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Effects of Movement-Based Mind-Body Interventions on Physical Fitness in Healthy Older Adults: A Meta-Analytical Review

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Keywords
Mind-body intervention · Strength · Balance · Mobility · Gait · Heterogeneity

Abstract
Introduction: Declines in physical fitness can notably affect healthy aging of older adults. Multimodal exercise training regimen such as mind-body interventions (MBIs) has been reported to mitigate these aging-related declines of physical function. This meta-analytical review aimed at pooling the effects of MBIs on physical fitness indices compared to active control (AC) and inactive control (IC) conditions in healthy older adults. ***Methods:*** The literature search was conducted in 3 databases using search terms with Boolean conjunctions. Randomized controlled trials applying MBIs focusing on improving physical fitness parameters in healthy seniors over 65 years of age were screened for eligibility. Eligibility and study quality were assessed by 2 researchers using the PEDro scale. Standardized mean differences (SMD) adjusted for small sample sizes (Hedges' *g*) served as main outcomes for the comparisons of MBIs versus IC and MBIs versus AC. ***Results:*** Thirty trials with 2,792 healthy community dwellers (mean age: 71.2 ± 4.7 years) were included. Large overall effects were found for strength ($p < 0.001$, SMD: 0.87 [90% CI: 0.43, 1.30], $I^2 = 94\%$), medium effects were observed for functional mobility ($p = 0.009$, SMD: 0.55 [90% CI: 0.20, 0.89], $I^2 = 83\%$), and small overall effects were found for static balance ($p = 0.02$, SMD: 0.35 [90% CI: 0.10, 0.60], $I^2 = 77\%$), endurance ($p = 0.0001$, SMD: 0.44 [90% CI: 0.25, 0.62], $I^2 = 0\%$), and flexibility ($p = 0.003$, SMD: 0.46 [90% CI: 0.21, 0.72], $I^2 = 54\%$) in favor of MBIs compared to IC. Small effects of strength slightly favoring AC ($p = 0.08$, SMD: −0.22 [90% CI: −0.43, −0.01], $I^2 = 52\%$) were found, whereas static balance moderately improved in favor of MBIs ($p < 0.001$, SMD: 0.46 [90% CI: 0.16, 0.76], $I^2 = 73\%$). ***Discussion/Conclusion:*** MBIs induce small to moderate effects in relevant domains of physical fitness in healthy older adults. Strength should be better targeted with traditional resistance training routines, whereas balance seems to sufficiently benefit from MBIs. However, large variability between the studies was observed due to differences in methodology, intervention content, and outcomes that affect conclusive evidence.

Introduction

Life expectancy has notably increased in the 21st century as a result of societal and health care changes [1]. To guarantee an independent living and a high quality of life in old age, the maintenance of healthy physiological func-

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Table 1. Levels and terms of the literature search process

Search level	Search terms with Boolean operators
Search #1	(all fields) power OR activity OR strength OR endurance OR coordination OR balance OR mobility OR recovery OR recreation OR health OR "physical fitness" OR "physical function" OR capacity OR function
Search #2	Search #1 AND (title) yoga OR Pilates OR "Tai Chi" OR "Qi Gong" (abstract) AND yoga OR Pilates OR "Tai Chi" OR "Qi Gong"
Search #3	Search #2 AND (all fields) old OR older OR elder OR senior OR aged OR age OR geriatrics OR "senior citizen" OR "senior citizens" OR seniors OR "old age" OR "older adults" NOT child OR children OR "young adults"

tioning is considered of utmost importance. Aging induces declines of strength, flexibility, endurance, mobility, balance, and coordination performance and thus results in lower physical activity levels of older adults that hamper healthy aging with notable effects on morbidity and mortality [2]. This vicious circle can be cut through by physical activity and exercise training that specifically promotes the components of intact physical functioning [3, 4]. Innovative and integrative interventions based on exercises and tailored to the needs of older adults are required [5]. Those interventions should motivate older persons to engage in physical activity in the long term, considering the main types of training/strain (balance, endurance, strength, flexibility, and coordination) and to rather delay clinical limitations (e.g., diseases, falls, and hospital administration).

In this regard, mind-body interventions (MBIs) have already proven to be a suitable approach in improving physical functioning of older adults [4, 5]. MBIs have been described by the National Centers for Complementary and Integrative Health, as interventions which aim to unite the body and mind to positively influence physical function, psychological status, and symptoms [6]. This integrative framework mainly targets relaxation techniques, meditation, and breathing exercises with structured movements [6]. Prominent agents of these movement-based MBIs are Yoga, Qi Gong, Tai Chi [7], and Pilates [8]. Tai Chi and Qi Gong have become increasingly popular within the MBIs although the effects, including breathing, relaxation, and movement control, are minor [9]. The respective movements of the MBIs are mainly performed in easy to more complex exercise sequences [10]. Studies on Tai Chi observed positive effects on flexibility, balance, and gait in older adults [9]. Yoga studies revealed improvements in numerous physiological and functional parameters such as walking, balance, muscle strength, cardiovascular health, and blood pressure [11]. On the other hand, Pilates is a relatively new and underexplored mode of MBIs. It has been estimated that 80% of all available Pilates studies were conducted between 2010 and 2014 [4]. Pilates follows the key principles of muscle strengthening, especially the lumbar-pelvic region, dynamic stretching, body control, flow of movements, concentration, and breathing [12] and can therefore be classified as MBI [13]. The aspects of all MBIs can be considered integratively with multimodal impact on balance, certain strength aspects, and functional mobility [4, 9–11, 14].

Several studies have already been conducted on the effects of MBIs on health-related outcomes. However, compelling and comprehensive evidence pooling of available MBI findings and examining its effects on a variety of relevant physical dimensions in older adults are still lacking. Therefore, the present meta-analytical review focuses on different types of movement-based MBIs (Yoga, Qi Gong, Tai Chi, and Pilates) and their physiological effects compared to both active control (AC) and inactive control (IC) conditions in healthy older community dwellers. Our work may contribute to a better understanding of the occurrence and magnitude of MBI-induced effects on older adults' physical functioning and thus to better tailor and adapt MBIs in order to improve a broad range of health-related physical function indices.

Methods

Search Strategy and Study Selection

This meta-analytical review was performed in accordance with the PRISMA guidelines [15]. The literature search was independently conducted by two researchers (S.A.E. and L.M.) until 23 November 2019 in three health-related, biomedical, and sports-related databases (Web of Knowledge, PubMed, and SPORTDiscus). Relevant search terms (operators) were combined with Boolean conjunctions (OR/AND) and applied on the following three search levels (see Table 1). Citation tracking of the articles as well as hand searching (e.g., within all reference lists of the articles) for important primary articles and review articles were additionally

Table 2. Study characteristics of included studies (n = 30) [9, 17–45]

Reference	Study design	Population (n; age, years (mean ± SD))	Groups (n per group)	Intervention in IG and AC (content, duration, load criteria, and material)	Training (duration, sessions per week, time per session)	Outcome measures	Study quality (PEDro)
Almazán et al. [17]	RCT	Older women (110; 69.2±8.9)	IG (n = 55) IC (n = 55)	*Pilates (IG)*: 10-min warm-up, 35-min Pilates, 15-min cool-down, 10 repetitions/exercise; material: resistance band, ring, ball	12 weeks, 2×/week, 60 min/session	CoP sway	9
Alvarenga et al. [18]	RCT	Older active women (31; IG: 65.5±3.3 AC: 65.4±4.5 IC: 73.3±5.6)	IG (n = 11) AC (n = 11) IC (n = 9)	*Pilates (IG)*: 12 repetitions/exercise + 1–3 sets; material: cadillac, combo chair, reformer *Pilates + inspiratory muscle training (AC)*: 30 repetitions + 2 sets, 50% initial load, 10% increase every 2 weeks; material: Powerbreath K5 devices	10 weeks, 2×/week, 45 min/session	6MWT Abdominal curl-up test	5
Donath et al. [29]	3-arm RCT	Older adults (48; IG: 70.8±6.5 AC: 69.1±5.8 IC: 69.0±6.1)	IG (n = 17) AC (n = 16) IC (n = 15)	*Pilates (IG)*: 10-min warm-up, 6–12 repetitions/exercise *Traditional balance training (AC)*: 10-min warm-up, 50-min static postural control and dynamic postural control exercises	8 weeks, 2×/week, 66 min/session	CoP sway Y balance test Perturbed kneeling ACSM curl-up test	8
Fourie et al. [19]	RCT	Older sedentary healthy women (50; IG: 66.1±4.8 IC: 65.3±5.0)	IG (n = 25) IC (n = 25)	*Pilates (IG)*: breathing, flowing from standing to sitting to lying down exercises, rest position	8 weeks, 3×/week, 60 min/session	Upper body strength Lower body strength Muscular endurance	6
Fourie et al. [20]	RCT	Older sedentary healthy women (50; IG: 66.1±4.8 IC: 65.3±5.0)	IG (n = 25) IC (n = 25)	*Pilates (IG)*: breathing, flowing from standing to sitting to lying down exercises, rest position	8 weeks, 3×/week, 60 min/session	Shoulder flexion/ extension Hip flexion Knee flexion	3
Frye et al. [30]	RCT	Community-dwelling older adults (72; 69.2±9.3)	IG (n = 23) AC (n = 28) IC (n = 21)	*Tai Chi (IG)*: 10-min meditation, 5-min Qi Gong warm-up, 45-min Yang style Tai Chi *Low-impact exercise (AC)*: 5-min warm-up, traditional Western exercises focusing on strength, flexibility, endurance, balance	12 weeks, 2×/week, 40–60 min/session	Chair stand test 2-min step test Sit-and-reach test 8-ft up and go Grip strength	7
Gabizon et al. [36]	RCT	Community-dwelling older adults (88; 71.2±4.3)	IG (n = 44) IC (n = 44)	*Pilates (IG)*: level 1–3 exercises; material: Theraband, resistance bands, Swiss ball	12 weeks, 3×/week (no further information)	CoP sway BBS TBGA	7
Hosseini et al. [33]	RCT	Older adults (60) (no exact age was given)	IG (n = 30) IC (n = 30)	*Tai Chi (IG)*: 5-min warm-up, 35-min 108 forms of Yang, Chen, Wu, Hao, Sun style Tai Chi Chuan, 5-min cool-down	8 weeks, 2×/week, 55 min/session	TUG TBGA	9
Hyun et al. [21]	RCT	Older women (40; IG: 70.0±2.2 AC: 69.3±2.6)	IG (n = 20) AC (n = 20)	*Pilates (IG)*: 5-min warm-up, 30-min Pilates, 5-min cool-down *Unstable support surface exercise (AC)*: 40-min balance exercises on aerostep TOGU	12 weeks, 3×/week, 40 min/session	CoP sway TUG	5
Josephs et al. [27]	RCT	Older adults at risk of fall (24; IG: 75.6±6.2 AC: 74.5±6.9)	IG (n = 13) AC (n = 11)	*Pilates (IG)*: 10 repetitions/exercise; material: reformer, cadillac, chair *Traditional exercise (AC)*: repetitions progressed individually; material: elastic resistance bands, ankle weights, foam balance pads, boxes of varying heights, half foam rollers	12 weeks, 2×/week, 60 min/session	TUG FAB	7
Lelard et al. [41]	RCT	Older adults (28; IG: 76.8±5.1 AC: 77.0±4.5)	IG (n = 14) AC (n = 14)	*Tai Chi (IG)*: 10 Tai Chi movements adapted for older adults under eyes opened and closed conditions *Balance training (AC)*: static and dynamic postural control exercises under eyes opened and closed conditions	12 weeks, 2×/week, 30 min/session	CoP sway 10-M walking speed	6

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Table 2 (continued)

Reference	Study design	Population (*n*; age, years (mean ± SD))	Groups (*n* per group)	Intervention in IG and AC (content, duration, load criteria, and material)	Training (duration, sessions per week, time per session)	Outcome measures	Study quality (PEDro)
Li et al. [34]	RCT	Community-dwelling older adults (256; 77.5±5.0)	IG (n = 125) IC (n = 131)	*Tai Chi (IG)*: 5- to 10-min warm-up, 24-form Yang style Tai Chi focusing on multidirectional weight shifting, awareness of body alignment, and multisegmental movement coordination including musical accompaniment, 5- to 10-min cool-down	24 weeks, 3×/week (no further information)	BBS DGI FR Single-leg standing 50-ft walk Up and go	9
Lin et al. [37]	RCT	Older adults (95; IG: 73.9±7.2 IC: 74.2±7.0)	IG (n = 48) IC (n = 47)	*Tai Chi (IG)*: 15-min warm-up, 30-min 10-form Tai Chi with Theraband, 15-min cool-down, 4–10 repetition/exercise + 2 sets; material: Theraband (thin, medium, heavy)	16 weeks, 2×/week, 60 min/session	SFT Shoulder flexion Elbow flexion Hip flexion Knee extension	7
Manor et al. [40]	RCT cross-over	Older adults living in supportive housing (57; 87.0±5.0)	IG (n = 29) IC (n = 28)	*Tai Chi (IG)*: focused on traditional Tai Chi warm-up exercises + 5 core movements from Cheng Man-Ch'ing's Yang style short form: "raising the power," "withdraw and push," "grasp the sparrow's tail," "brush knee twist step," "wave hand like clouds"	12 weeks, 2×/week, 60 min/session	SPPB Walking speed BBS TUG	8
Markovic et al. [22]	RCT	Older women (34; 70.0±4.0)	IG (n = 17) AC (n = 17)	*Pilates (IG)*: isometric exercise: 15–20 s, 2–4 sets; dynamic exercise: 15–20 repetitions *Huber training (AC)*: 3-min warm-up, 25- to 30-min Huber training, 30–60 contractions per session; material: Huber device	8 weeks, 3×/week, 60 min/session	CoP Trunk muscle strength Upper body muscle strength Lower body power	7
Nguyen et al. [44]	RCT	Community-dwelling older adults (96; 68.9±5.1)	IG (n = 48) IC (n = 48)	*Tai Chi (IG)*: 15-min warm-up, 30-min 24-form Tai Chi incorporating elements of balance, postural alignment, and concentration, 15-min cool-down	24 weeks, 2×/week, 60 min/session	SFT	6
Ni et al. [31]	RCT	Older adults (39; 74.2±7.0)	IG (n = 11) AC (n = 15) AC (n = 13)	*Tai Chi (IG)*: 5-min warm-up, 50-min Chen style Tai Chi focusing on whole-body motion using alternating fast and slow coordinated upper and lower body rotational movements, 5-min cool-down, 18 movements *Standard balance program (AC)*: 5-min warm-up, 50-min balance training: maintaining balance on compliant surfaces, picking up objects from ground and line, cone, ladder, chair, step, and ball drills, 5-min cool-down *Targeted yoga program (AC)*: 5-min warm-up, 50-min BYOGA with vinyasa yoga poses including balance muscles	12 weeks, 2×/week, 60 min/session	8-ft up and go OLS FR Walking speed CoP sway	6
Noradechanunt et al. [32]	RCT	Sedentary older adults (39; 67.7±6.7)	IG (n = 13) AC (n = 13) IC (n = 13)	*Tai Chi (IG)*: 10-min warm-up, 60-min 12 movement Sun style Tai Chi, 10-min cool-down, 10–15 sets of movements *Thai yoga (AC)*: 15-min warm-up, 80-min 15 posture routine, 10-min relaxation, all postures 20 s + 3–5 repetitions	12 weeks, 2×/week, 90 min/fig session	SFT	8
Okyuan and Bilgili [42]	RCT	Older adults (44) (no age information on the individual groups)	IG (n = 20) IC (n = 24)	*Tai Chi (IG)*: 5-min warm-up, 30-min Yang style Tai Chi Chuan focusing on multidirectional weight shifting, awareness of body alignment, and multisegmental movement coordination, 5-min cool-down	12 weeks, 2×/week, 40 min/session	TBGA	5
Pereira et al. [23]	RCT	Healthy older women (77; IG: 68.0±5.0 IC: 69.0±7.0)	IG (n = 38) IC (n = 39)	*Tai Chi (IG)*: 15-min warm-up, 24-form Tai Chi Chuan Yang style, 15-min stretching, 5 repetitions/exercise	12 weeks, 3×/week, 50 min/session	Muscular strength Unipodal position test	7
de Siqueira Rodrigues [24]	RCT	Elderly females (52; 66.0±4.0)	IG (n = 27) IC (n = 25)	*Pilates (IG)*: 10-min initial stretching, 40-min general conditioning, 10-min relaxation; material: two springs 81 kg force/meter	8 weeks, 2×/week, 60 min/session	TBGA	5

Table 2 (continued)

Reference	Study design	Population (*n*; age, years (mean ± SD))	Groups (*n* per group)	Intervention in IG and AC (content, duration, load criteria, and material)	Training (duration, sessions per week, time per session)	Outcome measures	Study quality (PEDro)
Son et al. [43]	RCT	Older women (45; IG: 72.8±4.7 AC: 71.5±3.6)	IG (*n* = 21) AC (*n* = 24)	*Tai Chi (IG)*: 21-form Sun style Tai Chi *Otago (AC)*: 15-min warm-up, 20-min strength training, 15-min balance retraining, 10-min cool-down	12 weeks, 2×/week, 60 min/session	Sit-to-stand test TUG FR OLS Gait parameters	9
Sun et al. [45]	RCT	Older adults (138; IG: 68.3±5.9 IC: 70.1±5.7)	IG (*n* = 72) IC (*n* = 66)	*Tai Chi (IG)*: 24-form Yang style Tai Chi	24 weeks, 2×/week, 60 min/session	OLS 5-m high walk speed 10-m walking speed Grip strength	8
Takeshima et al. [38]	RCT	Older adults (49; IG: 72.0±5.0 IC: 73.0±6.0)	IG (*n* = 25) IC (*n* = 24)	*Tai Chi (IG)*: 10-min warm-up, 40-min Yang style Tai Chi Chuan, 10-min cool-down	12 weeks, 2×/week, 60 min/session	CoP sway Limits of stability Arm curl test Chair stand test 8-ft up and go 12-min walk test Back-scratch test Sit-and-reach test FR	4
Taylor et al. [28]	RCT	Community-dwelling older adults (684; IG: 74.4±6.2 AC: 75.3±7.0 IC: 73.7±6.2)	IG (*n* = 220) AC (*n* = 233) IC (*n* = 231)	*Tai Chi (IG)*: 2×/week (10-form Sun style) *Tai Chi (AC)*: 1×/week (10-form Sun style)	20 weeks, 2×/week (no further information)	TUG Step test Chair stand test	6
Taylor-Piliae et al. [9]	2-phase RCT	Healthy adults (132; 69.0±5.8)	IG (*n* = 37) AC (*n* = 39) IC (*n* = 56)	*Tai Chi (IG)*: warm-up/instructions, 24-form Yang style Tai Chi *Western exercise (AC)*: 8- to 10-min warm-up, 15- to 25-min endurance, 15- to 20-min strength + flexibility; material: light hand weight, rubber exercise band	24 weeks, 2×/week, 60 min/session	Single-leg stance FR Arm curl test Chair stand test Back-scratch test Sit-and-reach test	8
Tozim and Navega [25]	RCT	Older women (31; IG: 67.0 IC: 64.9)	IG (*n* = 14) IC (*n* = 17)	*Pilates (IG)*: Pilates solo method, 4 progression stages; material: ball, elastic bands	8 weeks, 2×/week, 60 min/session	Respiratory muscle strength Expiratory muscle strength	6
Wolf et al. [35]	RCT	Frail adults (311; IG: 81.0±6.4 IC: 80.8±5.9)	IG (*n* = 158) IC (*n* = 153)	*Tai Chi (IG)*: 24-form Tai Chi, 10- to 50-min Tai Chi	48 weeks, 2×/week, 60 min/session	Gait speed Chair stand test FR	9
Zhang et al. [39]	RCT	Community-dwelling elderly (49; IG: 70.2±3.6 IC: 70.6±4.9)	IG (*n* = 24) IC (*n* = 25)	*Tai Chi (IG)*: 10-min warm-up, 40-min 24-form Tai Chi Chuan, 10-min cool-down	8 weeks, 7×/week, 60 min/session	OLS Trunk flexion test 10-M walking	6
Zou et al. [26]	RCT	Female adults (61; IG: 67.9±3.2 IC: 67.4±2.9)	IG (*n* = 32) IC (*n* = 29)	*Tai Chi (IG)*: 5-min warm-up, 80-min 24-form Yang style Tai Chi, 5-min cool-down	8 weeks, 3×/week, 90 min/session	3D gait analysis Modified Thomas test	8

AC, active control group; IG, intervention group; IC, inactive control group; RCT, randomized controlled trial; CoP, center of pressure; 6MWT, 6-min walking test; BBS, Berg Balance Scale; TBGA, Tinetti Balance and Gait Assessment; TUG, Timed Up and Go Test; FAB, Fullerton Advanced Balance Scale; DGI, Dynamic Gait Index; FR, Functional Reach; SFT, Senior Fitness Test; SPPB, Short Physical Performance Battery; OLS, One-Leg Stance.

carried out. After removing duplicates, the remaining studies underwent a manual screening process. Three search levels of screening (1) title, (2) abstract, and (3) full text were applied. Irrelevant articles, which had no title at all (e.g., numbers and symbols), remaining duplicates that have not been automatically detected, pilot or preliminary studies, and reviews or surveys were consensually excluded. According to the criteria mentioned below, two independent researchers (S.A.E. and L.M.) made a consensual final inclusion or exclusion decision. If a deviation between both examiners occurred, the title was rechecked and further abstract screening was conducted.

The following inclusion criteria were applied:

- Full-text article published in English in a peer-reviewed journal.
- Randomized controlled trial (RCT) intervention study with pre-post testing.
- At least one control group that either did not receive any active physical and functional exercise-based intervention (IC) and/or received an alternative exercise-based training program (AC).
- Yoga, Tai Chi, Qi Gong, and Pilates served as target interventions.
- Studies that included healthy community-dwelling older adults without neurological, orthopedic, and/or cardiac conditions.
- Exercise intervention program focused on improvements of physical fitness indices.
- Participants were at least 65 years of age (mean age of the given study sample was considered).
- Intervention duration of at least 4 weeks and/or 2 training sessions per week, and the studies must be published after 2000 so that the current study situation can be considered.

Assessment of Methodological Quality

The methodological quality of the included RCTs was rated using the PEDro (Physiotherapy Evidence Database) scale [16]. This scale consists of 11 dichotomous items (either yes or no). The first item (indicating inclusion and exclusion criteria) is not included in the sum score. Studies were rated by two reviewers independently (S.A.E. and L.M.). After completing the evaluation, both examiners came to a consensus on every item by discussion. The raters were not blinded to study authors, place of publication, or results.

Data Extraction

Physical fitness indices were divided into the following categories (subgroups): strength (lower and upper body), static balance, functional mobility, gait, endurance, and flexibility. Data were extracted by two researchers (S.A.E. and L.M.). Data were then transferred to an excel spreadsheet. Relevant study information regarding author, year, population, number and age of participants, AC condition and IC condition, intervention design, and training conditions was extracted. All outcome measures and the PEDro score of each study were listed (see Table 2).

Statistical Analysis

Standardized mean differences (SMD, with 90% confidence intervals) were computed separately for each study. Therefore, the difference of the target outcome between the intervention and the respective IC and AC condition including the pooled standard deviations was computed for both each category and subgroup. Standard errors were transformed into standard deviations by multiplying standard errors by the square root of the sample size. Therefore, Hedges *g* adjusted for small samples has been calculated. If studies only presented means and standard deviations in figures, the corresponding authors were contacted to provide the relevant means and standard deviations. If not available, the WebPlotDigitizer Version 4 (Free Software Foundation, Boston, MA, USA) was used to extract means with standard deviations. Negative effects were symbolized with a minus sign. The Cochrane Review Manager Software (RevMan 5.3; Cochrane Collaboration, Oxford, UK) was used to compute the effect sizes using an inverse-variance approach [46] with a random-effects model [47]. Forest plots were generated for the respective outcome measures. Thereby, the magnitude of SMD was classified according to the following scale: 0–0.19 = negligible effect, 0.20–0.49 = small effect, 0.50–0.79 = moderate effect, and 0.80 = large effect [48]. To examine a potential publication bias, a funnel plot was created and qualitatively evaluated. Statistical analyses were performed using the software Cochrane Review Manager Software (RevMan 5.3; Cochrane Collaboration, Oxford, UK). A p value <0.05 was seen as statistically significant.

Results

Trial Flow

In total, 2,597 potentially relevant articles were found (see Fig. 1). After removing duplicates, 2,055 article titles remained for a careful title screening. The abstracts of the remaining 608 potentially relevant articles were thoroughly studied. One-hundred nine full texts were further perused of which 79 did not meet inclusion criteria. Thirty studies were finally included in the quantitative meta-analysis. All studies were published after 2000.

Study Population and Study Quality

2,792 healthy community dwellers with a mean age of 71.2 ± 4.7 years have been enrolled in the 30 included trials. Eleven studies included only female participants [17–26, 49]. The mean sample size was 96 ± 128 ranging from 24 [27] to 684 [28] including older participants. Trials comprised various study arms: MBIs (n = 1,177), IC condition (total number of participants, n = 1,163), and AC condition which included Pilates plus inspiratory muscle training (n = 11), traditional balance training (n = 43), low-impact exercise (n = 28), unstable support surface exercises (n = 20), traditional exercises (n = 11), Tai Yoga (n = 26), Otago exercises (n = 24), Tai Chi 1 time per week (n = 233), Western exercises (n = 39), and Huber training (n = 17). In total, we included 11 Pilates and 19 Tai Chi study interventions. All studies applied a standard randomization procedure for group assignment. Seven out of the 30 studies used a 3-armed

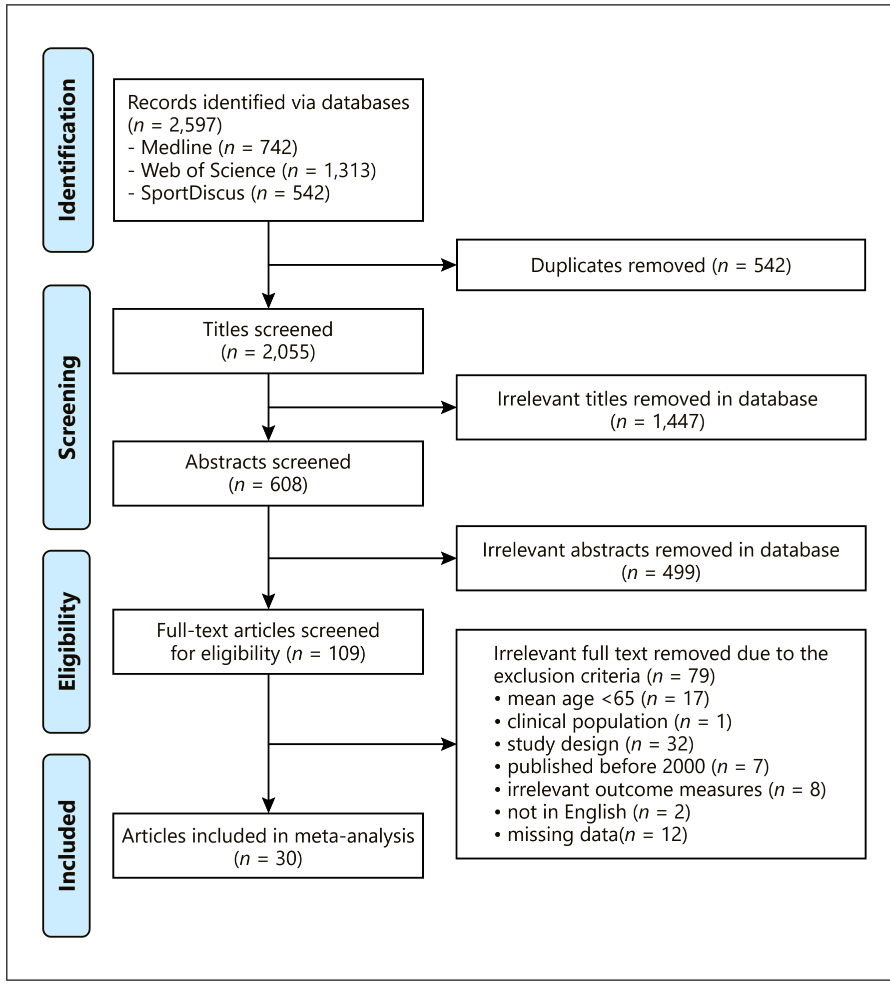

Fig. 1. Flow of study screening and selection due to inclusion criteria.

design [9, 18, 28–32]. The study quality (PEDro score) ranged from 3 [20] to 9 [17, 33–35, 49] (see Table 3). Thirteen studies blinded the testing personnel [9, 17, 22, 27, 28, 32–37, 49]. Five studies with a PEDro score between 3 and 7 did not report inclusion and exclusion criteria [19, 20, 22, 38, 39]. Training intervention duration ranged from 8 [19, 20, 22, 25, 26, 29, 33, 39] to 48 weeks [35], with most interventions lasting 8 or 12 weeks [17, 19–27, 29–33, 36, 38–41, 49] (n = 22). Training frequencies varied between 2 and 7 times per week. More than half of the trials used a training frequency of 2 times per week (n = 21). Training session duration was between 30 and 90 min. Roughly, half of the trials conducted a 60-min workout (n = 17). When Tai Chi was indicated, Tai Chi Chuan, Sun style, and Yang style were subsumed under the umbrella term "Tai Chi" [23, 26, 32, 33, 38, 39, 42, 49].

Risk of Bias Assessment

The majority of the comparisons did not reveal a clear or trending funnel shape (see Fig. 2, 3) indicating that small and large studies with different effect and sample sizes are missing among all trials and outcomes. Thus, a tendency of publication bias can be assumed across the majority of all computed comparisons. Only balance, functional mobility, and endurance depict a slight funnel shape for the IC comparison (Fig. 2b, c, e) and strength, balance, and functional mobility in the AC comparison (Fig. 3a–c). Moreover, few data points are available in the majority of the AC comparisons.

Data Analysis of MBI versus IC

MBI versus IC for Upper and Lower Body Strength

Highly significant and large overall effects were observed for total strength (p = 0.001, SMD: 0.87 [90% CI: 0.43, 1.30], I^2 = 94%; Fig. 4). A moderate to large and sig-

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Table 3. PEDro criteria and sum scores of the included studies [9, 17–45]

Author	Eligibility specified	Subjects randomly allocated	Concealed allocation	Similar baseline values	Blinding of subjects	Blinding of therapist	Blinding of assessor	Dropout <15%	Received treatment as allocated	Statistical between-group comparison	Point measures and variability provided	Sum (2–11)
Almazán et al. [17]	√	√	–	√	√	√	√	–	√	√	√	**9**
Alvarenga et al. [18]	√	√	–	–	–	–	–	–	√	√	√	**5**
Donath et al. [29]	√	√	√	√	√	–	–	–	√	√	√	**8**
Fourie et al. [19]	–	√	√	√	–	–	–	–	√	√	√	**6**
Fourie et al. [20]	–	√	√	–	–	–	–	–	√	–	–	**3**
Frye et al. [30]	√	√	–	√	–	–	–	√	√	√	√	**7**
Gabizon et al. [36]	√	√	√	–	–	–	√	√	√	–	√	**7**
Hosseini et al. [33]	√	√	√	√	–	–	√	√	√	√	√	**9**
Hyun et al. [21]	√	√	–	–	–	–	–	–	√	√	√	**5**
Josephs et al. [27]	√	√	√	–	–	–	√	–	√	√	√	**7**
Lelard et al. [41]	√	√	–	√	–	–	–	–	√	√	√	**6**
Li et al. [34]	√	√	√	√	–	–	√	√	√	√	√	**9**
Lin et al. [37]	√	√	–	√	––	–	√	–	√	√	√	**7**
Manor et al. [40]	√	√	–	√	–	–	√	√	√	√	√	**8**
Markovic et al. [22]	–	√	√	–	–	–	√	√	√	√	√	**7**
Nguyen et al. [44]	√	√	–	√	–	–	–	–	√	√	√	**6**
Ni et al. [31]	√	√	–	√	–	–	–	–	√	√	√	**6**
Noradechanunt et al. [32]	√	√	√	√	–	–	√	–	√	√	√	**8**
Okuyan and Bilgili [42]	√	√	–	–	–	–	–	–	√	√	√	**5**
Pereira et al. [23]	√	√	–	√	–	–	–	√	√	√	√	**7**
de Siqueira Rodrigues [24]	√	√	–	–	–	–	–	–	√	√	√	**5**
Son et al. [43]	√	√	√	√	–	–	√	√	√	√	√	**9**
Sun et al. [45]	√	√	√	√	–	–	–	√	√	√	√	**8**
Takeshima et al. [38]	–	√	–	–	–	–	-	–	√	√	√	**4**
Taylor et al. [28]	√	√	–	–	–	–	√	–	√	√	√	**6**
Taylor-Piliae et al. [9]	√	√	–	√	–	–	√	√	√	√	√	**8**
Tozim and Navega [25]	√	√	–	√	–	–	–	–	√	√	√	**6**
Wolf et al. [35]	√	√	√	√	–	–	√	√	√	√	√	**9**
Zhang et al. [39]	–	√	–	√	–	–	–	√	√	√	√	**6**
Zou et al. [26]	√	√	√	√	–	–	–	√	√	√	√	**8**

The sum of the PEDro Score for each study is highlighted in bold.

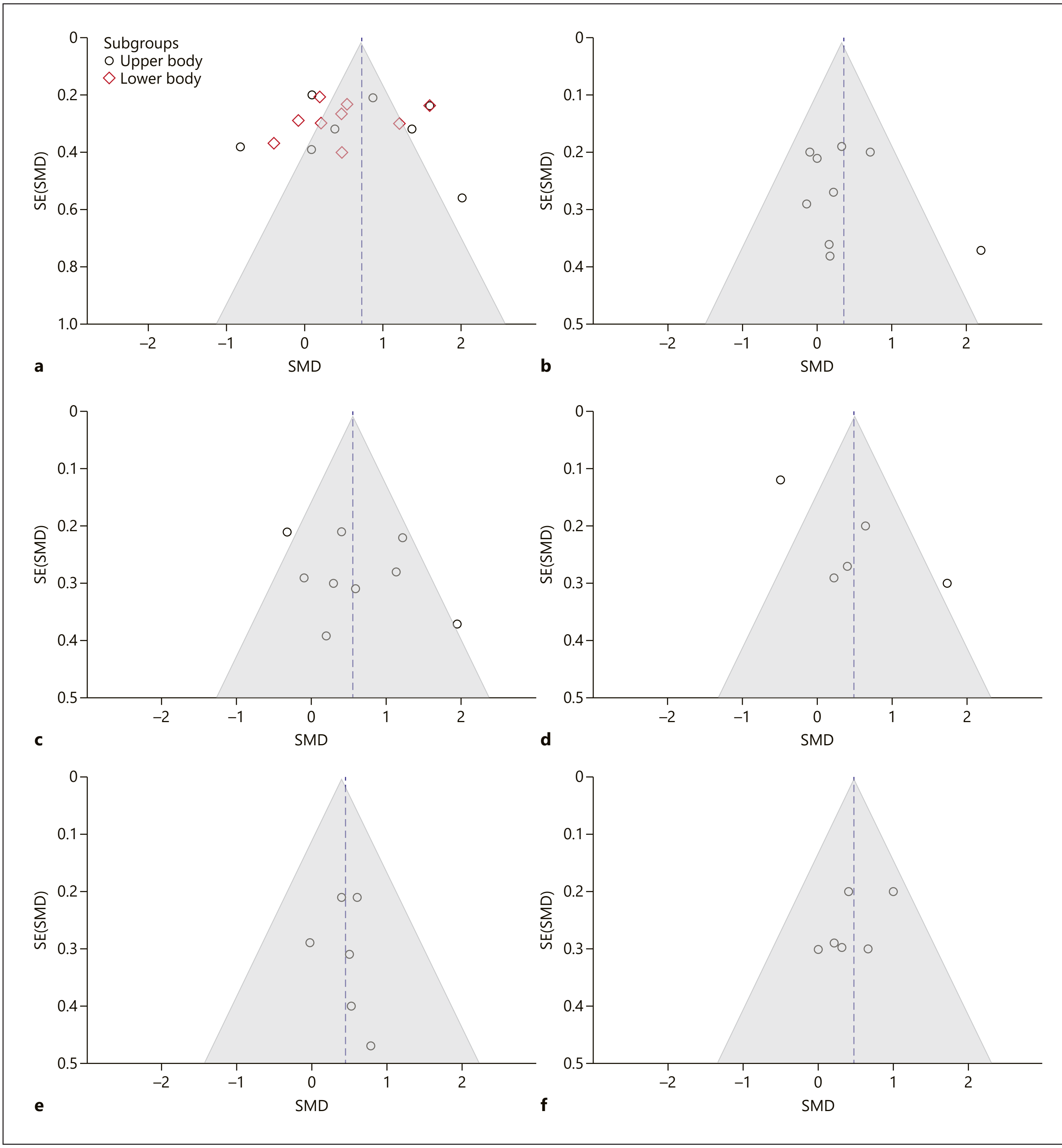

Fig. 2. Funnel plot for publication bias assessment for MBI versus IC: upper and lower body strength (**a**); static balance (**b**); functional mobility (**c**); gait (**d**); endurance (**e**); and flexibility (**f**). The dashed line indicates the mean SMD. MBI, mind-body intervention; IC, inactive control; SE, standard error; SMD, standardized mean difference.

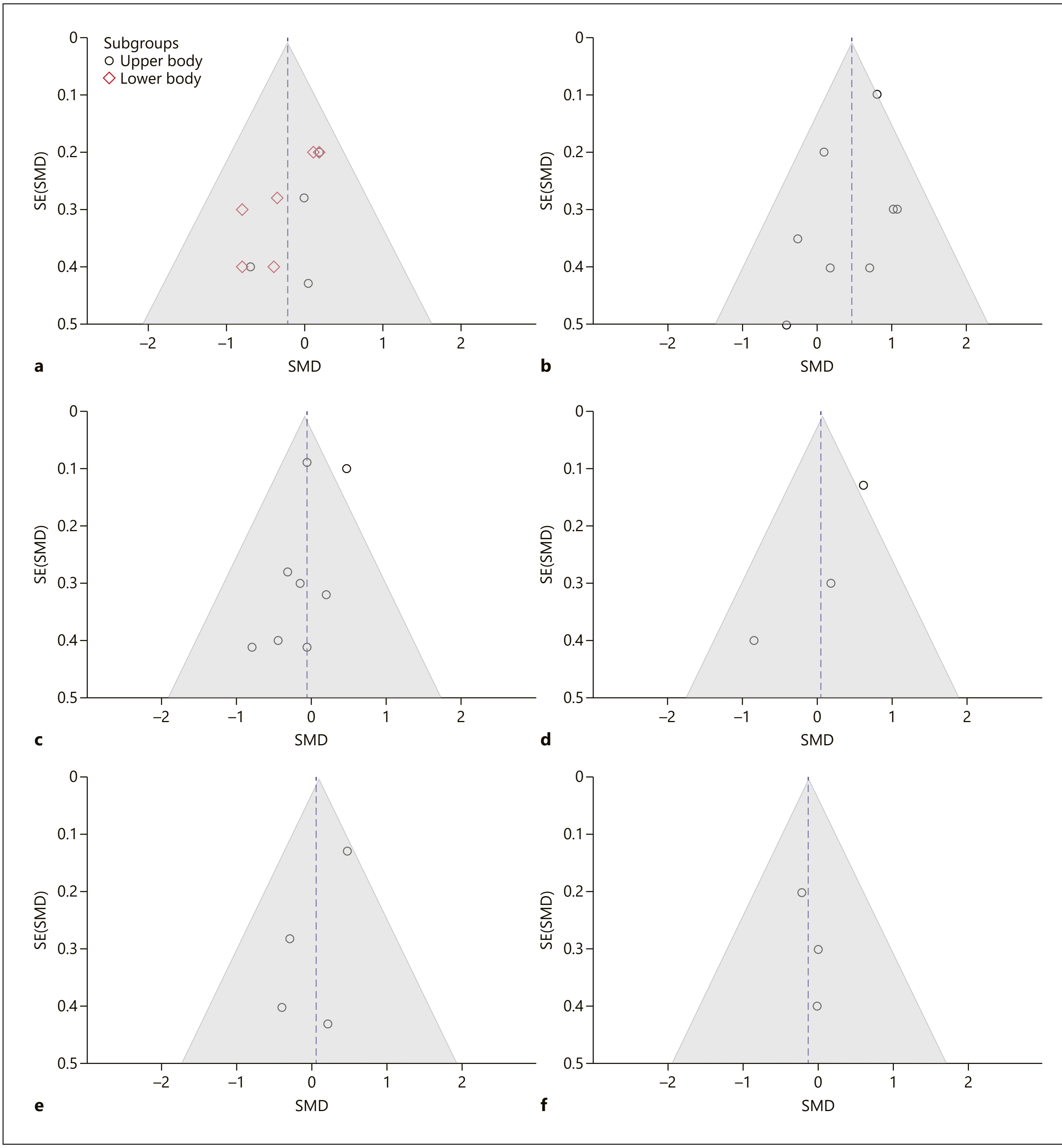

Fig. 3. Funnel plot for publication bias assessment for MBI versus AC: upper and lower body strength (**a**); static balance (**b**); functional mobility (**c**); gait (**d**); endurance (**e**); and flexibility (**f**).The dashed line indicates the mean SMD. MBI, mind-body intervention; AC, active control; SE, standard error; SMD, standardized mean difference.

Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
1.1.1 Upper Body				
Alvarenga et al., 2018	2.01	0.56	4.9	2.01 [1.09, 2.93]
Fourie et al., 2012	1.37	0.32	5.8	1.37 [0.84, 1.90]
Frye et al., 2007	0.21	0.3	5.9	0.21 [–0.28, 0.70]
Lin et al., 2015	0.87	0.21	6.1	0.87 [0.52, 1.22]
Nguyen et al., 2012	1.60	0.24	6.1	1.60 [1.21, 1.99]
Noradechanunt et al., 2017	0.09	0.39	5.6	0.09 [–0.55, 0.73]
Sun et al., 2015	0.10	0.2	6.1	0.10 [–0.23, 0.43]
Tozim et al., 2018	0.38	0.32	5.8	0.38 [–0.15, 0.91]
Subtotal (90% CI)			46.4	0.79 [0.39, 1.19]
Heterogeneity: $\tau^2 = 0.37$, $\chi^2 = 39.62$, df = 7 ($p < 0.00001$); $I^2 = 82\%$				
Test for overall effect: $Z = 3.24$ ($p = 0.001$)				
1.1.2 Lower Body				
Fourie et al., 2012	1.20	0.3	5.9	1.20 [0.71, 1.69]
Frye et al., 2007	0.21	0.3	5.9	0.21 [–0.28, 0.70]
Lin et al., 2015	0.19	0.21	6.1	0.19 [–0.16, 0.54]
Manor et al., 2014	0.47	0.27	6.0	0.47 [0.03, 0.91]
Nguyen et al., 2012	1.60	0.24	6.1	1.60 [1.21, 1.99]
Noradechanunt et al., 2017	0.47	0.4	5.6	0.47 [–0.19, 1.13]
Pereira et al., 2008	0.54	0.23	6.1	0.54 [0.16, 0.92]
Tozim et al., 2018	–0.08	0.29	5.9	–0.08 [–0.56, 0.40]
Wolfet al., 2006	3.55	0.2	6.1	3.55 [3.22, 3.88]
Subtotal (90% CI)			53.6	0.91 [0.18, 1.64]
Heterogeneity: $\tau^2 = 1.70$, $\chi^2 = 212.42$, df = 8 ($p < 0.00001$); $I^2 = 96\%$				
Test for overall effect: $Z = 2.06$ ($p = 0.04$)				
Total (90% CI)			**100.0**	**0.87 [0.43, 1.30]**
Heterogeneity: $\tau^2 = 1.09$, $\chi^2 = 261.57$, df = 16 ($p < 0.00001$); $I^2 = 94\%$				
Test for overall effect: $Z = 3.30$ ($p = 0.0010$)				
Test for subgroup differences: $\chi^2 = 0.06$, df = 1 ($p = 0.80$); $I^2 = 0\%$				

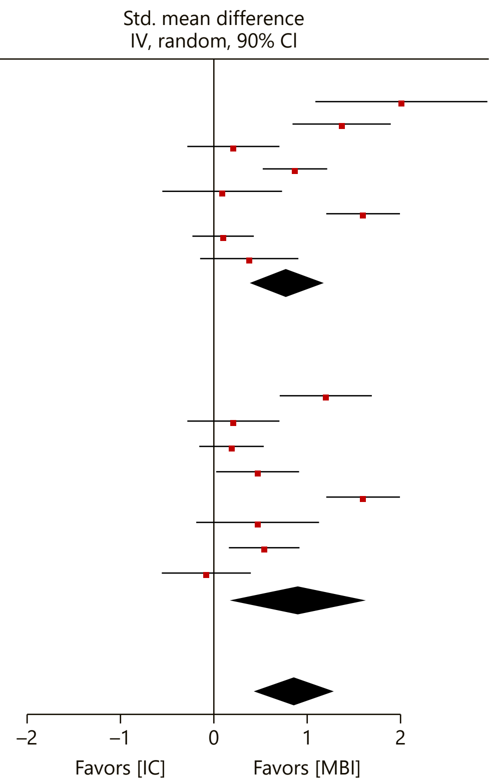

Fig. 4. Forest plot of the analysis for MBI versus IC for upper and lower body strength performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
Almazan et al., 2019	0.33	0.19	12.4	0.33 [0.02, 0.64]
Donath et al., 2015	0.16	0.36	8.5	0.16 [–0.43, 0.75]
Cabizon et al., 2016	–0.01	0.21	11.9	–0.01 [–0.36, 0.34]
Manor et al., 2014	0.22	0.27	10.5	0.22 [–0.22, 0.66]
Pereira et al., 2008	0.70	0.20	12.1	0.70 [0.37, 1.03]
Sun et al., 2015	–0.10	0.20	12.1	–0.10 [–0.43, 0.23]
Takeshima et al., 2017	–0.14	0.29	10.1	–0.14 [–0.62, 0.34]
Wolf et al., 2006	0.36	0.11	14.0	0.36 [0.18, 0.54]
Zhang et al., 2006	2.19	0.37	8.3	2.19 [1.58, 2.80]
Total (90% CI)			**100.0**	**0.37 [0.10, 0.63]**
Heterogeneity: $\tau^2 = 0.17$, $\chi^2 = 39.02$, df = 8 ($p < 0.00001$); $I^2 = 79\%$				
Test for overall effect: $Z = 2.29$ ($p = 0.02$)				

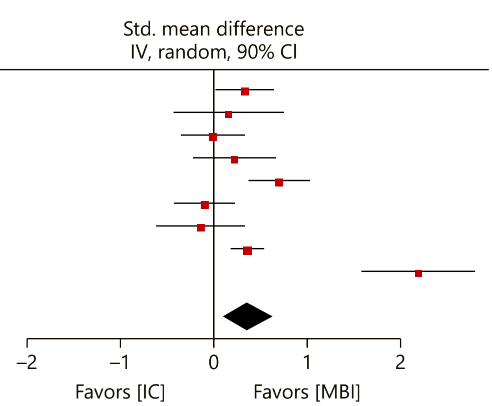

Fig. 5. Forest plot of the analysis for MBI versus IC for static balance performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

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Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
Frye et al., 2007	0.59	0.31	9.7	0.59 [0.08, 1.10]
Gabizon et al., 2016	–0.33	0.21	11.0	–0.33 [–0.68, 0.02]
Hosseini et al., 2018	1.13	0.28	10.1	1.13 [0.67, 1.59]
Lin et al., 2015	0.40	0.21	11.0	0.40 [0.05, 0.75]
Manor et al., 2014	0.29	0.30	9.9	0.29 [–0.20, 0.78]
Nguyen et al., 2012	1.21	0.22	10.9	1.21 [0.85, 1.57]
Noradechanunt et al., 2017	0.19	0.39	8.7	0.19 [–0.45, 0.83]
Okuyan et al., 2017	1.94	0.37	8.9	1.94 [1.33, 2.55]
Rodrigues et al., 2010	0.30	0.30	9.9	0.30 [–0.19, 0.79]
Takeshima et al., 2017	–0.10	0.29	10.0	–0.10 [–0.58, 0.38]
Total (90% CI)			**100.0**	**0.55 [0.20, 0.89]**

Heterogeneity: $\tau^2 = 0.36$, $\chi^2 = 52.40$, df = 9 ($p < 0.00001$); $I^2 = 83\%$
Test for overall effect: $Z = 2.61$ ($p = 0.009$)

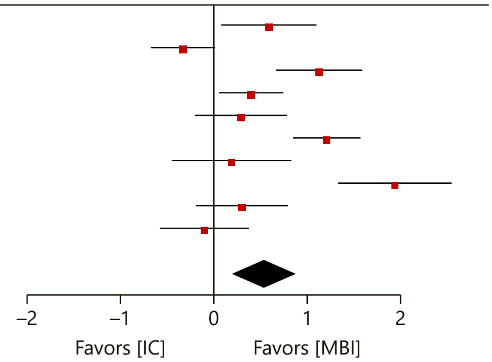

Fig. 6. Forest plot of the analysis on MBI versus IC for functional mobility performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
Manor et al., 2014	0.39	0.27	19.6	0.39 [–0.05, 0.83]
Sun et al., 2015	0.64	0.20	20.5	0.64 [0.31, 0.97]
Wolf et al., 2006	–0.5	0.12	21.3	–0.50 [–0.70, –0.30]
Zhang et al., 2006	0.21	0.29	19.3	0.21 [–0.27, 0.69]
Zou et al., 2017	1.72	0.03	19.2	1.72 [1.23, 2.21]
Total (90% CI)			**100.0**	**0.47 [–0.16, 1.10]**

Heterogeneity: $\tau^2 = 0.68$, $\chi^2 = 62.57$, df = 4 ($p < 0.00001$); $I^2 = 94\%$
Test for overall effect: $Z = 1.23$ ($p = 0.22$)

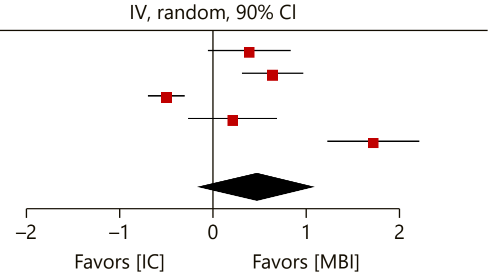

Fig. 7. Forest plot of the analysis on MBI versus IC for gait performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
Alvarenga et al., 2018	0.78	0.47	5.8	0.78 [0.01, 1.55]
Frye et al., 2007	0.51	0.31	13.3	0.51 [0.00, 1.02]
Lin et al., 2015	0.38	0.21	28.9	0.38 [0.03, 0.73]
Nguyen et al., 2012	0.61	0.21	28.9	0.61 [0.26, 0.96]
Noradechanunt et al., 2017	0.52	0.40	8.0	0.52 [–0.14, 1.18]
Takeshima et al., 2017	–0.02	0.29	15.2	–0.02 [–0.50, 0.46]
Total (90% CI)			**100.0**	**0.44 [0.25, 0.62]**

Heterogeneity: $\tau^2 = 0.00$, $\chi^2 = 3.87$, df = 5 ($p = 0.57$); $I^2 = 0\%$
Test for overall effect: $Z = 3.87$ ($p = 0.0001$)

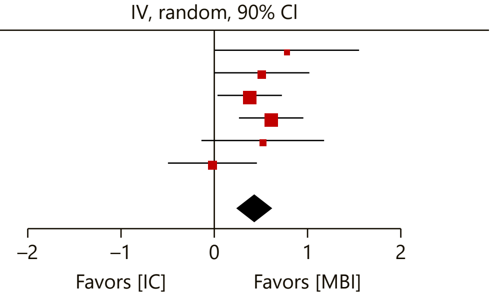

Fig. 8. Forest plot of the analysis on MBI versus IC for endurance performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

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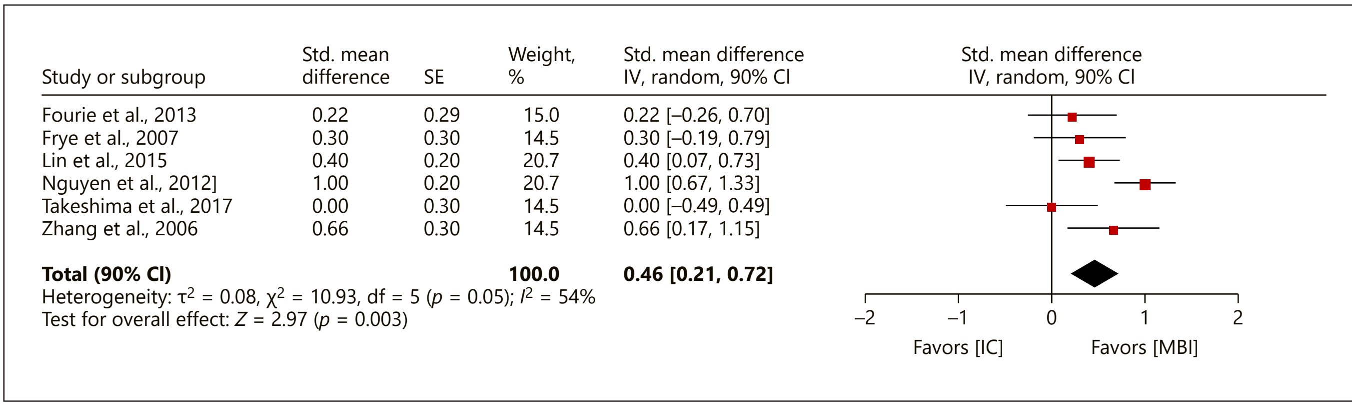

Fig. 9. Forest plot of the analysis on MBI versus IC for flexibility performance. MBI, mind-body intervention; IC, inactive control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

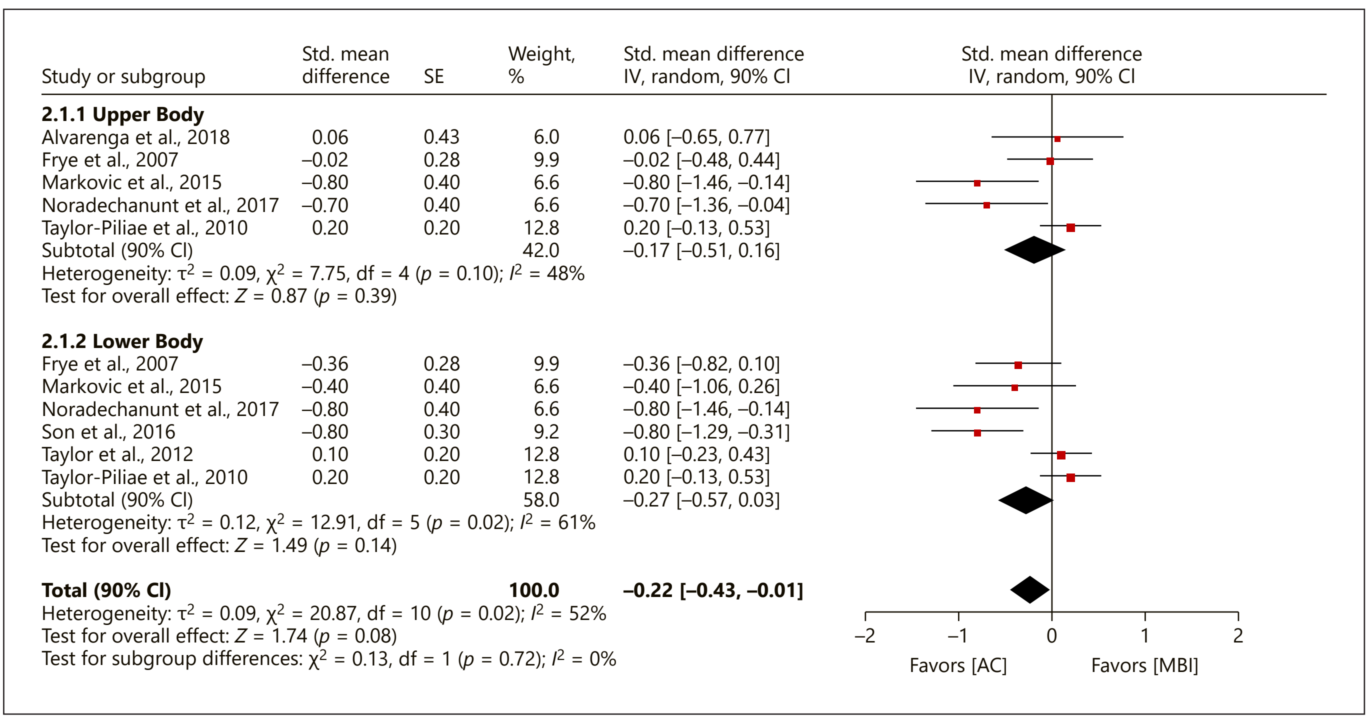

Fig. 10. Forest plot of the analysis on MBI versus AC for upper and lower strength performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

nificant effect was found for upper body strength (p = 0.001, SMD: 0.79 [90% CI: 0.39, 1.19], I^2 = 82%; Fig. 4) in favor of MBI compared to IC. With respect to lower body strength, a large and significant effect (p = 0.04, SMD: 0.91 [90% CI: 0.18, 1.64], I^2 = 96%; Fig. 4) in favor of MBI compared to IC was observed.

MBI versus IC for Static Balance

Small overall but significant effects with comparatively narrow confidence limits but large heterogeneity were found for static balance performance (p = 0.02, SMD: 0.37 [90% CI: 0.10, 0.63], I^2 = 79%; Fig. 5) in favor of MBI compared to IC.

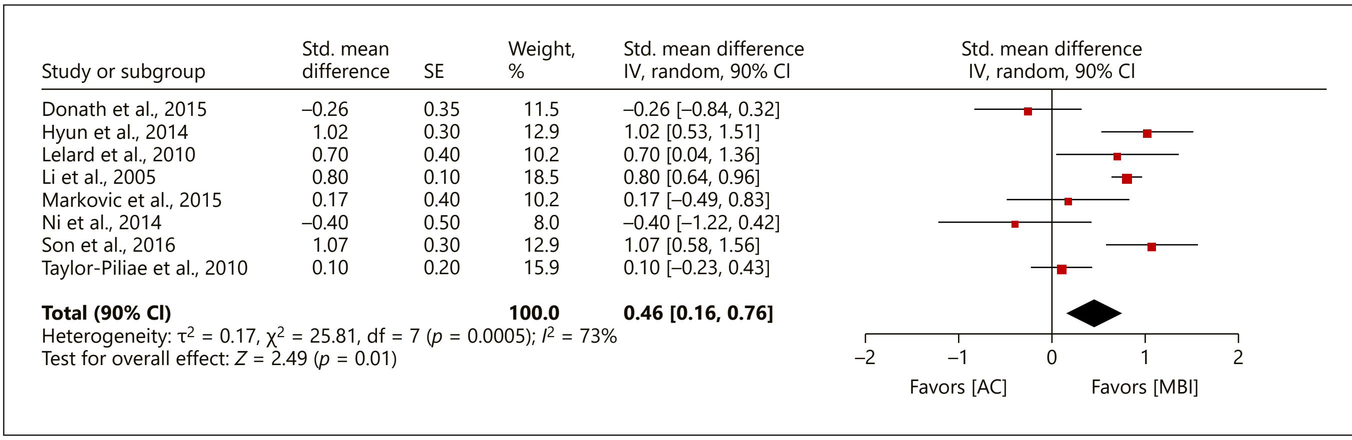

Fig. 11. Forest plot of the analysis on MBI versus AC for static balance performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

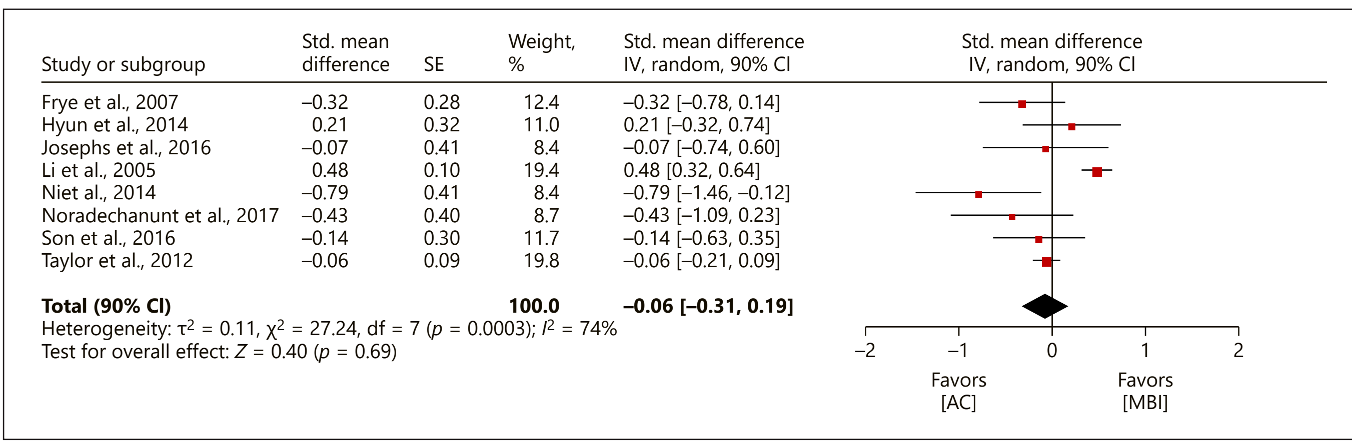

Fig. 12. Forest plot of the analysis on MBI versus AC for functional mobility performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

MBI versus IC for Functional Mobility

Moderate and significant overall effects with narrow confidence limits and large heterogeneity were observed for functional mobility (p = 0.009, SMD: 0.55 [90% CI: 0.20, 0.89], I^2 = 83%; Fig. 6) in favor of MBI compared to IC.

MBI versus IC for Gait

With very large heterogeneity, moderate but insignificant effects were found for gait performance (p = 0.22, Fig. 7) favoring MBI compared to IC.

MBI versus IC for Endurance

Small to moderate but significant and very homogenous overall effects with narrow confidence limits were found for endurance performance (p < 0.001, SMD: 0.44 [90% CI: 0.25, 0.62], I^2 = 0%; Fig. 8) in favor of MBI compared to IC.

MBI versus IC for Flexibility

Relevantly small to moderate and mildly heterogeneous overall effects with narrow confidence limits were found for flexibility performance (p = 0.003, SMD: 0.46 [90% CI: 0.21, 0.72], I^2 = 54%; Fig. 9) in favor of MBI compared to IC.

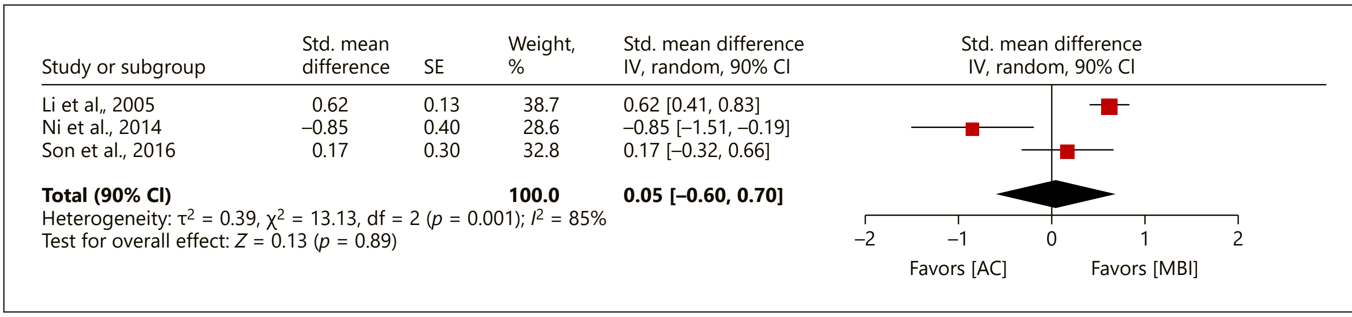

Fig. 13. Forest plot of the analysis on MBI versus AC for gait performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

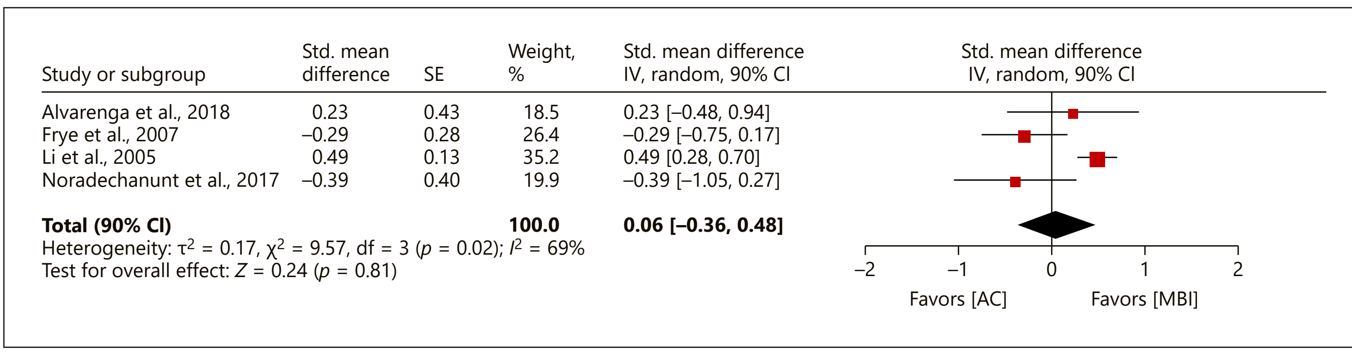

Fig. 14. Forest plot of the analysis on MBI versus AC for endurance performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

Data Analysis of MBI versus AC

MBI versus AC for Upper and Lower Body Strength

The overall effect relevantly favored AC at borderline significance level with, however, trivial effect sizes. Trivial and insignificant effects with acceptable heterogeneity were found for the upper body and lower body strength performance indices ($p = 0.08$, Fig. 10) favoring AC compared to MBI.

MBI versus AC for Static Balance

Small to moderate but significant overall effects with narrow confidence limits and moderate to large heterogeneity were observed for static balance performance ($p = 0.01$, SMD: 0.46 [90% CI: 0.16, 0.76], $I^2 = 73\%$; Fig. 11) in favor of MBI compared to AC.

MBI versus AC for Functional Mobility

No effects in favor of either training arm with large heterogeneity were found for functional mobility performance ($p = 0.69$, Fig. 12).

MBI versus AC for Gait

No effects in favor of either training condition were found for gait performance ($p = 0.89$, Fig. 13). Large underlying heterogeneity was observed.

MBI versus AC for Endurance

No effects were found for endurance performance ($p = 0.81$, Fig. 14).

MBI versus AC for Flexibility

No effects were found for flexibility performance ($p = 0.85$, Fig. 15).

Discussion

This is the first meta-analytical review that comparatively investigated the effects of movement-based MBIs compared to both AC and IC conditions on different dimensions of physical functioning in healthy community-

Study or subgroup	Std. mean difference	SE	Weight, %	Std. mean difference IV, random, 90% CI
Frye et al., 2007	0	0.3	26.2	0.00 [–0.49, 0.49]
Noradechanunt et al., 2017	–0.01	0.4	14.8	–0.01 [–0.67, 0.65]
Taylor-Piliae et al., 2010	–0.22	0.2	59.0	–0.22 [–0.55, 0.11]
Total (90% CI)			**100.0**	**–0.13 [–0.38, 0.12]**

Heterogeneity: $\tau^2 = 0.00$, $\chi^2 = 0.48$, df = 2 ($p = 0.79$); $I^2 = 0\%$
Test for overall effect: $Z = 0.85$ ($p = 0.39$)

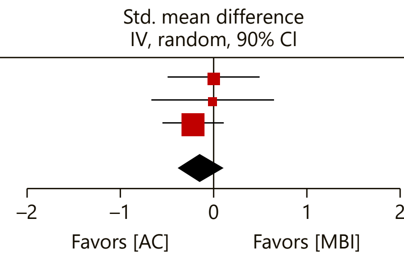

Fig. 15. Forest plot of the analysis on MBI versus AC for flexibility performance. MBI, mind-body intervention; AC, active control; SE, standard error; IV, independent variable; CI, confidence interval; SMD, standardized mean difference.

dwelling older adults. This review mainly provides the evaluation of two different forms of MBIs (Pilates and Tai Chi) as only these studies met the inclusion criteria. Our meta-analytical review revealed pronounced effects in favor of MBIs for upper and lower body strength, static balance, functional mobility, endurance, and flexibility compared to the ICs and for static balance compared to the ACs. Only regarding strength indices, the AC conditions were slightly favored compared to MBI. Compared to being inactive, it can be concluded that MBIs can be regarded as a multimodal, time-saving, integrative, and functional training strategy that trains relevant domains of physical functioning such as strength, balance, mobility, endurance, or flexibility.

MBI versus IC

Significantly small to large overall effects in favor of MBI for the majority of major physical fitness components, such as upper and lower body strength, static balance, functional mobility, endurance, and flexibility, have been observed. Performance improvements of upper and lower body strength in favor of MBI are plausible as exercise-based MBIs include various movement patterns that require adequate lower and upper body strength levels [50]. These findings are in line with previous studies on multimodal resistance training compared to IC conditions [51, 52]. Static balance performance showed only small overall effects compared to moderate strength performance effects. This finding seems reasonable as balance training adaptations are considered highly task specific, and mere static balance tasks are not well targeted and reflected in MBI approaches [53]. In contrast to that, a previous meta-analysis showed that MBIs with a main focus on Pilates can reveal positive effects on static balance in older subjects, when balance is incorporated, and seniors have less initial balance performance [54]. Two further meta-analyses revealed positive effects on static balance performance following Tai Chi interventions [43, 55], which comprise a variety of different static balance conditions. Functional mobility performance showed overall moderate effects with large effects in some selected studies. Thus, MBI has a huge potential to improve functional mobility performance. In this regard, the multimodal character of MBIs proves to be useful and beneficial to elicit relevant improvement of health-related physical domains in general and strength and functional mobility in particular. It seems furthermore reasonable to assume that an increase in lower body strength supports the effects on functional mobility. This assumption is underpinned by findings of a study conducted by Chen et al. [56]. Although MBIs are not primarily designed for improvements in endurance performance, we found at least small but relevant effects in our meta-analysis. These relevant endurance effects can already be with low-impact exercises, as already shown by Hopkins and colleagues [57]. In our meta-analysis, flexibility performance has also slightly benefitted from MBI and showed small but meaningful overall effects in favor of MBI. As Pilates training reflects stretching components [58], this finding can be attributed to the task-specific application of some Pilates exercises [13, 59]. This also applies for Tai Chi: besides the postural aspects when performing different poses or during a change between poses, large functional strength and flexibility components are considered. Accordingly, the targeted tensing of muscles and relaxing, the control of the target muscles, and the correct alignment of body segments seem crucial [60]. Therefore, it is assumed that especially the task-specific components in the Pilates interventions [13] and the flowing changes between different move-

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ments and poses of Tai Chi exercises [41, 61] mainly account for the positive effects on flexibility. Gait performance was not affected, as gait is considered a robust pattern [62] that less likely benefits from MBI. A recent study showed that either a multicomponent training program or interval-walking training can improve gait parameters over a short time (Two weeks). These results also indicate that the type of training is essential in terms of intended adaptations [63]. Accordingly, the lack of gait adaptations can be at least partly explained by the fact that Pilates and Tai Chi are less gait-specific training approaches. Overall, MBIs provide multimodal neuromuscular and cardiocirculatory training stimuli that improve the majority of health-related physical fitness parameters. Therefore, MBI serves as a less time-consuming training approach in older adults that covers a wide spectrum of training adaptations.

MBI versus AC

For MBI versus an AC condition, only static balance performance showed small overall beneficial effects in favor of MBI. In contrast, trivial overall effects in favor of the AC condition for upper and lower body strength were observed. No effects have been found in either direction for functional mobility, gait, endurance, and flexibility performance. Thus, no clear direction of an adaptation of the physical domains can be observed. This finding is mainly due to the large heterogeneity of the AC conditions reflecting a broad range of different task-related exercise contents. A further explanation could be that Tai Chi and Pilates entail a higher proportion of task-specific exercises, and thus neuromuscular adaptations were at least slightly higher than in the AC groups [64]. The lack of effects on upper and lower body strength, functional mobility, gait, endurance, and flexibility can mainly be explained by the fact that the AC conditions partly contained those components [64].

Strengths and Limitations

The reporting of this systematic meta-analytical review was conducted according to the PRISMA statement [15]. This is the first meta-analysis that provides pooled effect sizes of different MBI approaches in comparison with both AC and IC conditions in healthy community-dwelling older adults. Despite notable heterogeneity of the underlying studies in terms of sample sizes, study characteristics, training intensity, duration, and diverse alternative exercise programs, our meta-analyses provides a comprehensive, structured, and quantitative view on current scientific evidence on the effects of multimodal MBI (mainly Pilates and Tai Chi) on a variety of physical fitness measures, such as strength, gait, static balance, functional mobility, endurance, and flexibility outcomes. The 30 included studies with nearly 3,000 participants build a solid and valid data pool for robust conclusions on overall and subgroup level. However, the AC programs present notable heterogeneity with some overlap to certain components of MBIs. Nevertheless, AC conditions did never meet the criteria for being categorized as MBI by our underlying definition. Therefore, it would be interesting for future reviews or studies to focus on specific assessment tests and to ensure the quality and homogeneity of the results. Due to several lacking explanations of the interventions, it was not always possible to determine which form of Tai Chi training was involved. Therefore, it was not possible to make a statement about which form might be more effective for healthy, older adults. This was also the case in some explanations of the Pilates exercises. It can be assumed that the Pilates interventions included task-specific exercises that affected various target parameters.

Conclusion

MBI can serve as an integrative and multimodal training approach for the improvement of several physical fitness domains in older adults. This holds particularly true for Tai Chi and Pilates. Compared to traditional exercise recommendations for older adults that separately propose strength, balance, endurance, and flexibility, MBI might be employed as a time-saving functional training alternative. Gait and static balance should thereby be specifically tackled as those aspects are underrepresented in MBI approaches. However, the applied training modalities showed a wide range of variability which made it difficult to deliver consistent and valid training recommendations, particularly when compared to alternative training programs. Furthermore, high variability and heterogeneity of the test and training procedure impede reliable conclusions on the content, volume, and intensity of potentially superior MBI or alternative training approaches when the training parameters notably differ between studies. Future studies should therefore provide more information and data on the exact training purpose, intensity, volume, and mode of exercises. This information would facilitate a valid comparison or meta-regression in which intensity and volume could be further investigated as modulators of the occurrence and magnitude of specific training effects.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

L.D., S.A.E. and L.M. developed the theoretical formalism, performed the analytic calculations, and performed the numerical simulations. M.M., S.H., T.M., and L.D. contributed to the final version of the manuscript. L.D. supervised the project.

References

1 Lutz W, Sanderson W, Scherbov S. The coming acceleration of global population ageing. Nature. 2008;451(7179):716–9.
2 Spirduso WW, Francis KL, MacRae PG. Physical dimensions of aging. 2nd ed. Champaign, IL: Human Kinetics; 2005.
3 Katigbak C, Maglalang DD, Nguyen T, Wang M, Lo L-C. Older Chinese Americans' perspectives on physical activity: a mixed methods study. J Appl Gerontol. 2020 May;39(5): 472–80.
4 Cancela JM, de Oliveira IM, Rodríguez-Fuentes G. Effects of Pilates method in physical fitness on older adults. A systematic review. Eur Rev Aging Phys Act. 2014;11(2):81–94.
5 Lee E-KO, Yoon H, Lee J, Yoon J, Chang E. Body-mind-spirit practice for healthy aging. Educ Gerontol. 2012;38(7):473–85.
6 Hall DL, Luberto CM, Philpotts LL, Song R, Park ER, Yeh GY. Mind-body interventions for fear of cancer recurrence: a systematic review and meta-analysis. Psychooncology. 2018;27(11):2546–58.
7 Farhang M, Miranda-Castillo C, Rubio M, Furtado G. Impact of mind-body interventions in older adults with mild cognitive impairment: a systematic review. Int Psychogeriatr. 2019;31(5):643–66.
8 Suárez-Iglesias D, Miller KJ, Seijo-Martínez M, Ayán C. Benefits of Pilates in Parkinson's disease: a systematic review and meta-analysis. Medicina. 2019;55:476.
9 Taylor-Piliae RE, Newell KA, Cherin R, Lee MJ, King AC, Haskell WL. Effects of Tai Chi and Western exercise on physical and cognitive functioning in healthy community-dwelling older adults. J Aging Phys Act. 2010; 18(3):261–79.
10 Jahnke R, Larkey L, Rogers C, Etnier J, Lin F. A comprehensive review of health benefits of qigong and tai chi. Am J Health Promot. 2010; 24(6):e1–25.
11 Chen KM, Tseng WS, Ting LF, Huang GF. Development and evaluation of a yoga exercise programme for older adults. J Adv Nurs. 2007;57(4):432–41.
12 Pucci GCMF, Neves EB, Saavedra FJF. Effect of Pilates method on physical fitness related to health in the elderly: a systematic review. Rev Bras Med Esporte. 2019;25(1):76–87.
13 Wells C, Kolt GS, Bialocerkowski A. Defining Pilates exercise: a systematic review. Complement Ther Med. 2012;20(4):253–62.
14 Sekendiz B, Altun Ö, Korkusuz F, Akın S. Effects of Pilates exercise on trunk strength, endurance and flexibility in sedentary adult females. J Bodyw Mov Ther. 2007;11(4):318–26.
15 Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Ann Intern Med. 2015; 162(11):777.
16 Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003;83(8):713–21.
17 Aibar-Almazán A, Martínez-Amat A, Cruz-Díaz D, De la Torre-Cruz MJ, Jiménez-García JD, Zagalaz-Anula N, et al. Effects of Pilates on fall risk factors in community-dwelling elderly women: a randomized, controlled trial. Eur J Sport Sci. 2019;19(10):1386–94.
18 Alvarenga G, Charkovski S, Santos L, da Silva M, Tomaz G, Gamba H, et al. The influence of inspiratory muscle training combined with the Pilates method on lung function in elderly women: a randomized controlled trial. Clinics. 2018;73:e356.
19 Fourie M, Gildenhuys GM, Shaw I, Shaw BS, Toriola AL, Goon DT. Effects of a mat Pilates programme on muscular strength and endurance in elderly women. Afr J Phys Health Educ Recreat Dance. 2012;18:296–304.
20 Fourie M, Gildenhuys GM, Shaw I, Shaw BS, Toriola AL, Goon DT. Effects of a mat Pilates program on flexibility in elderly woman. Med Sport Riv Fisiopatol Sport. 2013;66: 545–53.
21 Hyun J, Hwangbo K, Lee CW. The effects of Pilates mat exercise on the balance ability of elderly females. J Phys Ther Sci. 2014;26(2): 291–3.
22 Markovic G, Sarabon N, Greblo Z, Krizanic V. Effects of feedback-based balance and core resistance training vs. Pilates training on balance and muscle function in older women: a randomized-controlled trial. Arch Gerontol Geriatr. 2015;61(2):117–23.
23 Pereira MD, Oliveira R, Silva M, Souza L, Vianna L. Effects of Tai Chi Chuan on knee extensor muscle strength and balance in elderly women. Braz J Phys Ther. 2008;12:121–6.
24 de Siqueira Rodrigues BG, Ali Cader S, Bento Torres NVO, de Oliveira EM, Martin Dantas EH. Pilates method in personal autonomy, static balance and quality of life of elderly females. J Bodyw Mov Ther. 2010;14:195–202.
25 Tozim BM, Navega MT. Efeito do método pilates na força dos músculos inspiratórios e expiratórios em idosos. Rev Bras Cineantropom Desempenho Hum. 2018;20(1):1–9.
26 Zou L, Wang C, Tian Z, Wang H, Shu Y. Effect of Yang-style Tai Chi on gait parameters and musculoskeletal flexibility in healthy Chinese older women. Sports. 2017;5(3):52.
27 Josephs S, Pratt ML, Calk Meadows E, Thurmond S, Wagner A. The effectiveness of Pilates on balance and falls in community dwelling older adults. J Bodyw Mov Ther. 2016; 20(4):815–23.
28 Taylor D, Hale L, Schluter P, Waters DL, Binns EE, McCracken H, et al. Effectiveness of Tai Chi as a community-based falls prevention intervention: a randomized controlled trial. J Am Geriatr Soc. 2012;60(5):841–8.
29 Donath L, Roth R, Hürlimann C, Zahner L, Faude O. Pilates vs. balance training in health community-dwelling seniors: a 3-arm, randomized controlled trial. Int J Sports Med. 2015;37(3):202–10.
30 Frye B, Scheinthal S, Kemarskaya T, Pruchno R. Tai Chi and low impact exercise: effects on the physical functioning and psychological well-being of older people. J Appl Gerontol. 2007;26(5):433–53.
31 Ni M, Mooney K, Richards L, Balachandran A, Sun M, Harriell K, et al. Comparative impacts of Tai Chi, balance training, and a specially-designed yoga program on balance in older fallers. Arch Phys Med Rehabil. 2014; 95(9):1620–e30.
32 Noradechanunt C, Worsley A, Groeller H. Thai yoga improves physical function and well-being in older adults: a randomised controlled trial. J Sci Med Sport. 2017;20(5):494–501.

33 Hosseini L, Kargozar E, Sharifi F, Negarandeh R, Memari AH, Navab E. Tai Chi Chuan can improve balance and reduce fear of falling in community dwelling older adults: a randomized control trial. J Exerc Rehabil. 2018;14(6):1024–31.
34 Li F, Harmer P, Fisher KJ, McAuley E, Chaumeton N, Eckstrom E, et al. Tai chi and fall reductions in older adults: a randomized controlled trial. J Gerontol A Biol Sci Med Sci. 2005;60:187–94.
35 Wolf SL, O'Grady M, Easley KA, Guo Y, Kressig RW, Kutner M. The influence of intense Tai chi training on physical performance and hemodynamic outcomes in transitionally frail, older adults. J Gerontol A Biol Sci Med Sci. 2006;61:184–9.
36 Gabizon H, Press Y, Volkov I, Melzer I. The effects of Pilates training on balance control and self-reported health status in community-dwelling older adults: a randomized controlled trial. J Aging Phys Act. 2016;24(3):376–83.
37 Lin SF, Sung HC, Li TL, Hsieh TC, Lan HC, Perng SJ, et al. The effects of Tai-Chi in conjunction with thera-band resistance exercise on functional fitness and muscle strength among community-based older people. J Clin Nurs. 2015;24(9–10):1357–66.
38 Takeshima N, Islam M, Kato Y, Koizumi D, Narita M, Rogers N, et al. Effects of 12 weeks of Tai Chi Chuan training on balance and functional fitness in older Japanese adults. Sports. 2017;5(2):32.
39 Zhang JG, Ishikawa-Takata K, Yamazaki H, Morita T, Ohta T. The effects of Tai Chi Chuan on physiological function and fear of falling in the less robust elderly: an intervention study for preventing falls. Arch Gerontol Geriatr. 2006;42(2):107–16.
40 Manor B, Lough M, Gagnon MM, Cupples A, Wayne PM, Lipsitz LA. Functional benefits of Tai Chi training in senior housing facilities. J Am Geriatr Soc. 2014;62(8):1484–9.
41 Lelard T, Doutrellot PL, David P, Ahmaidi S. Effects of a 12-week Tai Chi Chuan program versus a balance training program on postural control and walking ability in older people. Arch Phys Med Rehabil. 2010;91(1):9–14.
42 Okuyan C, Bilgili N. Effect of tai chi chuan on fear of falling, balance and physical self-perception in elderly: a randomised controlled trial. Turk Geriatri Dergisi. 2017;20:232–41.
43 Song R, Ahn S, So H, Lee E-H, Chung Y, Park M. Effects of T'ai Chi on balance: a population-based meta-analysis. J Altern Complement Med. 2015;21:141–51.
44 Nguyen MH, Kruse A. The effects of Tai Chi training on physical fitness, perceived health, and blood pressure in elderly Vietnamese. Open Access J Sports Med. 2012;3:7–16. https://doi.org/10.2147/OAJSM.S27329.
45 Sun J, Kanagawa K, Sasaki J, Ooki S, Xu H, Wang L. Tai chi improves cognitive and physical function in the elderly: a randomized controlled trial. J Phys Ther Sci. 2015;27(5):1467–71. https://doi.org/10.1589/jpts.27.1467.
46 Deeks J, Higgins J. Statistical algorithms in review manager 5. 2007.
47 Borenstein M, Hedges LV, Higgins JP, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res Synth Methods. 2010;1(2):97–111.
48 Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. reprint. New York, NY: Psychology Press; 2009.
49 Son NK, Ryu YU, Jeong HW, Jang YH, Kim HD. Comparison of 2 different exercise approaches: Tai Chi versus Otago, in community-dwelling older women. J Geriatr Phys Ther. 2016;39(2):51–7.
50 Weber M, Schnorr T, Morat M, Morat T, Donath L. Effects of mind-body interventions involving meditative movements on quality of life, depressive symptoms, fear of falling and sleep quality in older adults: a systematic review with meta-analysis. Int J Environ Res Public Health. 2020;17(18):6556.
51 Sañudo B, de Hoyo M, McVeigh JG. Improved muscle strength, muscle power, and physical function after flywheel resistance training in healthy older adults: a randomized controlled trial. J Strength Cond Res. 2020 Feb 7;1.
52 Vikberg S, Sörlén N, Brandén L, Johansson J, Nordström A, Hult A, et al. Effects of resistance training on functional strength and muscle mass in 70-year-old individuals with pre-sarcopenia: a randomized controlled trial. J Am Med Dir Assoc. 2019;20(1):28–34.
53 Giboin LS, Gruber M, Kramer A. Task-specificity of balance training. Hum Mov Sci. 2015;44:22–31.
54 Franco MR, Grande GHD, Padulla SAT. Effect of Pilates exercise for improving balance in older adults (PEDro synthesis). Br J Sports Med. 2018;52(3):199–200.
55 Liu H, Frank A. Tai chi as a balance improvement exercise for older adults: a systematic review. J Geriatr Phys Ther. 2010;33(3):103–9.
56 Chen PY, Wei SH, Hsieh WL, Cheen JR, Chen LK, Kao CL. Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people. Arch Gerontol Geriatr. 2012;55(3):677–82.
57 Hopkins DR, Murrah B, Hoeger WW, Rhodes RC. Effect of low-impact aerobic dance on the functional fitness of elderly women. Gerontologist. 1990;30(2):189–92.
58 Geweniger V, Bohlander A. Pilates in der Prävention: Grundlagen. In: Das Pilates-Lehrbuch. Berlin, Heidelberg: Springer; 2016. p. 19–60.
59 Bueno de Souza RO, Marconde LF, ASF de A, Luciano Pontes Junior F, de Melo RC. Effects of mat Pilates on physical functional performance of older adults: a meta-analysis of randomized controlled trials. Am J Phys Med Rehabil. 2018;97:414–25.
60 Gatts S. A Tai Chi Chuan training model to improve balance control in older adults. Curr Aging Sci. 2008;1(1):68–70.
61 Chen S. Effect of Tai Chi exercises on the balance, functional gait, and flexibility of elderly Filipino males. Proceedings of the 2nd symposium on health and education 2019 (SOHE 2019). Wuhan, China: Atlantis Press; 2019.
62 Villarreal DJ, Poonawala HA, Gregg RD. A robust parameterization of human gait patterns across phase-shifting perturbations. IEEE Trans Neural Syst Rehabil Eng. 2017;25(3):265–78.
63 Sanchis-Sanchis R, Blasco-Lafarga C, Encarnación-Martínez A, Pérez-Soriano P. Changes in plantar pressure and spatiotemporal parameters during gait in older adults after two different training programs. Gait Posture. 2020;77:250–6.
64 Giboin LS, Gruber M, Kramer A. Task-specificity of balance training. Hum Mov Sci. 2015;44:22–31.