *Sports Medicine* 53 (2022): 503–518, https://doi.org/10.1007/s40279-022-01769-x.

12. G. Huang, X. Shi, J. A. Davis-Brezette, and W. H. Osness, "Resting Heart Rate Changes After Endurance Training in Older Adults: A Meta-Analysis," *Medicine and Science in Sports and Exercise* 37, no. 8 (2005): 1381–1386, https://doi.org/10.1249/01.mss.0000174899.35392.0c.

13. R. A. Swoap, N. Norvell, J. E. Graves, and M. L. Pollock, "High Versus Moderate Intensity Aerobic Exercise in Older Adults: Psychological and Physiological Effects," *Journal of Aging and Physical Activity* 2, no. 4 (1994): 293–303, https://doi.org/10.1123/japa.2.4.293.

14. C. E. Garber, B. Blissmer, M. R. Deschenes, et al., "Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise," *Medicine and Science in Sports and Exercise* 43, no. 7 (2011): 1334–1359, https://doi.org/10.1249/MSS.0b013e318213fefb.

15. M. J. Raymond, R. E. Bramley-Tzerefos, K. J. Jeffs, A. Winter, and A. E. Holland, "Systematic Review of High-Intensity Progressive Resistance Strength Training of the Lower Limb Compared With Other Intensities of Strength Training in Older Adults," *Archives of Physical Medicine and Rehabilitation* 94, no. 8 (2013): 1458–1472, https://doi.org/10.1016/j.apmr.2013.02.022.

16. D. L. Mayfield, N. J. Cronin, and G. A. Lichtwark, "Understanding Altered Contractile Properties in Advanced Age: Insights From a Systematic Muscle Modelling Approach," *Biomechanics and Modeling in Mechanobiology* 22 (2022): 309–337, https://doi.org/10.1007/s10237-022-01651-9.

17. J. Grgic, "Use It or Lose It? A Meta-Analysis on the Effects of Resistance Training Cessation (Detraining) on Muscle Size in Older Adults," *International Journal of Environmental Research and Public Health* 19, no. 21 (2022): 14048, https://doi.org/10.3390/ijerph192114048.

18. T. M. Gill, E. A. Gahbauer, L. Han, and H. G. Allore, "The Relationship Between Intervening Hospitalizations and Transitions Between Frailty States," *Journal of Gerontology* 66, no. 11 (2011): 1238–1243, https://doi.org/10.1093/gerona/glr142.

19. K. E. Covinsky, R. M. Palmer, R. H. Fortinsky, et al., "Loss of Independence in Activities of Daily Living in Older Adults Hospitalized With Medical Illnesses: Increased Vulnerability With Age," *Journal of the American Geriatrics Society* 51, no. 4 (2003): 451–458, https://doi.org/10.1046/j.1532-5415.2003.51152.x.

20. L. Bosquet, N. Berryman, O. Dupuy, et al., "Effect of Training Cessation on Muscular Performance: A Meta-Analysis," *Scandinavian Journal of Medicine & Science in Sports* 23, no. 3 (2013): e140–e149, https://doi.org/10.1111/sms.12047.

21. K. Häkkinen, M. Alen, M. Kallinen, R. U. Newton, and W. J. Kraemer, "Neuromuscular Adaptation During Prolonged Strength Training, Detraining and Re-Strength-Training in Middle-Aged and Elderly People," *European Journal of Applied Physiology* 83, no. 1 (2000): 51–62, https://doi.org/10.1007/s004210000248.

22. E. Van Roie, S. Walker, S. Van Driessche, et al., "Training Load Does Not Affect Detraining's Effect on Muscle Volume, Muscle Strength and Functional Capacity Among Older Adults," *Experimental Gerontology* 98 (2017): 30–37, https://doi.org/10.1016/j.exger.2017.07.017.

23. F. Millan-Domingo, E. Garcia-Dominguez, J. Gambini, G. Olaso-Gonzalez, J. Viña, and M. C. Gomez-Cabrera, "Diet and Exercise in Frailty and Sarcopenia. Molecular Aspects," *Molecular Aspects of Medicine* 100 (2024): 101322, https://doi.org/10.1016/j.mam.2024.101322.

24. T. M. Gill, H. G. Allore, E. A. Gahbauer, and T. E. Murphy, "Change in Disability After Hospitalization or Restricted Activity in Older Persons," *Journal of the American Medical Association* 304, no. 17 (2010): 1919–1928, https://doi.org/10.1001/jama.2010.1568.

25. J. Courel-Ibáñez, J. G. Pallarés, S. García-Conesa, Á. Buendía-Romero, A. Martínez-Cava, and M. Izquierdo, "Supervised Exercise (Vivifrail) Protects Institutionalized Older Adults Against Severe Functional Decline After 14 Weeks of COVID Confinement," *Journal of the American Medical Directors Association* 22, no. 1 (2021): 217–219, https://doi.org/10.1016/j.jamda.2020.11.007.

26. M. Izquierdo and S. M. Fiatarone, "Urgent Need for Integrating Physical Exercise Into Geriatric Medicine: A Call to Action," *British Journal of Sports Medicine* 57 (2023): 953–954, https://doi.org/10.1136/bjsports-2023-106912.

27. M. Izquierdo and S. M. Fiatarone, "Promoting Resilience in the Face of Ageing and Disease: The Central Role of Exercise and Physical Activity," *Ageing Research Reviews* 88 (2023): 101940, https://doi.org/10.1016/j.arr.2023.101940.

28. J. Higgins and S. Green, "Cochrane Handbook for Systematic Reviews of Interventions." (2015), www.cochrane-handbook.org.

29. Á. Buendía-Romero, T. Vetrovsky, F. Estévez-López, and J. Courel-Ibáñez, "Effect of Physical Exercise Cessation on Strength, Functional, Metabolic and Structural Outcomes in Older Adults: A Protocol for Systematic Review and Meta-Analysis," *BMJ Open* 11, no. 12 (2021): e052913, https://doi.org/10.1136/bmjopen-2021-052913.

30. J. P. Michel, M. Leonardi, M. Martin, and M. Prina, "WHO's Report for the Decade of Healthy Ageing 2021–30 Sets the Stage for Globally

Comparable Data on Healthy Ageing," *Lancet* 2, no. 3 (2021): e121–e122, https://doi.org/10.1016/S2666-7568(21)00002-7.

31. D. Drevon, S. R. Fursa, and A. L. Malcolm, "Intercoder Reliability and Validity of WebPlotDigitizer in Extracting Graphed Data," *Behaviour Modification* 41 (2017): 323–339, https://doi.org/10.1177/0145445516673998.

32. C. J. Weir, I. Butcher, V. Assi, et al., "Dealing With Missing Standard Deviation and Mean Values in Meta-Analysis of Continuous Outcomes: A Systematic Review," *BMC Medical Research Methodology* 18, no. 1 (2018): 25, https://doi.org/10.1186/s12874-018-0483-0.

33. B. S. Row, K. M. Knutzen, and N. J. Skogsberg, "Regulating Explosive Resistance Training Intensity Using the Rating of Perceived Exertion," *Journal of Strength and Conditioning Research* 26, no. 3 (2012): 664–671, https://doi.org/10.1519/JSC.0b013e31822ac367.

34. S. Morishita, A. Tsubaki, M. Nakamura, S. Nashimoto, J. B. Fu, and H. Onishi, "Rating of Perceived Exertion on Resistance Training in Elderly Subjects," *Expert Review of Cardiovascular Therapy* 17, no. 2 (2019): 135–142, https://doi.org/10.1080/14779072.2019.1561278.

35. J. A. C. Sterne, J. Savović, M. J. Page, et al., "RoB 2: A Revised Tool for Assessing Risk of Bias in Randomised Trials," *BMJ* 366 (2019): 1–8, https://doi.org/10.1136/bmj.l4898.

36. R. Brignardello-Petersen, A. Bonner, P. E. Alexander, et al., "Advances in the GRADE Approach to Rate the Certainty in Estimates From a Network Meta-Analysis," *Journal of Clinical Epidemiology* 93 (2018): 36–44, https://doi.org/10.1016/j.jclinepi.2017.10.005.

37. L. V. Hedges, "Distribution Theory for Glass's Estimator of Effect Size and Related Estimators," *Journal of Educational and Behavioral Statistics* 6 (1981): 107–128, https://doi.org/10.3102/10769986006002107.

38. L. V. Hedges, E. Tipton, and M. C. Johnson, "Robust Variance Estimation in Meta-Regression With Dependent Effect Size Estimates," *Research Synthesis Methods* 1, no. 1 (2010): 39–65, https://doi.org/10.1002/jrsm.5.

39. E. Tipton, "Small Sample Adjustments for Robust Variance Estimation With Meta-Regression," *Psychological Methods* 20, no. 3 (2015): 375–393, https://doi.org/10.1037/met0000011.

40. J. Cohen, *Statistical Power Analysis for the Behavioural Sciences* (Hillside: NJ Lawrence Earlbaum Association, 1988).

41. W. G. Melsen, M. C. J. Bootsma, M. M. Rovers, and M. J. M. Bonten, "The Effects of Clinical and Statistical Heterogeneity on the Predictive Values of Results From Meta-Analyses," *Clinical Microbiology and Infection* 20, no. 2 (2014): 123–129, https://doi.org/10.1111/1469-0691.12494.

42. J. H. Ansai, T. R. Aurichio, R. Gonçalves, and J. R. Rebelatto, "Effects of Two Physical Exercise Protocols on Physical Performance Related to Falls in the Oldest Old: A Randomized Controlled Trial," *Geriatrics & Gerontology International* 16, no. 4 (2016): 492–499, https://doi.org/10.1111/ggi.12497.

43. K. C. Bezerra-Melo, G. A. dos Santos, F. d. S. Araujo, and S. R. Moreira, "Detraining Period of the PILATES Method on Functional Capacity of Elderly Women With Type 2 Diabetes: A Randomized Clinical Trial," *Journal of Bodywork and Movement Therapies* 31 (2022): 77–83, https://doi.org/10.1016/j.jbmt.2022.03.012.

44. A. Caldo-Silva, G. E. Furtado, M. U. Chupel, et al., "Effect of Training-Detraining Phases of Multicomponent Exercises and BCAA Supplementation on Inflammatory Markers and Albumin Levels in Frail Older Persons," *Nutrients* 13, no. 4 (2021): 1106, https://doi.org/10.3390/nu13041106.

45. M. J. Carvalho, E. Marques, and J. Mota, "Training and Detraining Effects on Functional Fitness After a Multicomponent Training in Older Women," *Gerontology* 55, no. 1 (2009): 41–48, https://doi.org/10.1159/000140681.

46. U. Englund, H. Littbrand, A. Sondell, G. Bucht, and U. Pettersson, "The Beneficial Effects of Exercise on BMD Are Lost After Cessation: A 5-Year Follow-Up in Older Post-Menopausal Women," *Scandinavian Journal of Medicine and Science in Sports* 19, no. 3 (2009): 381–388, https://doi.org/10.1111/j.1600-0838.2008.00802.x.

47. I. G. Fatouros, A. Kambas, I. Katrabasas, et al., "Strength Training and Detraining Effects on Muscular Strength, Anaerobic Power, and Mobility of Inactive Older Men Are Intensity Dependent," *British Journal of Sports Medicine* 39, no. 10 (2005): 776–780, https://doi.org/10.1136/bjsm.2005.019117.

48. J. M. González-Ravé, R. Cuéllar-Cañadilla, T. García-Pastor, and S.-G. D. Juárez, "Strength Improvements of Different 10-Week Multicomponent Exercise Programs in Elderly Women," *Frontiers* 8 (2020): 130, https://doi.org/10.3389/fpubh.2020.00130.

49. V. I. Kalapotharakos, K. Diamantopoulos, and S. P. Tokmakidis, "Effects of Resistance Training and Detraining on Muscle Strength and Functional Performance of Older Adults Aged 80 to 88 Years," *Aging Clinical and Experimental Research* 22, no. 2 (2010): 134–140, https://doi.org/10.1007/BF03324786.

50. A. Lacroix, T. Muehlbauer, Y. J. Gschwind, B. Pfenninger, O. Bruegger, and U. Granacher, "Effects of a Supervised Versus an Unsupervised Combined Balance and Strength Training Program on Balance and Muscle Power in Healthy Older Adults: A Randomized Controlled Trial," *Gerontology* 62, no. 3 (2015): 275–288, https://doi.org/10.1159/000442087.

51. S. Y. Park and I. H. Lee, "Effects on Training and Detraining on Physical Function, Control of Diabetes and Anthropometrics in Type 2 Diabetes; a Randomized Controlled Trial," *Physiotherapy Theory and Practice* 31, no. 2 (2015): 83–88, https://doi.org/10.3109/09593985.2014.958265.

52. A. Pereira, M. Izquierdo, A. J. Silva, A. M. Costa, J. J. González-Badillo, and M. C. Marques, "Muscle Performance and Functional Capacity Retention in Older Women After High-Speed Power Training Cessation," *Experimental Gerontology* 47, no. 8 (2012): 620–624, https://doi.org/10.1016/j.exger.2012.05.014.

53. J. A. Serra-Rexach, N. Bustamante-Ara, M. Hierro Villarán, et al., "Short-Term, Light–To Moderate-Intensity Exercise Training Improves Leg Muscle Strength in the Oldest Old: A Randomized Controlled Trial," *Journal of the American Geriatrics Society* 59 (2011): 594–602, https://doi.org/10.1111/j.1532-5415.2011.03356.x.

54. W. Sun, L. Wang, C. Zhang, Q. Song, H. Gu, and D. Mao, "Detraining Effects of Regular Tai chi Exercise on Postural Control Ability in Older Women: A Randomized Controlled Trial," *Journal of Exercise Science and Fitness* 16, no. 2 (2018): 55–61, https://doi.org/10.1016/j.jesf.2018.06.003.

55. E. W. Telenius, K. Engedal, and A. Bergland, "Long-Term Effects of a 12 Weeks High-Intensity Functional Exercise Program on Physical Function and Mental Health in Nursing Home Residents With Dementia: A Single Blinded Randomized Controlled Trial Physical Functioning, Physical Health and Activity," *BMC Geriatrics* 15, no. 1 (2015): 158, https://doi.org/10.1186/s12877-015-0151-8.

56. A. Zech, M. Drey, E. Freiberger, et al., "Residual Effects of Muscle Strength and Muscle Power Training and Detraining on Physical Function in Community-Dwelling Prefrail Older Adults: A Randomized Controlled Trial," *BMC Geriatrics* 12 (2012): 1–8, https://doi.org/10.1186/1471-2318-12-68.

57. W. Bao, Y. Sun, T. Zhang, et al., "Exercise Programs for Muscle Mass, Muscle Strength and Physical Performance in Older Adults With Sarcopenia: A Systematic Review and Meta-Analysis," *Aging and Disease* 11, no. 4 (2020): 863–873, https://doi.org/10.14336/AD.2019.1012.

58. J. Grgic, A. Garofolini, J. Orazem, F. Sabol, B. J. Schoenfeld, and Z. Pedisic, "Effects of Resistance Training on Muscle Size and Strength in Very Elderly Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Trials," *Sports Medicine* 50 (2020): 1983–1999, https://doi.org/10.1007/s40279-020-01331-7.

59. M. Izquierdo, J. E. Morley, and A. Lucia, "Exercise in People Over 85," *BMJ* 368 (2020): 1–2, https://doi.org/10.1136/bmj.m402.

60. J. Courel-Ibanez, A. Buendia-Romero, J. G. Pallares, S. Garcia-Conesa, A. Martinez-Cava, and M. Izquierdo, "Impact of Tailored Multicomponent Exercise for Preventing Weakness and Falls on Nursing Home Residents' Functional Capacity," *Journal of the American Medical Directors Association* 23 (2022): 98–104, https://doi.org/10.1016/j.jamda.2021.05.037.

61. E. L. Cadore, M. L. Sáez de Asteasu, and M. Izquierdo, "Multicomponent Exercise and the Hallmarks of Frailty: Considerations on Cognitive Impairment and Acute Hospitalization," *Experimental Gerontology* 122 (2019): 10–14, https://doi.org/10.1016/j.exger.2019.04.007.

62. A. Casas-Herrero, E. L. Cadore, F. Zambom-Ferraresi, et al., "Functional Capacity, Muscle Fat Infiltration, Power Output, and Cognitive Impairment in Institutionalized Frail Oldest Old," *Rejuvenation Research* 16, no. 5 (2013): 396–403, https://doi.org/10.1089/rej.2013.1438.

63. B. J. Schoenfeld, B. Contreras, J. Krieger, et al., "Resistance Training Volume Enhances Muscle Hypertrophy but Not Strength in Trained Men," *Medicine and Science in Sports and Exercise* 51, no. 1 (2019): 94–103, https://doi.org/10.1249/MSS.0000000000001764.

64. C. Grandou, L. Wallace, F. M. Impellizzeri, N. G. Allen, and A. J. Coutts, "Overtraining in Resistance Exercise: An Exploratory Systematic Review and Methodological Appraisal of the Literature," *Sports Medicine* 50, no. 4 (2020): 815–828, https://doi.org/10.1007/s40279-019-01242-2.

65. J. Grgic, B. J. Schoenfeld, J. Orazem, and F. Sabol, "Effects of Resistance Training Performed to Repetition Failure or Non-Failure on Muscular Strength and Hypertrophy: A Systematic Review and Meta-Analysis," *Journal of Sport and Health Science* 11 (2021): 202–211, https://doi.org/10.1016/j.jshs.2021.01.007.

66. A. F. Vieira, D. Umpierre, J. L. Teodoro, et al., "Effects of Resistance Training Performed to Failure or Not to Failure on Muscle Strength, Hypertrophy, and Power Output: A Systematic Review With Meta-Analysis," *Journal of Strength and Conditioning Research* 35, no. 4 (2021): 1165–1175, https://doi.org/10.1519/jsc.0000000000003936.

67. J. J. González-Badillo, L. Sánchez-Medina, J. Ribas-Serna, and D. Rodríguez-Rosell, "Toward a New Paradigm in Resistance Training by Means of Velocity Monitoring: A Critical and Challenging Narrative," *Sports Medicine* 8, no. 1 (2022): 118, https://doi.org/10.1186/s40798-022-00513-z.

68. A. Hernández-Belmonte, L. M. Alegre, and J. Courel-Ibáñez, "Velocity-Based Resistance Training in Soccer: Practical Applications and Technical Considerations," *Strength & Conditioning Journal* 45, no. 2 (2023): 140–148, https://doi.org/10.1519/SSC.0000000000000707.

69. D. L. Marques, H. P. Neiva, D. A. Marinho, and M. C. Marques, "Changes in Strength-Related Outcomes Following Velocity-Monitored Resistance Training With 10% and 20% Velocity Loss in Older Adults," *Experimental Gerontology* 186, no. January (2024): 1–8, https://doi.org/10.1016/j.exger.2024.112361.

70. R. Pind, P. Purge, E. Mäestu, E. Vahtra, P. Hofmann, and J. Mäestu, "Session Rating of Perceived Exertion Is Different for Similar Intensity and Duration Prescribed Low-Intensity Sessions and Has a Different Effect on Performance in Young Cross-Country Skiers," *Journal of Strength and Conditioning Research* 37 (2021): 187–193, https://doi.org/10.1519/jsc.0000000000004180.

71. T. J. Suchomel, S. Nimphius, C. R. Bellon, W. G. Hornsby, and M. H. Stone, "Training for Muscular Strength: Methods for Monitoring and Adjusting Training Intensity," *Sports Medicine* 51, no. 10 (2021): 2051–2066, https://doi.org/10.1007/s40279-021-01488-9.

72. D. Stensvold, H. Viken, S. L. Steinshamn, et al., "Effect of Exercise Training for Five Years on all Cause Mortality in Older Adults-The Generation 100 Study: Randomised Controlled Trial," *BMJ* 371 (2020): 371, https://doi.org/10.1136/bmj.m3485.

73. M. L. Sáez de Asteasu, N. Martínez-Velilla, F. Zambom-Ferraresi, et al., "Inter-Individual Variability in Response to Exercise Intervention or Usual Care in Hospitalized Older Adults," *Journal of Cachexia, Sarcopenia and Muscle* 10, no. 6 (2019): 1266–1275, https://doi.org/10.1002/jcsm.12481.

74. C. Rodriguez-Lopez, J. Alcazar, C. Sanchez-Martin, et al., "Neuromuscular Adaptations After 12 Weeks of Light- Vs. Heavy-Load Power-Oriented Resistance Training in Older Adults," *Scandinavian Journal of Medicine & Science in Sports* 32, no. 2 (2022): 324–337, https://doi.org/10.1111/sms.14073.

75. P. J. J. Herrod, J. N. Lund, and B. E. Phillips, "Time-Efficient Physical Activity Interventions to Reduce Blood Pressure in Older Adults: A Randomised Controlled Trial," *Age and Ageing* 50, no. 3 (2021): 980–984, https://doi.org/10.1093/ageing/afaa211.

76. Á. Buendía-Romero, A. Hernández-Belmonte, F. Franco-López, et al., "A Sensitive and Practical Evaluation to Detect Lower-Limb Strength Changes in Geriatrics: The Isometric Knee Extension Test," *Applied Sciences* 13, no. 5 (2023): 2946, https://doi.org/10.3390/app13052946.

77. Á. Buendía-Romero, A. Hernández-Belmonte, A. Martínez-Cava, et al., "Isometric Knee Extension Test: A Practical, Repeatable, and Suitable Tool for Lower-Limb Screening Among Institutionalized Older Adults," *Experimental Gerontology* 155 (2021): 111575, https://doi.org/10.1016/j.exger.2021.111575.

78. M. K. Danilovich, D. E. Conroy, and T. G. Hornby, "Feasibility and Impact of High-Intensity Walking Training in Frail Older Adults," *Journal of Aging and Physical Activity* 25, no. 4 (2017): 533–538, https://doi.org/10.1123/japa.2016-0305.

79. I. Baltasar-Fernandez, H. Soto-Paniagua, J. Alcazar, et al., "Long-Term Effects of a 6-Week Power-Based Resistance Training and Fast Walking Interval Training Program on Physical Function, Muscle Power, Disability, and Frailty in Pre-Frail and Frail Older Adults," *Gerontology* 70, no. 7 (2024): 701–714, https://doi.org/10.1159/000536363.

80. N. F. Toraman and N. Ayceman, "Effects of Six Weeks of Detraining on Retention of Functional Fitness of Old People After Nine Weeks of Multicomponent Training," *British Journal of Sports Medicine* 39, no. 8 (2005): 565–568, https://doi.org/10.1136/bjsm.2004.015586.

81. N. F. Toraman, "Short Term and Long Term Detraining: Is There any Difference Between Young-Old and Old People?," *British Journal of Sports Medicine* 39, no. 8 (2005): 561–564, https://doi.org/10.1136/bjsm.2004.015420.

82. T. Valenzuela, Y. Okubo, A. Woodbury, S. R. Lord, and K. Delbaere, "Adherence to Technology-Based Exercise Programs in Older Adults: A Systematic Review," *Journal of Geriatric Physical Therapy (2001)* 41, no. 1 (2018): 49–61, https://doi.org/10.1519/JPT.0000000000000095.

83. S. Rivera-Torres, T. D. Fahey, and M. A. Rivera, "Adherence to Exercise Programs in Older Adults: Informative Report," *Gerontology and Geriatric Medicine* 5 (2019): 2360, https://doi.org/10.1177/2333721418823604.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.