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Interventions to maintain mobility: What works?

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ABSTRACT

Mobility, in broad terms, includes everything from the ability to move within your immediate environment (e.g., get out of bed) to the ability to drive across the country. Mobility is essential to maintaining independence and wellbeing, particularly for older adults. This is highlighted by the large number of interventions developed for older adults with the goal of maintaining such mobility. The current paper reviews the state of the science with respect to mobility interventions. Inclusion criteria for the review were: (1) articles must have been peer-reviewed; (2) interventions were evaluated in a randomized controlled trial (RCT); (3) studies included a mobility outcome such as lifespace, driving, or walking ability; (4) studies included a sample of healthy community-dwelling older adults (e.g., not investigations of disease conditions); and (5) studies must have reported enough empirical data and detail such that results could potentially be replicated. Three main types of interventions were identified: cognitive training, educational interventions, and exercise interventions. A detailed summary and evaluation of each type of intervention, and the current evidence regarding its effectiveness in maintaining mobility, are discussed. Several interventions show clear evidence of effectiveness, and thus are prime areas for translation of results to the older population. Needs and issues for future intervention research are also detailed.

1. Introduction

As the population continues to age, there has been a growth in the number of studies and publications related to maintaining the mobility and independence of older adults. There has been increasing interest in both physical and mental fitness and interventions to maintain such fitness throughout the lifespan (Willis et al., 2006; Taylor et al., 2012). Although a growing and rich area of research, there has yet to be a comprehensive review of the current state of the science. Thus, this paper will provide a review of research in this area and will focus on what is known with respect to the impact of non-pharmacological/medical interventions on the safe mobility of community-dwelling older adults.

Mobility, broadly defined, refers to an individual's purposeful movement through the environment and follows a continuum from total immobility (unable to get out of bed) to frequent travel to distant locations. Mobility is known to decline with age (Guralnik et al., 1996) and is associated with changes in sensory, cognitive, and physical functioning (Guralnik and Lacroix, 1992; Salive et al., 1994; Barberger-Gateau and Fabrigoule, 1997). Loss of mobility results in decreased autonomy (Ettinger, 1994), declining everyday function (Manton, 1988), increased risk of depression (Marottoli et al., 1997), increased number of acute conditions (Branch and Meyers, 1987), increased risk for falls (Fried et al., 2000), and increased risk for motor vehicles crashes (Owsley et al., 1998).

Mobility can be assessed in a number of ways. For example, it can be evaluated through self-report, in which an individual indicates his/or her extent of travel as a measure of "lifespace" or "driving space" (Stalvey et al., 1999), discussed below. For the purposes of this review, mobility was defined as any objective or self-report measure of an everyday activity as it relates to the purposeful movement of an individual through physical space. General patterns of mobility indices included those related to driving or those related to physical movement within the environment. Driving mobility may include items such as the amount driven in a typical week, the physical space driven (e.g., "Have you driven outside of you state?"), or indicators of impaired driving mobility, such as driving cessation or crashes. Assessments of physical movement within the environment included performance-based measures common to the literature (such as gait characteristics) and general indices of lifespace. "Lifespace" is defined as the amount of physical space through which an individual reports moving during a specific time period (e.g., "Have you travelled outside of your neighborhood in the last week?").

Historically, research regarding these mobility outcomes focused on identification of specific risk factors predictive of an individual's risk of developing mobility decline (Tinetti et al., 1988; Campbell et al., 1993; Cummings et al., 1995). Identification of at-risk individuals has spurred research focused on

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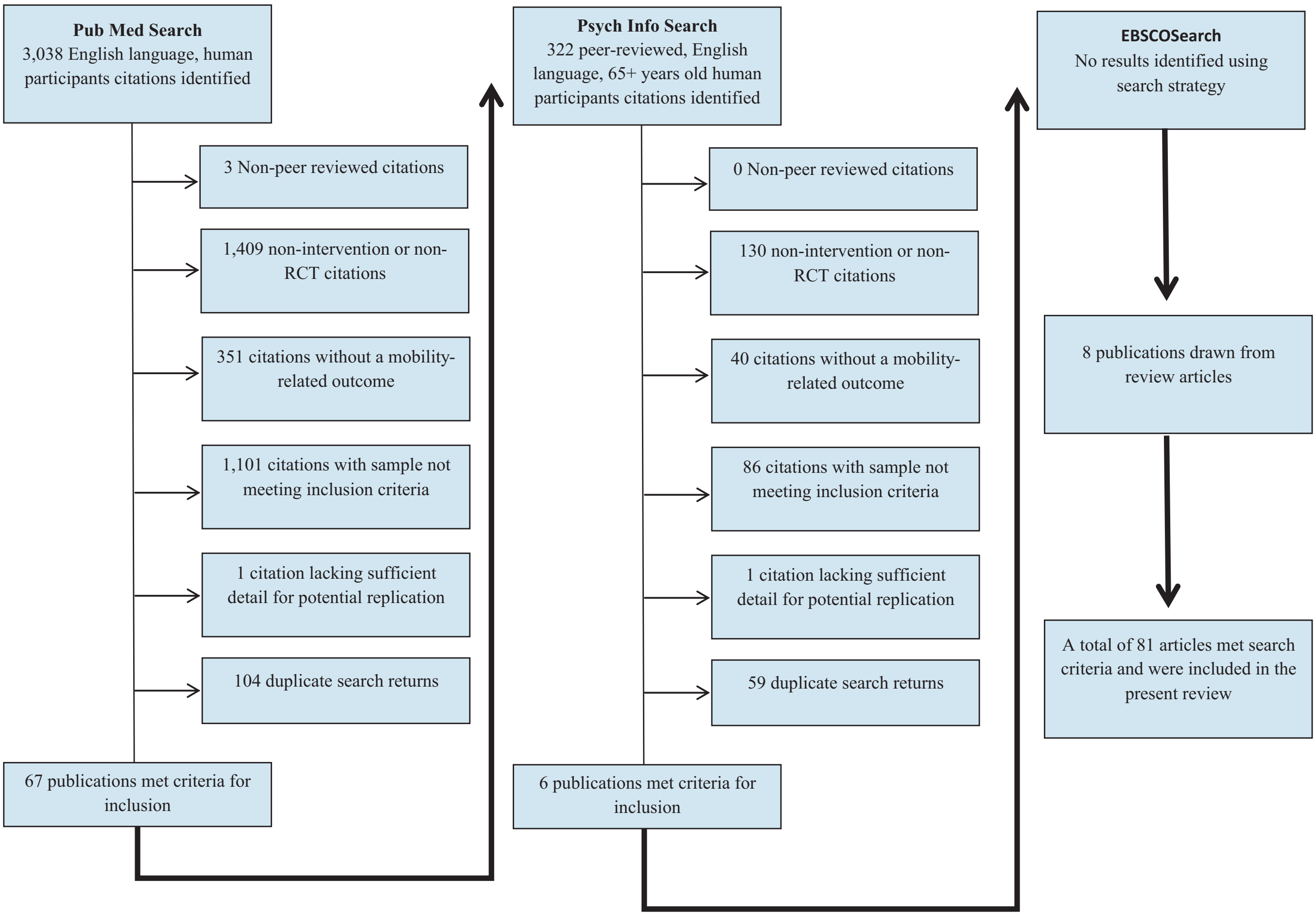

Fig. 1. Inclusionary and exclusionary process for systematic literature review.

potential interventions to maintain or improve mobility. A wide range of interventions have been developed, each with varying levels of success and methodologies. However, the importance of evidence-based interventions designed to improve mobility though improved physical function (e.g., exercise), sensory function (e.g., sensory feedback from one's feet), improved cognitive function (e.g., cognitive training), or changes in lifestyle factors (e.g., educational intervention) could have implications for reversing the negative ramifications of mobility loss. A systematic literature review was conducted as an exploratory assessment of the current state of science regarding mobility-focused interventions and their relationship to the independent mobility of older adults. The most common categories of interventions are those focusing on cognitive remediation, educational programs focused mainly on possible lifestyle changes, and physical activity through various exercise programs. As such, these were the focus of the current review.

2. Methods

2.1. Procedure

For the purposes of this literature review, only studies in English published between 1990 and August 2012 that met the following criteria were considered: (1) peer-reviewed articles; (2) interventions were conducted as a randomized controlled trial (RCT); (3) included a mobility outcome such as lifespace, driving, or walking ability; (4) included a sample of healthy, community-dwelling older adults (e.g., not investigations of disease conditions); and (5) reported enough empirical data and information that results could be replicated (e.g., methods of the measures, intervention, and sample were clearly described). Interventions targeting falls, as well as those targeting specific medical populations (such as diseases), were beyond the scope of this project and were not included. The initial electronic search was conducted by a doctoral-level student and utilized a systematic combination of altering each of three qualifiers, namely: (1) *the targeted intervention approaches* (i.e., "cognitive intervention", "cognitive training", "exercise intervention", "exercise training", "education intervention"), (2) *dependent variables of interest* (i.e., "mobility", "driving", "life space", "gait") and (3) *a sample qualifier* (i.e., "older adult"). Additionally, several non-empirical review papers were collected and cross-referenced to identify additional potential intervention studies that may have been missed in step one of this search. The authors then worked collaboratively to identify which of the articles from the electronic search met the five inclusion criteria of this review.

3. Results

The PubMed search resulted in 81 articles which met the above-listed criteria. Details concerning the number of articles produced per search engine, as well as the elimination strategy, are included in Fig. 1. The averages and ranges describing samples and interventions are provided below, organized by intervention type. The highest figure was used when a range was given for the number of hours (h) spent on the intervention (e.g., if provided with 60–75 min, 75 was included). Further detailed results of this search are presented in Appendix A. Patterns of results identified in this review are detailed in Section 4.

Regarding the cognitive training results, a total of six manuscripts representing five separate RCTs were identified. The interventions included a mixture of computerized and paper-and-pencil training exercises, with samples ranging from 21 to 908 participants aged 48 years and older. The interventions ranged from 4.5 h to 24 h in total duration, with a mean of 10.87 h of training conducted over the course of 2–8 weeks (with an average of 4.4 weeks).

There were 10 manuscripts detailing educational interventions, representing a total of eight RCTs. Activities ranged from completing an educational program at home to attending in-person classes or on-road training activities. Samples ranged from 65 to 632 participants aged 55 and older. Educational interventions ranged from 15 min to 10 h, conducted between 1 day and 2 years. For studies that included all the necessary data, the average number of hours of the education interventions was 5.72 h over an average of 7.58 months.

There were a total of 65 manuscripts detailing exercise-based RCTs. These were further broken into subcategories of "Walking" ($N=4$), "Walking + Other" ($N=6$), "Dance" ($N=2$), "Balance, Flexibility, and Strength" ($N=22$), "Combination" ($N=27$), and "Vibration" ($N=4$). It is a common practice in the exercise literature to discuss physical activity interventions in terms of aerobic vs. non-aerobic approaches. However, given the aims of this review and the overwhelming variety of exercise interventions (including variability in the definition of 'aerobic') that have been studied, it was more appropriate to designate the aforementioned subcategories.

Regarding the "Walking" interventions, a total of four articles from four RCTs were identified with interventions ranging from walking on a treadmill to walking outside or walking on a cobblestone mat. Sample size ranged from 20 to 37, with participants aged 60 and older. The interventions ranged from 18 to 26.25 h and 6 to 12 weeks in duration. For studies that included all the necessary data, the average number of hours spent completing the walking interventions was 22.13 h over an average of 8.5 weeks.

Regarding the "Walking + Other" interventions, a total of six articles from six RCTs were identified with interventions ranging from dual-exercise problem solving training to multi-sensory training. Sample size ranged from 13 to 134, with participants aged 60 and older. The interventions ranged from 9 to 48 h and 1 to 24 weeks in duration. For studies that included all the necessary data, the average number of hours spent completing the interventions was 25.2 h over an average of 11.83 weeks.

The "Dance" interventions included two articles from two RCTs that included salsa dancing and an aerobic dance program. Sample size ranged from 28 to 53, with participants aged 57 and older. The interventions ranged from 16 to 30 h and 8 to 12 weeks in duration, with an average of 23 h over an average of 10 weeks.

Regarding the "Balance, Flexibility, and Strength" interventions, a total of 22 manuscripts from 21 RCTs were identified. Interventions included elements of strength, balance and flexibility alone or in combination such as yoga, tai chi, and practice of functional abilities (e.g., ability to rise from chair without support). Sample size ranged from 16 to 684, with participants aged 60 and older. The interventions ranged from 1.33 to 78 h and 4 to 24 weeks in duration. For studies that included all the necessary data, the average number of hours spent completing the interventions was 24.63 h over an average of 15.05 weeks.

Regarding the "Combination" interventions, a total of 27 manuscripts from 26 RCTs were identified. Interventions were diverse and included combinations of strength, aerobic, educational elements, physical and occupational therapy, as well as practicing activities of daily living. Sample sizes were equally diverse and ranged from 15 to 429, with participants aged 58 and older. The interventions ranged from 14 to 270 h and 8 to 72 weeks in duration. For studies that included all the necessary data, the average number of hours spent completing the interventions was 63.46 h over an average of 23.39 weeks.

Finally, four articles from four RCTs were identified investigating the impact of completing various activities and exercises while standing on various platforms that vibrate. Sample size ranged from 16 to 73 participants aged 50 and older. The interventions ranged from 6 to 13 weeks in duration with an average of 9.25 weeks. Not enough detail was provided to report the range or average amount of hours spent completing these activities.

4. Discussion

Cognitive and physical interventions believed to maintain mobility are based on the premise that predictors of mobility decline are modifiable and thus, may translate to maintained mobility. Educational interventions are typically focused on the premise that a better understanding of the impact of lifestyle habits, such as poor fitness or participation in risky behaviors (such as driving at night), will result in a change in such behaviors for the better. Based on the findings of this literature review, the results of the cognitive interventions are positive while the results of the educational and physical interventions are mixed. A review of these findings is detailed below, organized by intervention type and outcome. Further details of each study are provided in Appendix A.

4.1. Cognitive interventions

Aging is associated with declines in many important domains of cognition including reasoning, decision making, spatial ability, information processing and memory (Dixon and Hultsch, 1999; Stine-Morrow and Soederberg Miller, 1999). Although cognitive decline has been widely believed to be an inevitable result of aging, we now have evidence that the brain maintains its plasticity, or the ability to reorganize its neural circuitry, in response to learning and experience across the lifespan, including into old age (Buonomano and Merzenich, 1998; Kramer and Willis, 2003). It is this belief in the life-long neural capacity for positive change that has led to the development of cognitive training programs.

The first set of cognitive training studies is related to driving outcomes, specifically driving safety and driving mobility. First, regarding driving safety, in one of the earliest studies evaluating a 10-h computerized cognitive intervention (speed of processing training), Roenker et al. (2003) found that participants at-risk for mobility decline who were randomized to the training condition demonstrated safer on-the-road driving performance as compared to the simulator trained control group ($N=95$). In addition, the participants in the speed of processing training condition were also able to respond significantly faster in a driving simulator, reacting 277 ms earlier to road signs in a visual-search paradigm (road sign test). It was argued that this improved reaction time would translate to a vehicle traveling at 55 mph stopping 22 ft sooner (Roenker et al., 2003). The impact of cognitive interventions on driving safety and mobility has also been investigated in a large multisite randomized clinical trial called the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study. ACTIVE was the first large study of its kind that evaluated the impact of three different cognitive training programs (memory, reasoning, and speed of processing) on cognitive, mobility, and everyday functional measures in older adults (Jobe et al., 2001; Ball et al., 2002; Willis et al., 2006). Ball et al. (2010) used a subsample of participants in the ACTIVE study to investigate the impact of three cognitive training programs against a no-contact control group on prospective at-fault state-reported motor vehicle crashes ($N=908$). Analyses were calculated using per person-year (the amount of time a participant could have driven) and per person-miles (the self-reported mileage multiplied by the person-years) so that the risk ratios would reflect differences in opportunities to crash between participants. They found that speed of processing training resulted in greater than a 40% reduction in at-fault crashes across a six year period per person-miles driven (RR = 0.58, 95% CI = 0.35–0.97) and per person-time (RR = 0.55, 95% CI = 0.33–0.92). After adjusting for demographics, health, vision, depressive symptoms, cognitive status, and site, both the speed of processing trained group (person-time, RR = 0.52, 95% CI = 0.31–0.87; person-miles, RR = 0.57, 95% CI = 0.34–0.96) and the reasoning trained group (person-time RR = 0.55, 95% CI = 0.33–0.92; person-miles, RR = 0.58, 95% CI = 0.35–0.97) demonstrated a significant reduction in at-fault crashes.

A similar line of research has investigated if cognitive training, specifically speed of processing training, can also maintain driving mobility. Edwards et al. (2009a) combined data (*N* = 550) from the ACTIVE project and the Staying Keen in Later Life (SKILL) project to examine the impact of speed of processing training on driving cessation in a sample of older adults at-risk for mobility decline (via poor performance on the Useful Field of View (UFOV® test) at baseline). As compared to the control group, those randomized to speed of processing training were 40% less likely to cease driving over the next three years (HH = 0.596, 95% CI = 0.356–0.995, *p* = .048). Similarly, in another article, Edwards et al. (2009b) furthered this research line using the SKILL project by investigating the impact of processing speed training on driving exposure (total number of challenging driving situations), driving space (physical space driven), and driving difficulty (sum of reported levels of difficulty while driving) in persons at-risk for mobility decline against two control groups, one that was also at-risk for mobility decline at baseline and one that was not at-risk (*N* = 500). Results indicated that those participants at-risk for mobility decline who were not randomized to training experienced greater decline via decreased driving exposure and space and increased driving difficulty after three years. Those at-risk for mobility decline who received training reflected the same maintained driving mobility as the reference control condition (those participants who were not at-risk for mobility decline at baseline).

Two additional studies evaluated cognitive training on gross motor performance. Li et al. (2010), randomly assigned 20 healthy older adults to either training or control groups. The trained participants were asked to complete five sessions of cognitive dual-task training in which they made two-choice decisions to visually presented information. All participants performed tests of cognition, balance, and mobility under single and dual task conditions. The training group experienced significant improvement in body sway during single-support balance, demonstrating benefit to gross motor performance. Similarly, Verghese et al. (2010) evaluated the impact of the Mindfit program, a cognitive training program including a mixture of visual, auditory and cross-modality tasks designed to train attention, executive function, and other cognitive abilities. The participants who completed the cognitive intervention improved gait velocity as well as walking while talking, again suggesting that cognitive training may improve mobility function in older adults.

In summary, the results of the cognitive training research generally demonstrated transfer of training to several mobility functions, including driving safety, driving difficulty, driving cessation, and gross motor function. Several of these studies were large multisite clinical trials. Thus, cognitive training shows particular promise as a method of extending safe mobility among older adults.

4.2. Educational interventions

Several studies have evaluated the impact of educational interventions on driving outcomes. Regarding classroom-based interventions, Owsley et al. (2003, 2004), evaluated an educational intervention with 403 licensed older adults experiencing a visual acuity deficit, a speed of processing deficit, or both. Drivers were evaluated at baseline and six months. The intervention promoted the performance of self-regulatory practices (e.g., the avoidance of challenging driving situations) and was individualized for each participant. At post-test, drivers in the intervention group reported more self-awareness about their driving, and also reported reductions in driving frequency and increases in avoidance of challenging driving situations, *N* = 365 (Owsley et al., 2003). There was not, however, a difference in crash rate so that the desired safety benefit of the intervention was not observed, *N* = 403 (Owsley et al., 2004). Similarly, in a RCT investigating on-road driving performance after a classroom-based driving re-training intervention, Bédard et al. (2004) did not find an impact of the intervention on objectively measured driving performance (*N* = 65).

Gaines and colleagues (2011) evaluated the CarFit educational program consisting of a 15 min assessment which provided participants with feedback on ways to improve the fit of the vehicle to the participant (e.g., improved seating position, seatbelt use, etc.; *N* = 175). Although the program was able to detect potential problems to driver safety at baseline, there were no significant changes in driving activity or behavior between the intervention and control groups at the six-month posttest.

Other researchers have found mixed results with combinations of classroom and on-road interventions. For example, Marottoli et al. (2007b) conducted a RCT with 118 community dwelling older adults who were at least 70 years of age. The intervention consisted of a mixture of two 4-h classes focused on common problem areas of older drivers and two 1-h on-road training sessions. Participants randomized to the control group were exposed to more general safety information. A driver knowledge test and driving performance were assessed at baseline and following the intervention at eight weeks. Results indicated that those older adults randomized to the intervention group showed significantly better objectively measured driving performance, as well as significantly better performance on the knowledge test. Similarly, Bédard et al. (2008) investigated the impact of a classroom-based driving program combined with on-road driving education (*N* = 75) at three different research sites. As compared to the waitlist control group, results revealed improvement in posttest driving knowledge. Additionally, there was improvement in objective on-road driving performance in two of the five driving measures at one site (participants used their own vehicles) and improvement in one of the five driving measures at the second site (participants using a dual-brake vehicle), thus indicating mixed transfer of the intervention to objective on-road driving measures.

Thus, with respect to driving outcomes, educational interventions have had mixed results. These interventions, however, varied greatly with respect to the content of the intervention, the time spent in the educational activity, and the timeframe over which the interventions were evaluated. Similarly, the characteristics of the participants varied across studies, from community dwelling older adults to those with specific visual and/or cognitive limitations.

With respect to educational interventions targeting other mobility outcomes, Mänty et al. (2009) performed a two-year RCT with 632 sedentary older adults aged 75–81 years. Physical activity counseling, consisting of a single session with follow-up telephone calls every four months, was compared to a no-contact control group. The outcome measure, perceived difficulty walking, showed a significant treatment effect at two years. Similarly, Gitlin et al. (2008) evaluated an intervention consisting of occupational therapy and physical therapy home instruction on several outcome measures (difficulty walking, Instrumental Activities of Daily Living (IADL), Activities of Daily Living (ADL), self-efficacy, and fear of falling). Results varied by outcome measure. For self-reported mobility difficulties, women and the oldest-old participants improved relative to their counterparts. For self-efficacy, less educated participants and women benefited the most. For ADL, the oldest participants, women, and the less educated participants improved relative to controls. For IADL, whites improved more than non-whites. Finally, for fear of falling, less educated participants improved relative to controls. Morey et al. (2009) also investigated the impact of a combination of in-person and telephone-based physical activity counseling on mobility. Results indicated that the intervention group, as compared to the control group, increased rapid gait speed and reported physical activity, but the control group experienced better objectively measured physical performance. Finally, other research (Mänty et al., 2009) using similar methodology investigated the impact of a face-to-face individualized physical activity counseling session followed by telephone contact every 4 months for 2 years (N = 632). Although more 'basic' mobility (perceived walking for 0.5 km) effects were non-significant, 'advanced' mobility (perceived walking for 2 km) were significant at posttest (2 years) as well as the subsequent 1.5 years.

In general, it appears that educational interventions can be beneficial under some circumstances, and that those participants with the greatest disability tend to benefit most from intervention. Furthermore, results of the Gitlin et al. (2008) study suggest that educational interventions may prove differentially effective based on the age, gender, and race of the participants. This suggests that in order to maximize treatment benefits, educational interventions should be appropriately tailored to specific participant characteristics. Future intervention studies should consider stratifying on participant demographics and functional status (e.g., those at greatest risk for decline) and evaluating treatment response as a function of such individual differences.

4.3. Exercise

Loss of muscle mass, decreasing flexibility, and increasing deficits in balance and coordination make successful navigation of everyday environments more difficult for older adults (Whitbourne, 1999; Ross et al., 2009). A wide range of exercise interventions have been investigated, using both aerobic and non-aerobic approaches to target mobility in older adults. Because of the overwhelming variety of exercise interventions that have been studied (as well as the vast differences in regard to the definition of aerobic vs. non-aerobic), for the purposes of the present review interventions have been divided into the following subcategories: "Walking", "Walking + Cognitive", "Dance", "Balance, Flexibility and Strength", "Combination", and "Whole Body Vibration".

Compared to maintenance of usual activity, older adults who regularly participate in a walking program demonstrate preserved or improved mobility or mobility-related functions. For example, Parkatti et al. (2012) conducted a 9 week intervention study in which adults aged 65 and older participated in Nordic Walking, which is walking rapidly with ski poles around a track (N = 37). Compared to no-treatment controls, the Nordic Walking group improved on a walking mobility measure (up and go) and on everyday functional outcomes like chair stands, arm curls, stepping in place, sit and reach, and back scratch. A similar pattern of mobility and everyday functional improvements was reported in studies of over-ground walking and progressive, high intensity treadmill walking (Kalapotharakos et al., 2006; Malatesta et al., 2010). Some studies directly compared two types of walking interventions to one another. For instance, Marsh et al. (2006), compared 6 weeks of over-ground walking on a flat, indoor track to walking on a treadmill and found that the over-ground training group was faster than the treadmill training group on the 400-m walk (N = 20). However, the groups did not differ on other outcomes such as walking velocity, lateral mobility, or performance on the short physical performance battery.

The aforementioned walking interventions offer older adults an uncomplicated, generally accessible, and effective form of exercise. In addition, there is evidence that some walking approaches involving a supplementary cognitive or sensorial component may confer even greater physical benefit than traditional walking alone. In support of this idea, in a RCT of 108 sedentary community dwelling adults aged 60–92, Li et al. (2005) found that compared to participants engaging in traditional walking, those who completed a walking intervention on cobblestone mats (mats with hard plastic replicas of stones that require more balance and attention to foot placement) over 16 weeks had better mobility outcomes. Cobblestone walkers demonstrated greater improvement than traditional walkers on everyday functional measures (such as chair-rise time, functional reach, static standing) as well as other mobility outcomes (e.g. 50-ft walk). In contrast, Kovacs and Williams (2004) found no significant differences between a dynamic multisensory training (involving walking on surfaces of different rigidity, under different visual and kinesthetic demands) compared to traditional walking or no-treatment (N = 30).

Shigematsu et al. (2008) conducted a 12 week RCT of community-dwelling older adults, aged 65–74 years old (N = 68). They compared traditional walking to square-stepping exercise, which entailed following an increasingly challenging pattern of foot placement instructions as one moved across a mat made up of 10 successive rows of four squares. Both groups improved on everyday functional measures (chair stands, functional reach, and standing from a lying position), but over and above the conventional walking group's performance, square-stepping participants also demonstrated improvement on other everyday functional measures (improved leg power) as well as walking mobility measures (forward/backward tandem walking, stepping with both feet, and walking around two cones). Trombetti et al. (2011) conducted a 6 month study in which cognitive task demands were increased during a music-based multi-task exercise program requiring participants to walk in time with music or to walk while simultaneously handling objects or instruments (N = 134). Compared to a wait-list control group, the training program led to improvements in mobility and everyday functional performance (gait velocity, stride length, stance time, mediolateral angular velocity, timed up and go and Tinetti test performance). On the other hand, similar dual exercise/problem solving training programs involving walking while simultaneously completing a cognitive task, failed to find significant differences on mobility (Marmeleira et al., 2009) and functional (You et al., 2009) outcomes. In sum, although it is important to note that the methodology varied between these studies, the mixed results indicate that more research is needed to confirm whether increasing cognitive load in exercise interventions confers any significant mobility benefits above traditional walking.

In comparison to walking, dance interventions involve more complicated elements of movement. Presently there are only a few studies which have investigated the effects of dance on mobility outcomes, but results have generally indicated a beneficial effect compared to no-treatment controls. Granacher et al. (2012) found that a salsa dancing intervention significantly increased stride length and velocity, while reducing stride time in a sample of 28 healthy community dwelling adults aged 63–82. Hopkins et al. (1990), in a study of 65 community dwelling adults aged 57–77, showed aerobic dance to be an effective intervention for improvement of cardiorespiratory endurance, balance, flexibility, and agility. Similar to walking interventions, dance may be a promising avenue for exercise interventions as it can potentially provide a socially stimulating and enjoyable activity within the community.

In contrast to the few studies of dance training, interventions involving elements of balance, strength, and flexibility are pervasive. While the wealth of available information is appreciated, it can be challenging to compare results among studies, given their variable foci. We will start with a discussion of progressive resistance training in its various forms and later move into a review of alternative forms of balance, strength, and flexibility interventions including Tai Chi, yoga, stretching, and multi-component interventions.

Progressive resistance training (PRT), involving weight machines, free-weights, and even aquatic exercise, has shown promise as a method of improving strength and mobility in older adults. This sort of training typically targets muscle strength and endurance through repetitive movements such as hip flexion/extension, knee flexion/extension, plantar flexion, and bicep curls, among others, under increasingly higher percentages of individuals' own body weight or one-repetition maximum load (1RM). Lamoureux et al. (2003) found beneficial effects of lower body PRT compared to normal activity, characterized by increases in strength, stride length, vertical heel obstacle clearance, crossing stride velocity, and decreases in stride duration. Bird et al. (2009) found that compared to flexibility training, PRT increased lower limb strength. However, there were no significant differences between groups on any mobility measures. In a later study, comparing order effects of PRT and flexibility training (4 months of one, then 4 months of the other) against no-treatment control, Bird et al. (2011) found that both exercise training programs conferred transient gains in strength, and longer-lasting gains (significant at 12-month follow-up) on mobility (via the timed up and go). Those who independently continued the exercise program upon completion of the study performed significantly better than controls on the step test at 12-month follow-up.

Bean et al. (2002, 2004) conducted multiple RCTs of InVEST training in community-dwelling older adults with mobility limitations. InVEST training consists of wearing a progressively weighted vest while performing a battery of exercises such as toe raises, chair stands, and step ups. Compared to a traditional walking group, stair climbing with the weighted vest increased functional capabilities like leg power, especially in individuals who were most impaired at baseline (2002). Interestingly, the walking comparison group improved more than the weighted stair climb group on the mobility outcome of 6-min walk. This suggests that the two interventions in question differentially improved the functions targeted by the respective interventions.

Bean et al. (2004) compared InVEST training to a control condition involving similar exercise without added weight. InVEST participants made greater improvements than controls in leg power, gait speed, and chair stand time. Similar improvements were reported by Bean et al. (2009) in an investigation of the differential effects of InVEST training and the National Institute on Aging's (NIA) PRT recommendations. In this RCT of 138 mobility limited community-dwelling adults over aged 65, both forms of PRT—InVEST and the NIA program—produced similar robust, clinically significant improvements on the Short Physical Performance Battery as well as self-reported functioning. In contrast to the generally positive findings regarding weighted vest training on mobility measures, negative results have also been reported. Greendale (2000) studied the effect of weighted vest training during usual activities. Two training groups, wearing vests weighted at 3% or 5% of individual body weight, did not improve strength or physical performance after the 27-week intervention.

One logical explanation for the discrepancy between the Bean and Greendale studies is the differential intensity of physical activity performed while wearing the vest—a stair-climbing exercise program versus usual activity. However, in contrast to this hypothesis, a RCT of 57 community-dwelling adults aged 65–94 with mild-moderate mobility impairments, conducted by Reid et al. (2008), revealed that high velocity resistance and traditional low velocity training produced similar gains in lower-limb strength, a strong predictor of functional mobility. Vincent et al. (2002) also compared high and low intensity resistance training in adults aged 60–83. Results indicated that both groups significantly improved their 1RM for all exercises tested, muscle strength and endurance, and time to climb one flight of stairs. These results suggest that older adults may benefit from even light resistance training.

Barrett and Smerdely (2002) found that relative to a stretching control program, older adults randomized to PRT improved on measures of quadriceps and bicep strength, along with functional reach and the step test after only 10 weeks. In a RCT of 70 older adults, seated and non-seated PRT had not improved mobility and strength outcomes relative to a wait-list control group at 12 weeks into the intervention (Ramsbottom et al., 2004). However, at the end of the full 24 week intervention, the training group demonstrated increased leg power, and improved mobility performance compared to controls. Taaffe et al. (1999) conducted a 24-week intervention comparing once-, twice-, and three-times weekly resistance training in community dwelling older adults aged 65–79. They found that at all durations, resistance training significantly improved muscle strength and chair rise times, suggesting older adults need not make a large weekly time commitment to PRT to reap mobility gains.

Shifting to other various types of balance/strength/flexibility interventions, we find that much like PRT, interventions focused on stretching, yoga, Tai-Chi, and driving-targeted exercise, among others, have shown mixed results with respect to mobility improvement. There are also many fewer studies of each type on which to base our conclusions.

Christiansen (2008) and Cristopoliski and colleagues (2009) found that compared to a no-treatment control condition, a stretching condition was effective in improving older adults' hip, knee, and ankle mobility, as well as freely chose gait speed and other gait characteristics like step length and pelvis rotation. In a unique exercise study investigating a physical-therapist-guided exercise program targeting driving mobility, adult drivers over age 70 improved road test scores and committed fewer critical driving errors than those who received an in-home educational program (Marottoli et al., 2007a).

In a study comparing stretching and Tai Chi interventions, participants in the 24-form Yang-style Tai Chi intervention improved significantly more than participants in the stretching group on all measures of functional balance (Li et al., 2004). Contrarily, Taylor et al. (2012) compared a twice weekly Tai Chi program with a once weekly Tai Chi program and low-level exercise active control and uncovered no significant differences between any of the groups on mobility outcomes. In a small pilot study of a Kripalu-style yoga intervention, within-subjects analysis showed significant improvements on the Berg Balance Scale and gait speed of individuals who completed the program (Zettergren et al., 2011).

Pahor et al.' (2006), in a multi-center RCT of 424 sedentary older adults aged 70–89, found that physical activity training, including 150 min of walking and complimentary strengthening, stretching, and balance exercises, reduced the risk of major mobility impairment and led to improved timed measures of chair-rise ability, standing balance, and walking speed compared to a health-education control group. Many other studies investigating the effects of multi-component exercise training on functional and mobility outcomes relative to controls have also found positive results (Wolfson et al., 1996; King et al., 2002; Nelson et al., 2004; Shumway-Cook et al., 2007; Beling and Roller, 2009; Manini et al., 2010; Yang et al., 2012), though at least one has failed to find a significant effect (Resnick et al., 2008).

Faber et al. (2006) conducted a multi-center RCT with 278 adults living in long-term care facilities with varying levels of assistance and with a mean age of 85 years. Two exercise interventions were compared to a social-contact control. The first intervention, Functional Walking, consisted of 10 balance and mobility exercises that mimic real-world functional requirements, for example, standing from a seated position, walking up and down a staircase, and stepping over an obstacle. The second intervention, In-Balance training, consisted of Tai-Chi-like slow and continuous motion exercises. Faber and colleagues found that for pre-frail older adults, both functional walking and in-balance interventions significantly reduced the risk of falling, improved performance on the Performance Oriented Mobility Assessment which measures characteristics of walking and balance, and improved performance on physical activity measures such as the timed get up and go test and the chair stands test. Of note was the additional finding that frail older adults participating in the exercise interventions were at *increased* risk of falling, and that frailty was a modifier of the beneficial effects of Functional Walking and In-Balance training on functional physical outcomes. A finding such as this might been seen as evidence for contraindication of exercise in frail adults; however, the issue may not be that simple.

For example, frail older women fared well in the Bean et al. (2004) study of InVEST training which consisted of wearing a progressively weighted vest while performing a battery of exercises such as toe raises, chair stands, and step ups. Compared to controls who completed similar exercises without added weight, frail InVEST participants made significant improvements in leg power, gait speed, and time to complete chair stands. Taken together, the Faber and Bean findings suggest that any exercise intervention targeting mobility must be carefully tailored to the capabilities of the individual participant, and that the form of exercise must be appropriately challenging and safe for maximum benefit. More research is needed to clarify the appropriate limits of exercise interventions for the frail subpopulation of older adults.

Finally, whole body vibration (WBV) is a relatively new idea in the field of exercise intervention on mobility outcomes. It involves either static standing or performance of dynamic exercise while on a vibrating platform. This is thought to enhance muscle function through additional stimulation of the neuromuscular system. Machado and colleagues (2010) conducted a study in women aged 65 and older, comparing WBV in conjunction with lower body exercise training to no-treatment control. Compared to no-treatment controls, the WBV group significantly improved on the timed up and go mobility measure. However, Rees et al. (2007) did not find such a beneficial effect of WBV. Their study of WBV in combination with heel lifts and dynamic squats did not reveal improvements in mobility outcomes greater than in controls who performed exactly the same exercises without vibration. Compared to controls, the WBV group did, however, improve on a measure of ankle plantar flexion strength. Furness and colleagues (2009) considered the effect of 0, 1, 2, or 3 weekly sessions of static WBV. The 3-session/week WBV group was faster than the 0-session/week control group on the 5 chair stands test. On timed up and go, the 3-session/week WBV group was faster than the 2-sessions/week group. On the Tinetti test, the 3-sessions/week group performed significantly better than all other groups. These results seem to indicate that more frequent WBV therapy may be more beneficial than fewer sessions. At last, Mikhael and colleagues (2010) explored WBV with participants standing in different positions. One group stood on the vibrating platform with flexed knees (FK), one group with locked knees (LK), and these groups were compared to a placebo control group. Neither WBV under the FK condition nor the LK condition improved on any measure of functional performance compared to controls. Upper body contraction velocity improved significantly more in FK participants than LK participants. Leg strength improved significantly more in LK participants than in controls. Relative upper body strength in both WBV groups was significantly greater than in controls following the intervention. Clearly, in such an emerging area of study, further research is needed to elucidate the efficacy of WBV and the parameters of its use in improving mobility in older adults.

In summary, while there is overwhelming evidence for improved muscle strength and power with a variety of progressive resistance training programs, more research is needed to elucidate the relatively weak findings of transfer to actual everyday mobility outcomes (such as driving space and lifespace). Aerobic exercise interventions such as walking, walking + cognitive, and dance also suffer from a lack of consistency in their effect on certain outcome measures. Furthermore, mobility outcome measures used repeatedly across aerobic and non-aerobic intervention studies alike (timed get up and go, stair climb, chair rise test) are in reality, still just estimates of transfer to real-world functioning. Future research should include measures of true real-world mobility functioning, for instance, amount of distance traveled in a typical day.

With respect to study design, many of the exercise studies suffered from very small sample sizes, limiting their ability to draw meaningful conclusions. Additionally, a number of studies compared disparate interventions instead of comparing an intervention to a no-contact or waitlist control group. This is problematic in that it increases the chance of a Type-II error. Otherwise effective exercise interventions may not show significant differences, even though they may actually be effective in preserving or improving mobility outcomes. Another source of murkiness in interpretation of results was the inclusion of many disparate forms of exercise within one intervention. Including elements of walking, strength training, balance, and flexibility within one intervention may increase the chance of improving mobility outcomes, yet it leaves us unable to conclude which component or specific combination of components were actually responsible for significant changes.

Finally, a limitation of some studies was a lack of consistent methodological detail. For example, some studies provided information regarding the amount of repetitions that were made during an intervention while other studies used time as the metric. Preferably, averages regarding both repetitions and the amount of time spent conducting the exercise should be included.

Though the beneficial effects of exercise on mobility maintenance have been shown, it is still unclear whether older adults can independently implement and consistently carry out these programs. Most of the studies reviewed here incorporated group-based exercise into their design. Faber et al. (2006), for example, explicitly stated that this was done in effort to improve motivation of participants and lower attrition. Indeed, most studies that included provisions for group interventions reported low attrition and generally at least some positive mobility outcomes.

Support is lent to the power of group interventions by Marsh et al.'s (2006) study of over-ground training versus treadmill training. Though the groups completed approximately equivalent amounts of training, the treadmill exercise group did not show mobility improvements and reported less favorable attitudes toward the intervention than the over-ground group. Due to a limited number of treadmills for study use, the treadmill group had much less social contact than the over-ground group, and the investigators cited this difference in social involvement as one possible explanation of outcome differences.

In addition to the influence of a peer group, another question pertinent to mobility intervention outcome is, how motivated will older adults be to engage in independent physical exercise? Outside of the lab, it is likely that older adults will largely have to be self-motivated in carrying out an exercise plan. Donat and Ozcan (2007) conducted a study of balance and strength training in 32 adults aged 65 and older, randomizing participants to an unsupervised home condition or to a supervised group condition. They found that both the supervised and unsupervised groups improved balance, flexibility, and functional mobility, but that the supervised group showed added significant improvements in proprioception and strength. In Bird et al.'s (2011) 1-year follow-up of their 2009 study of a resistance and flexibility training program, about half of their original participants maintained involvement in training since termination of the original study. Of those who continued to be involved in resistance and flexibility training, a majority reported completing workouts with a consistent group of peers. Participants showed measureable maintenance of mobility gains and perceived health benefits. Another encouraging report comes from Pahor et al. (2006), who gradually transitioned participants from frequent in-clinic intervention sessions to more in-home sessions, and reported reduced but generally good adherence rates across time. In sum, although not always effective, group support and regular feedback from trained supervisors seem to aid intervention adherence and long-lasting transfer.

Finally, another major question that must be considered with respect to exercise interventions is their cost. Hiring a personal trainer or buying the expensive equipment used in research is not a feasible healthcare plan for an overwhelming majority of older adults. What should physicians recommend to their older patients? Bird et al. (2011) reported that participants who continued to maintain their training regimen after the end of the official study widely utilized community recreational facilities. This may be one avenue for physician recommendation, although clearly not everyone has access to free and quality public recreation centers.

To conclude, a number of issues exist in the current exercise intervention literature that should be addressed by future research. A wide range of interventions have shown positive effects on mobility, however many studies suffer from very small sample sizes and a lack of corroborating research. While current mobility research is wide in scope, replication of findings will be needed to confirm current notions of effective interventions. Future research will also need to extend beyond the basic question of efficacy to address important practical questions which impact older adults in their daily lives: what exercise interventions are financially feasible, easily implemented, and intrinsically motivating to most older adults?

5. Conclusions

In recent years, there have been many changes within the health care industry. Patient care has become much more individualized, and treatments now include many more lifestyle modifications in addition to drug regimens. Along with this, research and marketing have shifted focus to healthy foods, exercise, and brain fitness training programs to promote longevity and a high quality of life. With the growing older adult population, there is little question that interventions that can be implemented directly within the community or public are needed to maintain the mobility, and thus wellbeing and independence, of older adults. However, clearly more research is needed to assess the exact mechanisms and benefits of such interventions.

With respect to future research, several areas in need of improvement became evident while conducting this review. First, a difficulty that arises when assessing mobility interventions is the diverse methodologies that are used throughout the literature (see Downs and Black (1998) for a checklist of methodological issues to consider for RCT interventions). Appropriate control groups, representative samples, and appropriately powered studies are some of the key areas that need to be carefully considered in future studies. Many of the exercise studies reviewed here had samples that were too small to assess the efficacy of the intervention. Second, research regarding the long-term implications of these interventions is urgently needed. Interventions should be designed such that (1) individuals will continue to complete them at home, and/or (2) the benefits are great enough to maintain transfer effects through several years. Given the wide range of interventions that have demonstrated transfer to one or more mobility outcomes, researchers should also include cost-benefit analyses when evaluating the interventions. Such information would be of special interest to policy makers and medical practitioners when evaluating the needs of this population. In addition, it is impossible to truly assess the "file drawer problem" that is likely prevalent with intervention research. Nonsignificant results can be just as important in advancing the future science as significant results. Unfortunately, it can be very difficult to publish such results. Clearly, a more balanced picture of the interventions that work, as well as the interventions that do not, is needed within the peer-reviewed published literature. In a similar vein, it is important that replication of results is conducted and published. Finally, more emphasis is needed on evaluating the transfer of these interventions to real-world outcomes, such as walking, types of daily activities completed, and driving. While many of the laboratory-based measures do provide evidence of transfer, only assessment of the individual's actual daily functioning and activities will demonstrate if these interventions are maintaining or improving mobility, independence, and quality of life.

Based on the literature reviewed, it is clear that cognitive and exercise interventions hold promise for maintaining everyday mobility. The conclusions regarding educational interventions on actual mobility outcomes are less clear. Future research should investigate possible personalized interventions that tap multiple constructs.

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Appendix A.

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Cognitive training					
Ball et al. (2010)	Memory training vs. Reasoning training vs. Speed of processing training vs. No-contact control	10, 70-min sessions; 2 sessions/week for 5 weeks	State-recorded motor vehicle collisions (MVC) Mobility Driving Habits Questionnaire	Participants in speed of processing training had significantly lower rates of at-fault MVC per year of driving exposure (RR 0.55, 95% CI, 0.33–0.92) and per person mile driven (RR 0.58, 95% CI 0.35–0.97). After adjustment for demographics, vision, physical and mental health status, the reasoning group also had significantly lower rate of at-fault MVC per year of driving exposure (RR 0.44, 95% CI, 0.24–0.82) and per person mile driven (RR 0.50, 95% CI 0.27–0.92). There were no significant effects of memory training on driving mobility.	Adults aged 65–91 ($N = 908$) Subsample of ACTIVE study
Li et al. (2010)	Computerized dual-task training (visual and auditory discrimination task training) vs. No-treatment control	5, 60-min sessions across 2 weeks	Single-support and Double-support standing balance; 40-ft walk test; 5 Chair Rise time (Note: physical outcome measures tested alone and concurrently with *N*-back task at 2 levels of difficulty)	The training group showed significant improvements in mediolateral speed ($p = .013$), variability ($p = .029$), and peak-to-peak center of pressure parameters ($p = .046$) for single-support standing balance, and center of gravity alignment during double-support dynamic balance ($p = .026$), while the control group made no significant improvements.	Adults aged ≥ 70 ($N = 21$)
Verghese et al. (2010)	*Mindfit* computer training (visual, auditory, and cross-modality tasks training attention and executive function) vs. Wait-list control	45–60 min sessions; 3 sessions/week for 8 weeks	Gait velocity; Walking; Walking-while-talking; Physical Activity Questionnaire	As compared to controls, trained participants improved significantly on the walking-while-talking condition ($p = .05$).	Adults aged ≥ 70 ($N = 24$); Sedentary, “at-risk” for mobility decline: frail, with slow gait, walking difficulty,
Edwards et al. (2009a)	Speed of processing training vs. Social/computer-contact control	10, 60-min sessions; 2 sessions/week for 5 weeks	Mobility Driving Habits Questionnaire	As compared to controls, trained participants were protected against driving cessation ($HR = 0.596$) in the subsequent 3 years as compared to controls.	Adults aged 63–91 ($N = 568$), Subset of SKILL and ACTIVE participants “at risk” for mobility decline via poor UFOV performance
Edwards et al. (2009b)	Cognitive speed of processing training vs. Social/computer-contact control vs. Low-risk reference	10, 60-min sessions; 2 sessions/week for 5 weeks	Mobility Driving Habits Questionnaire Turn 360 Test	At-risk social-contact controls experienced more driving difficulty and reduced driving mobility across time as compared to the low-risk reference group ($p < .015$). The at-risk trained group did not significantly differ from the low-risk reference group across time ($p > .05$), except on the driving difficulty composite ($p = .004$), indicating that they had maintained their driving mobility.	Adults aged ≥ 60 ($N = 134$) Subset of SKILL and ACTIVE participants “at risk” for mobility decline via poor UFOV performance
Roenker et al. (2003)	Speed of processing training vs. Simulator training control group (social contact) vs. Low risk reference group	Speed of processing training: average of 4.5 h over 2 weeks. Control: 2, 2-h sessions over 2 weeks	Driving simulator measures: simple reaction time, choice reaction time On-the-road driving evaluation: 445 driving behaviors rated on a scale of 0–2 (very unsafe – safe/appropriate)	There was a significant group x time interaction on the dangerous maneuvers composite, $F(4, 184) = 2.89$, $p < .024$, with the trained group demonstrating significantly fewer dangerous maneuvers than the control and reference groups at 18-month follow-up. The simulator-trained group improved on the driving performance measures of turning into the correct lane and proper signal use.	Adults aged 48–94 ($N = 95$) Both trained groups were “at risk” for mobility decline via poor UFOV performance

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Educational training					
Gitlin et al. (2008)	Occupational therapy (OT) home visits + physical therapy contact + free home modifications vs. No-contact control. Note, the focus of this study was on the interaction between demographic variables and response to intervention	Over 12 months: 5 occupational therapy contacts (4, 90-min home visits, 1 20-min phone call); 1, 90-min physical therapy contact; 3 brief OT telephone consults; Final OT home visit at 10 months	Self-report measures of functional difficulty on IADLs, ADLs, and mobility/transferring	At 6-month assessment, women ($p = .048$) and those >80 year ($p = .001$) in the intervention group improved on mobility outcomes as compared to other demographic groups. At 12 months, relative to other demographic groups, participants >80 ($p = .007$) and those with less than a high school education ($p = .009$) reported improved mobility. Compared to other demographic groups, at 6 months intervention participants who were >80 ($p = .022$), women ($p = .036$), and less educated ($p = .028$) significantly improved self-reported ADLs. Findings remained consistent at 12 months only for individuals >80 ($p = .014$). At 12 months, relative to non-whites, Whites improved significantly more on self-report IADLs ($p = .028$).	Adults ≥ 70 ($N = 285$) At-risk via self-reported functional difficulties
Bédard et al. (2008)	55-Alive/Mature Driving Program (in-class and on-road education intervention) vs. Wait-list control	2 in-class sessions (3–4 h/session), 2 on-road sessions (30–40 min/session)	Safe Driving Knowledge Questionnaire On-road driving evaluation (based on Province of Manitoba procedure)	The intervention group demonstrated a reduction in the number of moving-in-the-roadway errors than the control group ($p < .05$). At site 1 (of 2), the intervention group also showed a significantly larger reduction in starting/stopping/backing errors compared to the control group ($p = .049$).	Canadian adults aged 65–87 ($N = 75$)
Gaines et al. (2011)	CarFit educational program (vehicle assessment by certified technician; vehicle walk-around for mobility conducted by occupational therapist; recommendations and resources given, but no changes made to vehicle) vs. No-contact control	1, 15-min assessment appointment	Driving questionnaire	At 6-month follow-up, the CarFit and no-contact control groups did not differ significantly on reported amount of driving activity or driving behaviors. Only 61% of the CarFit group participants reported following up on the program recommendations.	Older drivers ≥ 60 ($N = 175$)
Morey et al. (2009)	Physical activity counseling (PAC) (Baseline counseling and receipt of NIA exercise workbook, elastic resistance bands, exercise poster; telephone counseling; provider endorsement and telephone messages; quarterly tailored report) vs. Usual primary care (UC) control	Baseline counseling session; 2 telephone sessions/week for 6 weeks, then monthly up to 12 months; monthly recorded encouraging telephone messages from primary care provider over 12 months	Usual gait speed Rapid gait speed 2-min endurance walk Short Physical Performance Battery (SPPB) Late Life Function Instrument Late Life Disability Instrument	Compared to UC, the PAC group significantly increased rapid gait speed ($p = .04$). Compared to the PAC group, UC significantly improved SPPB performance at 12-month assessment ($p = .03$).	Male veterans aged ≥ 70 ($N = 355$)
Mänty et al. (2009)	Motivational physical activity counseling + regular telephone follow-up+ invitation to 2 voluntary lectures vs. No-treatment control	1, 50-min counseling session; Telephone contacts every 4 months over 2 years	Structured interview on self-report mobility limitation 7-point scale of habitual physical activity	There was a significant effect on advanced mobility at two years (OR, 0.84, 95% CI: 0.70 – 0.99; $p = .04$) and a subsequent 1.5 y post-intervention (OR 0.82, 95% CI: 0.68 – 0.99; $p = .04$). Basic mobility effects at post-test were non-significant (OR 0.87, CI: 0.69 – 1.09; $p = .22$).	Finnish adults aged 75–81 ($N = 632$) Sedentary or moderately physically active

von Bonsdorff et al. (2008)	Motivational physical activity counseling + regular telephone follow-up + invitation to 2 voluntary lectures vs. No-treatment control	1, 60-min face-to-face motivational counseling session; Telephone contacts every 4 months over 2 years	Self-report IADL ability Habitual physical activity scale	At 2-year follow-up, the physical activity counseling group showed an increase in physical activity as compared to the control group (OR = 2.0, 95% CI = 1.3–3.0). At 2-year follow-up, IADL disability had increased in both groups ($p < .001$). In participants without disability at baseline, subgroup analyses revealed that the intervention prevented incident disability (RR = 0.68, 95% CI = 0.47–0.97).	Finnish adults aged 75–81 ($N = 632$)
Marottoli et al. (2007b)	2 classroom sessions + 2 on-road sessions (focused on common driving problem areas for older adults) vs. Control education modules (focused on home, vehicle, environmental safety)	2, 4-h classroom sessions 2, 1-h on-road sessions Over 8-week period	36-point on-road driving performance assessment based on Connecticut DMV test 20-point road knowledge test from the AAA Driver Improvement Program 8-point road sign test	On-road driving performance scores improved more in the experimental than control group ($p = .001$). Knowledge test scores improved more in the experimental group compared to control group ($p < .001$).	Adult drivers aged ≥ 70 ($N = 118$) with prescribed driving assessment scores: 40–65 out of 72 possible points. Driving frequency differed between groups at baseline
Bédard et al. (2004)	Canada Safety Council Adaptation of AARP's *55-Alive* educational program vs. Wait-list control	2, 3-h classroom sessions	35-min driving circuit evaluation patterned on the Ministry of Transportation licensing exam	Both the experimental and control groups improved driving performance. There were no significant differences in the driving performance between the groups at posttest ($p = .747$).	Canadian adults aged 55–86 ($N = 65$)
Owsley et al. (2004)	Usual care (comprehensive eye examination) + *Knowledge Enhances Your Safety* education program vs. Usual care control	1, 2-h education session; 1, 1-h review session 1 month later	Police-reported collisions during 2-year follow-up (rate, either person/year of follow-up or person/miles of travel) Driving Habits Questionnaire Driving Perception and Practice Questionnaire subscale	Training produced no significant differences from usual care in crash rate per 100 person-years of driving (RR, 1.08; 95% CI, 0.71–1.64) and per 1 million person-miles of travel (RR, 1.40; 95% CI, 0.92–2.12). The training group reported significantly more avoidance of challenging driving maneuvers and self-regulatory behaviors at follow-up than controls ($p < .0001$).	Adult drivers ≥ 60 ($N = 403$) High risk: visually impaired, had been the driver in a crash within the last year
Owsley et al. (2003)	Usual care (comprehensive eye examination) + 1-on-1 educational program with health educator (topics included vision impairment and safe driving) vs. Usual care control	1, 2-h education session; 1, 1-h review session 1 month later	National Eye Institute Visual Function Questionnaire-25 Driving Habits Questionnaire Driving Perception and Practice Questionnaire subscale	Compared to controls, participants in educational group were significantly more likely to acknowledge less-than-excellent eyesight ($p = .02$), reported more difficulty with visually challenging driving situations ($p < .01$), more frequent performance of self-regulatory practices ($p < .01$), more frequent avoidance of hazardous driving situations ($p < .01$), fewer places traveled to ($p < .05$), fewer trips per week ($p < .02$), and fewer days driven per week ($p < .05$).	Adults aged 60–91 ($N = 365$) High risk: visually impaired, had been the driver in a crash within the last year
Walking exercise					
Parkatti et al. (2012)	Structured Nordic walking program (NW) (walking with poles, similar to ski poles, on indoor track) vs. No-treatment control	18, 60-min session; 2 sessions/week for 9 weeks	Chair Stand Test Arm curls Chair Sit and Reach Back Scratch Test 2-min Step in Place Test 8 ft Up and Go Test Walking Speed Ground Reaction Force	The NW group improved significantly as compared to controls on chair stands, arm curls, stepping in place, sit and reach, back scratch, and up and go ($p < .05$). There were no statistically significant differences between groups on gait analyses.	Finnish adults ≥ 65 ($N = 37$) Sedentary
Malatesta et al. (2010)	Individualized over-ground walking interval training (walking on indoor track) vs. No-treatment control	60–75 min sessions; 3 sessions/week for 7 weeks	Preferred walking speed Submaximal and Maximal Exercise Test Energy cost of walking	As compared to controls, training increased maximal grade% ($p < .001$), preferred walking speed ($p = .003$), and submaximal VO_2, gross/net energy cost of walking, heart rate, and $\%VO_2$ max ($p < .05$).	Adults aged 65–85 ($N = 22$)

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Kalapotharakos et al. (2006)	Progressive, high intensity treadmill exercise vs. No-treatment control	3 sessions/week for 12 weeks; Session duration increased over course of intervention, from 30 to 50 min	1RM knee extension/flexion 6-min walk distance Chair Rise Test Whole body reaction time	The aerobic exercise group improved significantly as compared to controls on all measures ($p < .05$).	Greek adults aged 60–75 ($N = 22$) Sedentary
Marsh et al. (2006)	Over-ground training (walking on flat indoor track) vs. Treadmill training[a] (walking on treadmill)	Identical protocol for both training groups: 18 sessions; 3 sessions/week for 6 weeks Note: training volume not specified, but groups did not differ significantly.	Walking velocity Short Physical Performance Battery (SPPB) Lateral mobility task 400-m walk	The over-ground training group was faster than the treadmill training group on the 400-m walk ($p < .05$). The training groups did not differ significantly on walking velocity, SPPB, or lateral mobility.	Adults aged 69–84 ($N = 20$) Sedentary
Walking + other exercise					
Li et al. (2005)	Cobblestone mat-walking (walking on synthetic mat with raised, stone-like surface, which lay on top of foam pads; in-place and continuous) vs. Traditional walking (walking outside or in lab)[a]	60-min sessions; 3 sessions/week for 16 weeks	Functional reach Static standing Chair stands 50-ft walk Timed Up and Go Perceptions of health-related benefits from exercise	The cobblestone mat-walking group improved more than traditional walkers on functional reach ($p = .01$), static standing balance ($p = .009$), chair stands ($p < .001$), and 50-ft walk ($p = .01$).	Adults aged 60–92 ($N = 108$) Sedentary
Marmeleira et al. (2009)	Dual exercise/problem solving training (e.g., walking in different directions while doing a motor task with the arms; completing a walking course after presentation of an associated auditory signal) vs. No-treatment control	60-min sessions; 3 sessions/week for 12 weeks	Simple and Dual-task reaction time Time-to-Contact (video projection) estimation accuracy, response bias, response time Foot Tap Test Timed Up and Go Functional reach	Training produced significantly greater improvements than no-treatment control on single-task movement ($p = .026$) and response ($p = .035$) times. Compared to controls, training produced significantly improved dual-task reaction time ($p = .018$) and reaction time ($p = .018$). Training and control groups did not differ significantly on any of the psychomotor measures ($p > .05$).	Portuguese adult drivers aged 60–82 ($N = 32$) Sedentary
Shigematsu et al. (2008)	Square-stepping exercise training (walking in a specified pattern across a mat with 40 squares, laid out in a 4x10 pattern) vs. Outdoor supervised walking[a] (long distance walking with increasing daily step count)	Square-stepping: 70-min sessions; 2 sessions/week for 12 weeks Outdoor walking: 40-min sessions; 1 session/week for 12 weeks	Chair stands Leg extension power Single-leg balance (eyes closed) Functional reach Forward/backward tandem walking Standing from lying down position Stepping with both feet Cone walking Vertical jump reaction time Weight transfer time	Compared to traditional walking, square-stepping training significantly improved leg power ($p = .03$), forward/backward tandem walking ($p = .01$), stepping with both feet ($p = .04$), walking around two cones ($p = .03$), and simple ($p < .001$) and choice ($p < .001$) reaction time.	Japanese adults aged 65–74 ($N = 68$)

Trombetti et al. (2011)	Music-based group multi-task exercise program (handling objects or instruments, walking in time with music; resumed usual activities during second half of study period) vs. Delayed intervention control group (usual activities for first half of intervention, completed intervention during second half of study period)	60-min sessions; 1 session/week for 6 months	Single- and dual-task walking and counting conditions: Usual, slow, fast gait; Stride velocity, length, cadence, time variability 1- and 2-legged stance Timed Up and Go Simplified Tinetti Test	At 6-month assessment: under the single-task condition, as compared to controls training increased usual gait velocity ($p = .03$) and stride length ($p = .02$). Under the dual-task condition, as compared to controls, training increased stride length ($p = .04$) and decreased stride length variability ($p = .002$). Compared to delayed intervention controls, training improved stance time for the 1-legged stance task ($p = .006$) and decreased mediolateral angular velocity ($p = .02$). Trained participants performed significantly better than controls on the Simplified Tinetti Test ($p < .001$) and Timed Up & Go Test ($p = .02$). At 12-month follow-up: improvements on dual-task gait variability, 1-legged stance duration, and the Tinetti Test were retained.	Swiss adults aged ≥ 65 ($N = 134$) At increased risk of falling
You et al. (2009)	Dual-task cognitive motor intervention (DT) (simultaneous walking and recall/computing tasks) vs. Placebo control (walking to classical music)	18, 30-min sessions; 5 sessions/week over 6 weeks	Gait velocity Gait stability Anterior-posterior and medio-lateral center of pressure deviations	No significant intervention-related changes in gait velocity and stability were observed between groups ($p > .05$). Neither group showed significant changes in center of pressure deviation ($p > .05$).	Adults aged 64–84 ($N = 13$) with a history of falls
Kovacs and Williams (2004)	Dynamic multisensory training (DMT) (walking on firm or foam surface; with eyes open or closed; with head neutral or tilted) vs. Walking control (WC) (traditional walking) vs. No-treatment control	48 trials, 5 consecutive days (number of hours not specified)	Toe clearance Heel clearance Horizontal shear (braking) force Obstacle crossing speed Gait velocity	Group x time repeated measures multivariate analysis revealed no significant differences between the DMT group, walking control group, and normal activities control group ($F(12, 24)$ $p = .12$).	Adults (M age = 82.5 y) ($N = 30$)
Dance exercise					
Granacher et al. (2012)	Salsa dancing vs. No-treatment control	16, 60-min sessions; 2 sessions/week for 8 weeks	1-legged sanding balance Dynamic postural control Walking velocity, time, stride length Countermovement jump power	Compared to controls, the salsa dancing group significantly increased stride velocity ($p = .002$) and stride length ($p = .006$) and decreased stride time ($p = .005$).	Swiss adults aged 63–82 ($N = 28$)
Hopkins et al. (1990)	Aerobic dance (stretching, walking, progressive dance movements to music) vs. Wait-list control	50-min sessions; 3 sessions/week for 12 weeks	Half-mile walk Modified Sit-and-Reach Sit-and-Stand Test Chair Agility Test "Soda Pop" Test 1-ft stand	The aerobic dance group was significantly different from controls on cardiorespiratory endurance ($p < .01$), strength/endurance ($p < .01$), balance ($p < .01$), flexibility ($p < .05$), and agility ($p < .01$). The exercise group was not different from controls on motor control/coordination.	Adult women aged 57–77 ($N = 53$)

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Balance, flexibility, and strength					
Watt et al. (2011)	Hip extension stretching vs. Shoulder abductor stretching control[a]	4-min stretching session; 2 sessions/day for 10 weeks	Passive hip extension range of motion Dynamic peak hip extension Peak anterior pelvic tilt Stride length Walking gait speed	The hip extension group, but not the control group, significantly improved passive hip extension range of motion ($p = .007$) and peak anterior pelvic tilt ($p = .047$). Control participants improved only in the domain of decreased anterior pelvic tilt ($p = .013$). Of treatment group participants who began the study with limited walking, peak hip extension, showed significantly increased stride length ($p = .019$), peak hip extension ($p = .012$), and decreased anterior pelvic tilt ($p = .006$) while walking.	Adults aged 65–87 ($N = 82$)
Bean et al. (2004)	InVEST training (progressive resistance training, e.g., toe raises, chair stands, chest press, with weighted vest) vs. Slow-velocity, low-resistance training control[a] (using body or limb weight for resistance)	30-min sessions; 3 sessions/week for 12 weeks	Leg power Leg strength Short Physical Performance Battery (SPPB) Standing balance Timed 2.4-m walk Chair-5 time	InVEST participants improved significantly more than controls on chair stand ($p = .019$) and double leg press power between 75% and 90% of 1RM ($p < .05$). InVEST and control participants alike demonstrated significant improvements in Chair Stand and SPPB ($p < .05$), while InVEST participants showed additional improvements on gait speed ($p = .006$) and unilateral stance time ($p = .028$).	Adult women aged ≥ 70 ($N = 21$) with SPPB score 4–10
Helbostad et al. (2004)	Home training (HT) (functional balance and strength exercises + 3 group meetings) vs. Combined training (CT)[a] (group training sessions + home exercises)	HT: twice-daily in-home training CT: twice-daily in-home training and twice-weekly group training Duration: 12 weeks for both groups	Walking speed Walking while changing direction Sit to Stand Timed Pick Up Time Up and Go Maximum step length Isometric muscle strength Posturography	At 3 months, there was significant overall improvement on all functional tasks (walking speed, figure 8, timed up and go, maximum step length, timed pick up, and sit to stand ($p < .02$), but no significant differences between groups. For both groups, only gait speed remained significantly better after 9 months.	Norwegian adults aged ≥ 75 ($N = 77$) Sedentary, frail
Ramsbottom et al. (2004)	Progressive strength training (seated and non-seated exercises) vs. Wait-list control	2 sessions/week for 24 weeks (number of hours/session not specified)	Postural sway Functional reach Leg extensor power (1RM) Timed Up and Go	No significant differences between groups at 12 weeks. At the end of the 24-week intervention, as compared to controls, the training group had significantly increased leg power ($p < .01$), functional reach ($p < .01$), and timed up and go ($p < .05$).	English adults aged >70 ($N = 16$)
Li et al. (2004)	Tai Chi (24-form Yang style focusing on controlled breathing, multidirectional weight shifting, awareness of body alignment, multi-segmental movement coordination) vs. Stretching exercise control[a] (Seated and standing stretches, deep breathing, relaxation)	60-min sessions; 3 sessions/week for 26 weeks (both groups)	Berg Balance Scale (BBS) Dynamic gait index (DG) Functional Reach (FR)	The Tai Chi group performed significantly better than the stretching control group on all 3 functional balance measures during the intervention ($p < .001$ BBS; $p < .001$ DG; $p < .001$ FR). Both groups showed significant decline on all scores from immediate post-test to 6-month follow up (p<.001), however, the Tai Chi group's decline was significantly slower than the control group on all measures.	Adults aged 70–92 ($N = 256$) Sedentary

Vincent et al. (2002)	High intensity resistance training (trained at 80% 1RM on weight machines) vs. Low intensity resistance training (trained at 50% 1RM on weight machines) vs. No-treatment control	3 sessions/week for 24 weeks for both training groups (number of hours/session not prescribed, but no significant differences in training volume ($p \geq .05$) between groups).	Lumbar extension Stair climb 1RM: leg press, leg curl, knee extension, chest press, seated row, overhead press triceps dip, biceps curl Muscle endurance	Both resistance training groups significantly increased absolute 1RM total strength compared to controls ($p \leq .05$) but were not significantly different from one another ($p \geq .05$). Compared to controls, high and low intensity training groups similarly decreased time to ascend one flight of stairs ($p < .05$). The percent change in stair climb time for the low intensity resistance group was significantly greater than for controls ($p < .05$). Leg and chest press muscle endurance increased significantly ($p \leq .05$) and similarly in both training groups and significantly more than in controls ($p < .05$).	Adults aged 60–83 ($N = 62$)
Barrett and Smerdely (2002)	Community-based progressive resistance training (PRT) (free weights) vs. Community-based stretching control program[a] (non-specific exercise program focusing on flexibility, with light cardiovascular and strengthening exercises)	60-min/session; 2 sessions/week for 10 weeks for both training groups	Quadriceps and bicep strength Functional reach Sit to Stand Test Step Test 10-m fast walk	Compared to stretching, the PRT group showed significantly greater improvements on right ($p < .003$) and left ($p < .003$) quadriceps strength, left side bicep strength ($p < .003$), functional reach ($p < .003$), and the step test ($p < .003$).	Adults aged ≥ 60 ($N = 40$)
Greendale et al. (2000)	3% of body weight vest (vest worn during usual activities) vs. 5% of body weight vest (vest worn during usual activities) vs. No-vest control	3-week break-in period of progressively more vest-wearing time; Vest-wearing time set at 2 h/day, 4 days/week, for 24 additional weeks for both training groups	Bilateral isokinetic, isometric, and endurance tests 8- and 50-ft walk (normal pace) 5 timed chair stands Timed stair climb 1-leg stand (eyes open) Functional reach	The weighted vest intervention had no significant effect on any strength or physical performance measurement.	Adults aged ≥ 60 ($N = 62$)
Taaffe et al. (1999)	High intensity resistance training (weight machines) 1 day/week vs. 2 days/week vs. 3 days/week vs. No-treatment control	1, 2, or 3 sessions/week for 24 weeks (number of hours/session not specified)	1-RM: bench press, military press, lat pull-down, biceps curl, leg press, knee extension/flexion, back extension Timed Chair Rise 6-m tandem walk	All training groups improved muscle strength significantly more than controls ($p < .01$) and were not significantly different from each other ($p > .05$). Once-weekly progressive resistance training was enough to significantly improve muscle strength ($p < .01$) and timed chair rise ($p < .01$).	Adults aged 65–79 ($N = 46$)
Rosie and Taylor (2007)	In-home, repeated, slow sit-to-stand exercise using *GrandStand System* (GS) (biofeedback monitor showing number of repetitions) vs. In-home knee extension exercise (KE)[a] (progressively more weighted knee extensions)	GS: 10 repetitions/day increased by 5 repetitions up to a maximum of 50; 6 weeks KE: 10 repetitions/day with progressively greater load and repetition count up to maximum of 2 sets of 10 repetitions with 4kg ankle weights; 6 weeks	Comfortable gait velocity 30-second chair stand Berg Balance Scale (BBS) 15-second step test	No significant between-group differences were observed. The GS group significantly improved BBS scores ($p = .001$) from pre- to posttest.	New Zealand adults aged ≥ 80 ($N = 66$) Sedentary, mobility-limited

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Marottoli et al. (2007a)	Physical-therapist-guided exercise program (PT) (exercises targeting driving-related physical abilities, e.g., cervical, trunk and axial rotation; shoulder flexion and abduction) vs. In-home educational program control (EC) (review of home safety issues, fall prevention, and vehicle care)	PT: 15-min sessions; 1 session/day, 7 days/week for 12 weeks; 12 weekly visits from physical therapist to review and monitor intervention EC: monthly in-home education modules presented by trained research assistants	On-road driving assessment: 36-item scale of driving maneuvers and traffic situations Evaluator's overall rating Critical errors	At 3 months, change in road test scores in the PT group (M = 2.43 points) was significantly greater than in the EC group (p = .03). Drivers in the intervention group committed 37% fewer critical errors (p = .08) than EC. There were no significant differences in evaluators' overall ratings (p = .29).	Adult drivers aged ≥ 70 (N = 178) with some mobility impairment
Taylor et al. (2012)	Tai Chi once/week (TC1) (group class based on modified 10-form sun style) vs. Tai-Chi twice/week (TC2) vs. Low-level exercise active control (LLE) (seated stretching, low-level strength and cardio exercises)	60-min sessions; 1 (TCI, LLE) or 2 (TC2) sessions/week for 20 weeks	Timed Up and Go The Step Test 30-second Chair Stand Test	There were no significant differences among groups on any mobility measures. All groups showed improved Step Test (p < .001 right and left leg) and 30-second Chair Stand (p < .001) but not Timed Up and Go (p = .54).	New Zealand adults aged ≥ 65 (≥55 years if Maori or Pacific Islander to account for ethnic disparities in health) (N = 684) fallers or at risk for falling
Bird et al. (2011)	Resistance training first (RT) (progressive weight lifting with pin-loaded machines, free weights, and body weight) vs. Flexibility training first (FT) (common stretches focusing on major muscle groups) vs. No-treatment control (major focus of this paper was differences between people who continued the interventions and those who discontinued)	RT: 2–3 sets of 10–12 repetitions/session FT: 40–45 min/session For both groups: 3 sessions/week for 16 weeks (2 sessions at community gym, 1 session at home) Week 17–20: 4-week washout period Week 21–36: alternate training program; 3 sessions/week for 16 weeks 12 month follow-up period	10-times Sit-to-Stand Timed Up and Go Step Test Medio-lateral sway range Sway velocity (eyes open, closed) Max torque (right and left knee flexion/extension)	Compared to controls, RT and FT made significant gains in strength immediately post-intervention (p < .05) but these differences in strength were no longer significant between exercise groups and controls at 12-month follow-up. Compared to controls, RT and FT made significant gains in timed up and go immediately post-intervention (p = .008) and this difference remained at follow-up (p = .021). Compared to those who discontinued exercise training, Individuals who continued the program independently after the intervention period performed significantly better on the Step Test at 12-month follow-up (p = .009).	Adults aged 60–75 (N = 33) Sedentary
Zettergren et al. (2011)	Kripalu style yoga (breathing, body awareness, physical poses in supine, seated, and standing positions, meditation) vs. No-treatment control	80-min sessions; 2 sessions/week for 8 weeks	Activities-Specific Balance Scale (w/assistance) Monofilament testing for lower extremity sensation 4-square Step Test Berg Balance Scale Timed Up and Go Gait speed (self-selected & fast) Timed rise from floor	Kripalu yoga produced significant improvements in balance scores (p < .003) and fast walking speed (p < .031). No other significant changes were noted. Only paired t-tests were reported.	Adults aged >65 (N = 16)

Avelar et al. (2010)	Aquatic muscle endurance training (AQ) (walking, stretching, muscle endurance exercises in pool) vs. Non-aquatic muscle endurance training (NA) (walking, stretching, muscle endurance exercises in gym) vs. No-treatment control (received weekly phone calls to check on status)	40-min sessions; 2 sessions/week for 6 weeks	Dynamic Gait Index (DGI) Berg Balance Scale (BBS) Tandem Gait Test Gait Speed Test	Compared to controls, the AQ group showed significantly better DGI ($p = .001$) and BBS ($p = .007$). The NA group also had significantly better DGI ($p = .002$) and BBS ($p = .010$) than the control group. AQ and NA groups did not differ significantly on any of the outcomes.	Brazilian adults aged 60–80 ($N = 36$) with history of falls
Bean et al. (2009)	InVEST training (progressive resistance training, e.g., toe raises, pelvic raises, chair stands, etc. with weighted vest) vs. National Institute on Aging's strength training program (NIA)[a] (11 exercises using barbells or ankle weights with progressively more weight)	45–60-min sessions; 3 sessions/week for 16 weeks	Limb power Limb strength Limb velocity Short Physical Performance Battery (SPPB)	Compared to the NIA program, InVEST training produced significantly greater gains in limb power ($p = .02$), but not strength. Both InVEST and NIA training significantly improved limb 1RM ($p < .001$), limb velocity ($p < .001$), and performance on the SPPB ($p < .001$) and did not significantly differ from one another. Post hoc analysis of baseline leg velocity suggests InVEST training may be more functionally beneficial than NIA training for individuals with baseline limb velocity impairment.	Adults ≥ 65 ($N = 138$) Somewhat mobility-limited
Bird et al. (2009)	Resistance training first (RT) (progressive weight lifting with pin-loaded machines, free weights, and body weight) vs. Flexibility training first (FT)[a] (common stretches focusing on major muscle groups)	RT: 2–3 sets of 10–12 repetitions/session FT: 40–45 min/session For both groups: 3 sessions/week for 16 weeks (2 sessions at community gym, 1 session at home) Week 17–20: 4-week washout period Week 21–36: alternate training program; 3 sessions/week for 16 weeks 12 month follow-up period	Sway velocity (eyes open, closed) Mediolateral sway range Timed Up and Go 10 times sit-to-stand Step Test 30-second balance test (eyes open, eyes closed) Lower limb strength Max torque (right and left knee flexion/extension)	RT increased lower limb strength ($p < .001$) to a significantly greater degree than FT ($p < .001$). FT led to significant improvements in mediolateral sway range with eyes open and eyes closed ($p = .007$). Both RT and FT significantly improved performance on Sit to Stand, Timed Up and Go, and the Step Test ($p \geq .006$), but did not differ significantly from one another ($p > .05$).	Adults ($M = 66.9$ y) ($N = 32$) Sedentary
Cristopoliski et al. (2009)	Stretching exercise vs. No-treatment control	3 sessions/week for 4 weeks	Temporal and spatial gait analysis	The stretching group improved significantly more ($p < .05$) than controls on all measures of flexibility and the following gait characteristics: stance phase duration, swing phase duration, and double support phase duration. Compared to controls, the stretching group significantly increased step length, gait velocity, anterior and lateral pelvis tilt, and pelvis rotation ($p < .05$).	Brazilian adult women (Stretch: $M = 65.9$ y; Control: $M = 65.4$ y) ($N = 20$)

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Reid et al. (2008)	High-velocity progressive resistance training (HV) (using pneumatic resistance training equipment) vs. Slow-velocity progressive resistance training (SV) (using pneumatic resistance training equipment) vs. Stretching control (SC) (lower extremity range of motion and flexibility exercises)	HV & SV: 3 sets of 8 repetitions/session; 3 sessions/week for 12 weeks SC: 2 sessions/week for 12 weeks (time/session not specified)	1RM: knee extension (KE) and leg press (LP) Peak power Total leg lean mass	Compared with controls, 1RM KE (but not LP) improved significantly in both the HV group and SV group ($p < .01$). Intervention groups did not differ significantly from one another ($p > .05$). Compared to controls, KE power and specific peak power at 40% and 70% 1RM improved significantly from baseline in HV and SV ($p < .01$; $p \leq .004$), and training groups were not significantly different from one another ($p > .05$). LP specific peak power gains were significantly greater in HV training participants (36%) compared to SV participants (19%) and stretching controls (18%) ($p < .05$). Improvements in LP specific peak power at 70% were significantly greater in the HV group (46%) than in the SV group (20%) and control group (14%) ($p < .05$).	Adults aged 65–94 ($N = 57$) with mild-moderate mobility impairments
Christiansen (2008)	In-home stretching program (hip and ankle stretching, using counter for support) vs. No-treatment control	9 min/session; 2 sessions/day for 8 weeks	Maximal joint range of motion Hip extension motion Maximum ankle dorsiflexion Gait parameters during freely chosen and set gait speed (stride length, joint displacement)	Compared to controls, the stretching group significantly increased composite hip and knee extension ($p = .023$), ankle dorsiflexion ($p = .02$), and freely chosen gait speed ($p = .016$).	Adults aged 62–82 ($N = 37$)
Symons et al. (2005)	Isometric training only (IT) vs. Isokinetic-concentric only (IC) vs. Isokinetic-eccentric only (IE)[a] All groups trained on Biodex dynamometer	For each leg, 3 sets of 10 repetitions/session; 3 sessions/week for 12 weeks	Peak isometric, isokinetic (concentric & eccentric) knee extensor strength Concentric work Concentric power Stair ascent, descent Gait speed	IT, IC, and IE training all significantly improved peak isometric and isokinetic, concentric and eccentric strength ($p < .01$) and did not differ significantly from one another ($p > .05$). There were no main effects of training group, but each group made the greatest gains in the specific type of muscle contraction that was part of their training. All training groups significantly decreased step time ($p < .03$) and increased peak concentric work and power ($p < .01$). Groups did not differ significantly on step time improvement ($p > .05$), but the IC group made significantly greater peak concentric work gains compared to IT and IE ($p < .02$) and peak concentric power compared to IT ($p < .03$).	Adults aged 65–87 ($N = 30$)

Lamoureux et al. (2003)	Lower body progressive resistance training (PRT) (hip flexion/extension, knee flexion/extension, ankle plantar flexion on pin-loaded weight machines) vs. Normal activity control group	Weeks 1–12: 3 sessions/week Weeks 13–24: 2 sessions/week (time/session not specified)	Strength (1RM) Gait kinematics while stepping over obstacle; negotiating a raised surface (at 3 levels of difficulty): Stride length Stride duration Crossing stride velocity Maximum vertical heel clearance Toe, heel distance Hip, knee, ankle angles Toe vertical descending velocity	PRT participants improved mean strength significantly more than controls over time ($p < .05$). Compared to controls, the PRT group significantly increased stride length, decreased stride duration, increased vertical heel obstacle clearance, and increased crossing stride velocity for the stepping over tasks and for the raised surface tasks at all levels of difficulty ($p < .05$). PRT and controls group differed significantly on peak vertical force after the intervention ($p < .05$), the PRT group making significant improvements while controls did not change. PRT significantly reduced toe distance to the obstacle and increased heel distance after crossing on both tasks ($p < .05$); significantly decreased knee and ankle ankles on both tasks ($p < .05$); significantly decreased vertical toe descending velocity on the stepping over task at all difficulty levels and at the most challenging level on the raised surface task ($p < .05$).	Australian adults 62–88 ($N = 45$) Sedentary
Combination					
Wolfson et al. (1996)	Balance (B) (maintain balance on foam surface during visual and manual perturbations) vs. Strength (S) (progressive lower extremity weight lifting with sandbags or traditional weight machines) vs. Balance + Strength (B + S) vs. Education control (EC) (fall prevention and stress management education)	B, S: 45-min sessions; 3 sessions/week for 12 weeks B + S: 45-min balance training + 45 min strength training; 3 times/week for 12 weeks All groups (control included) participated in additional 6-month maintenance period of Tai Chi training	Loss of balance during sensory organization testing (LOB) Functional base of support (FBOS) Single stance time (SST) Voluntary limits of stability Summed isokinetic torque of 8 lower extremity movements (ISOK) Usual gait velocity (GVU).	Compared to EC, the B training group significantly improved balance scores (LOB; $p = .02$). B and B + S groups improved significantly more than EC on FBOS ($p = .02$) and SST ($p = .02$). S and B + S training led to significantly greater gains in ISOK than the EC group ($p = .02$). The B+ S group showed significant gains in GVU at post-maintenance assessment ($p < .05$).	Adults aged ≥ 75 ($N = 110$)
Nelson et al. (2004)	Home-based progressive strength, balance, general exercise intervention (EX) (chair stands, knee/hip extension, etc. + enjoyable general exercise) vs. Home-based nutrition education control (EC) (goal to increase participants' daily serving of fruits, vegetables, and calcium-rich food)	EX: 6 home visits in first month; 1 visit/month for remainder of intervention; 120 min of other activities/week (walking, gardening, etc.); over 6 months EC: 2 home visits with registered dietitian in first month; 1 visit/month for remainder of intervention; 6 months	Physical Performance Test (PPT) EPESE Short Physical Performance Battery(SPPB) 1RM (legs, arms, shoulders) Tandem walk 1-legged stand Maximum gait speed 6-min walk	Compared to controls, the EX group improved significantly on the PPT ($p = .02$), SPPB ($p = .02$), tandem walk ($p = .0002$) and 1-legged stand ($p = .007$). The exercise intervention group significantly improved on the PPT ($p \leq .05$) and SPPB ($p \leq .05$), while the control group declined (non-significantly) on both measures. Six-minute walk performance did not change significantly in either group.	Adults aged ≥ 70 ($N = 70$) with moderate lower body functional impairment

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Uemura et al. (2012)	Dual-task switching exercise (DSE) (performing start/stop, weight-shifting, direction changes while performing cognitive tasks) vs. Steady state walking training (SS)[a] (walking on straight walkway while performing cognitive task) Note: groups performed predominantly the same exercises (stretching, agility training, strength training), then 5 min of differential training	35-min sessions; 1 session/week for 24 weeks	10-m walk time Gait initiation reaction time Backward center of pressure displacement (COP)	DSE and SS groups showed significant improvement of steady-state walking time under the dual-task condition ($p = .018$) and did not differ significantly ($p > .05$). The DSE group was significantly more effective than SS in improving both the reaction time ($p = .015$) and backward COP displacement ($p = .011$) during gait initiation under the dual-task condition. There were no significant differences between the groups in steady-state gait and gait initiation performance under the single-task condition.	Adults aged ≥ 65 ($N = 15$) Sedentary
Yang et al. (2012)	Balance and strength home exercise program (based on Otago balance, strength, and graduated walking program) vs. No-treatment control (fall prevention educational book provided; usual activities)	50-min sessions; 5 sessions/week for 6 months	Dynamic bilateral stance Step Test 5-Time Sit to Stand Lower limb strength Walking speed Modified Clinical Test of Sensory Interaction on Balance Limits of stability Rhythmic weight shift Walk Across Test Step Quick Turn Test Sit-to-stand stability Functional reach	The intervention group improved significantly more than controls on functional reach ($p < .001$), the Step Test ($p < .001$), hip abductor strength ($p = .001$), and gait step width ($p < .001$). There were non-significant trends for improvement on most other measures. 23.7% of intervention participants improved their balance enough to no longer be classified as having mild balance dysfunction, a significantly higher proportion than control participants (4.8%; $p = .003$)	Australian adults aged ≥ 65 ($N = 225$) with mild balance dysfunction or balance concerns
Faber et al. (2006)	Functional walking (FW) (balance, mobility, transfer training, e.g., standing up from a chair, reaching and stepping forward and sideward, heel and toe stands, etc.) vs. Balance training (BT)[a] (Tai Chi) vs. No-treatment control	90-min sessions (including 30-min social component); 1 session/week for 4 weeks; then 2 sessions/week for 16 weeks	Performance Oriented Mobility Assessment (POMA) Physical Performance Score: walking speed, timed chair stands, Timed Get Up and Go FICSIT-4 Balance Test Groningen Activity Restriction Scale (GARS)	FW and BT groups were combined because they had comparable intervention effects on the POMA, physical performance score, and GARS. The exercise group improved POMA scores significantly more than controls ($p < .01$). Post hoc analyses revealed the frail condition to be a significant modifier of the physical performance measure ($p < .001$) and to a lesser extent, the POMA ($p = .073$). Frail participants in the exercise group declined in physical performance scores ($p = .039$) and remained the same on the POMA ($p = .369$), while pre-frail participants improved their physical performance score ($p < .001$) and POMA ($p = .001$).	Dutch adults aged 63–98 ($N = 208$) Pre-frail and frail

Pahor et al. (2006)	Physical activity training (PA) (aerobic, strength, balance, and flexibility exercises) vs. Successful aging intervention (SA) (health education control)	PA: weeks 1–8: 40–60-min sessions; 3 supervised sessions/week Weeks 1–10: 1 session/week of group behavioral counseling Weeks 9–24: 2 supervised sessions/week; 3 or more home sessions/week Week 25–52: maintenance of home-based intervention, optional supervised session, monthly telephone contacts SA: weeks 1–26: 1 group session/week. After week 26, once-monthly meetings Upper extremity stretching for last 5 min of each meeting	Short Physical Performance Battery (SPPB) 400-m walk (without sitting)	The PA training group improved significantly more than SA on the Short Physical Performance Battery ($p < .001$). 400-m walk speed remained approximately stable in PA group and declined in SA ($p < .001$).	Adults aged 70–89 ($N = 424$) Sedentary, at-risk for disability
Beling and Roller (2009)	A Matter of Balance small-group balance program (MOB) (standing balance activities, stretching, walking an obstacle course) vs. Wait-list control	60-min/session; 3 sessions/week for 12 weeks	GAITRite system measurements: Gait cadence, stride length, velocity, base width, swing, double support, stance Manual muscle testing Range of Motion Sensory Organization Test (SOT) Motor Control Test Motor Adaptation Test Timed Up and Go Test Berg Balance Scale (BBS)	There was a significant group x time interaction on BBS scores, with the MOB group significantly improving performance ($p \leq .05$) and the control group declining in performance over time. There were no other significant within- or between-subjects main effects on the BBS, Timed Up and Go, SOT, or gait measures. Compared to controls, the MOB group showed a significant increase in bilateral dorsiflexion ($p \leq .05$) and greater knee extension ($p \leq .05$).	Adults aged ≥ 65 ($N = 19$)
Donat and Ozcan (2007)	Supervised exercise training (balance training, strengthening and stretching of the lower limbs, increasing flexibility, posture exercises and functional activities + walking) vs. Unsupervised home exercise training (same protocol, unsupervised)	45–50-min sessions; 3 sessions/week for 8 weeks 10 min/day walking	Visual Analog Scale Quadriceps muscle dynamometer Sit and Reach Test Timed Up and Go 1-leg & tandem standing Berg Balance Scale Knee position sense	Both the supervised and unsupervised home exercise groups showed significant improvement in balance, functional mobility, and flexibility ($p < .05$). Compared to unsupervised training, supervised training showed additional significant benefits to both strength and proprioception ($p < .05$).	Turkish adults ≥ 65 ($N = 32$) nursing home residents, ambulatory and self-care independent, sedentary
de Vreede et al. (2005)	Functional task exercise (FT) (aerobic warm-up, core exercises, flexibility training; resistance, repetitions, distance slowly increased) vs. Resistance training (RT) (aerobic warm-up, different core exercises than FT group, flexibility training) vs. No-treatment control	60-min sessions; 3 sessions/week for 12 weeks	Assessment of Daily Activity Performance (ADAP) Timed Up and Go Test Isometric knee extensor strength Isometric elbow flexor strength Leg extension power	The FT group showed a mean improvement of 6.8 points on the ADAP, increasing their scores significantly more than the RT group ($p = .007$) and the control group ($p < .001$), an improvement that was retained 6 months after the conclusion of training ($p = .002$). The RT group significantly increased isometric knee extension and elbow flexion compared with the FT group ($p = .003$ and $p = .03$, respectively) and the control group ($p = .003$ and $p = .04$, respectively).	Dutch women aged ≥ 70 ($N = 74$)

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Bean et al. (2002)	Stair climbing with weighted vest (SCE) vs. Standardized walking program (WALK)[a] (self-paced walking on the street or indoors)	SCE: 12 flights of stairs/session; 3 sessions/week for 12 weeks WALK: 3 sessions/week for 12 weeks; 15 min/session for week 1, then increased by 10 min/week up to a maximum of 45 min/session	Leg power and strength Tandem gait Chair Stand Time Stair Time Habitual and maximal gait velocity Short Physical Performance Battery (SPPB) 6 min walk test	A 17% increase in the SCE group's double leg press peak power was significantly greater than the WALK group ($p = .013$). WALK significantly improved 6-min walk in comparison to SCE ($p = .037$). Though SPPB performance improved approximately three times more in SCE than WALK participants (12.1% vs. 3.6%), these differences were not significant ($p = .184$), and no other physical performance comparisons were significant between groups. More seriously mobility-limited SCE participants significantly improved stair climb time ($p < .05$) and SPPB performance ($p < .05$). Stair climb time was also significantly improved from baseline in the WALK group ($p < .05$), as was habitual gait speed ($p < .05$).	Adults aged ≥ 65 ($N = 40$) with mobility limitations
Earles et al. (2001)	Power training (training rapid movements of knee, hip extensors/flexors under load + 45 min extra exercise weekly) vs. Walking	Power training: 60-min classes; 3 classes/week for 12 weeks Walking: 30-min/day, 6 days/week for 12 weeks	Leg press power Leg extensor strength 6-min walk distance Semi-tandem stance 1-leg stance Chair rises 8-ft walk Short Physical Performance Battery(SPPB) Physical Performance Test	Compared to walking, power training significantly improved leg press power ($p = .0001$) and leg press power at levels of resistance of 30–70% of body mass ($p \leq .01$). Neither group improved significantly on any measure of functional task performance.	Adults aged ≥ 70 ($N = 43$)
Rooks et al. (1997)	Self-paced resistance training (RT) (stair climbing with progressively weighted belt, seated knee extension, standing plantar flexion, knee raises, and bicep curls) vs. Walking (self-paced walking in parking area, wooded path, or indoors depending on weather) vs. Wait-list control	RT: 3 sets/exercise/session; 3 sessions/week for 10 months Walking: 12 min, gradually increasing to 45 min/session; 3 sessions/week for 10 months	1RM bilateral knee extension Dominant hand grip strength Balance field test battery Right lower extremity simple reaction time Timed stair climb Pen pickup task	Compared to controls, RT and walking groups improved tandem stance ($p < .05$) and stair climbing speed ($p < .05$). Compared to walking and control groups, RT improved lower extremity strength ($p < .05$) and 1-legged stance with eyes open ($p < .05$). Compared to controls, the RT group made gains in 1-legged stance with eyes closed ($p < .05$), simple reaction time ($p < .05$), and pen pickup task ($p > .05$).	Adults aged 65–95 ($N = 131$)

Freiberger et al. (2012)	Strength and Balance (SB) vs. Fitness (F) (strength, balance, endurance) vs. Multifaceted (MF)[a] (strength, balance, fall risk education) vs. No-treatment control	32, 60-min sessions over 16 weeks	Timed Up and Go Timed Up and Go with Cognitive Load Romberg's Test Chair Rise Test 10-m walking speed	Compared to controls, all experimental groups improved timed up and go at 6 months ($p < .05$), while only the F group significantly improved timed up and go with cognitive load ($p < .05$). Relative to controls, the SB and F groups improved Chair Rise performance at 6 months ($p < .05$) normal pace walking speed at 24 months ($p < .05$), and Romberg's test at 12 months ($p < .05$). Relative to controls, the F group significantly improved fast pace walking speed ($p < .05$), and the MF group showed improvement on Romberg's test at 24 months	German adults aged 70–90 ($N = 280$) had fallen in the past 6 months or had a fear of falling
Huang et al. (2011)	Cognitive behavioral intervention + Tai Chi (CT) (Restructuring misconceptions about fears of falling + Yang-style Tai Chi) vs. CB alone (CB) (Restructuring misconceptions about fears of falling) vs. Usual care control	CT: 60-min sessions; 5 sessions/week for 8 weeks CB: 60–90-min sessions; 1 session/week for 8 weeks	Tinetti Mobility Scale	At 5-months post-intervention the CT group had a higher mean mobility score than the CB and control groups ($p < .001$). Relative to CB and controls, the combined CT showed a greater mean gait score ($p < .001$) and mean balance score ($p < .001$).	Taiwanese adults aged ≥ 60 ($N = 176$)
Martins et al. (2011)	Aerobic training (AT) (low-impact rhythmic walking and stepping sequences with changes in direction + upper body arm movements) vs. Strength training (ST) (8 callisthenic exercises focusing on major muscle groups, using elastic bands) vs. No-treatment control	AT: 45 min/session; 3 days/week for 16 weeks ST: 1 set of 12 reps of each exercise in week 1 progressed to 3 sets of 12 repetitions by the end of the intervention	Senior Fitness Test Battery: Chair stands Arm curls Chair Sit and Reach Back scratch 8-ft Up and Go 6-min walk test	Relative to controls, the AT group improved performance on chair stand ($p < .01$), arm curl ($p < .01$), chair sit and reach ($p < .01$), 6 min walk test ($p < .05$) and 8-ft up and go ($p < .01$). Compared to controls, the ST group had significantly better scores on chair stand ($p < .01$), arm curl ($p < .01$), 6 min walk test ($p < .05$) and the 8-ft up and go ($p < .05$).	Portuguese adults aged 65–95 ($N = 78$)
VanSwearingen et al. (2011)	Task-oriented motor sequence learning exercise (TO) (task-oriented stepping and walking patterns, progressively faster, higher amplitude or accuracy of performance required before moving on to new patterns) vs. Impairment-oriented, multicomponent exercise (IO)[a] (gentle stretching, lower extremity strength training, balance exercises, and endurance training on seated stair climber or stationary bike)	2 sessions/week for 12 weeks	Gait speed over instrumented walkway Accelerometer-measured daily physical activity Gait Efficacy Scale (GES) Late-Life Function and Disability Instrument (basic and advanced lower extremity components)	Compared to the IO group, the TO group showed significantly greater improvement on the GES ($p = .008$), the Late Life-FDI-Basic lower extremity component ($p = .038$), and greater reduction of the energy cost of walking ($p = .0002$).	Adults ($M = 77.2$ y) ($N = 47$) with slow and variable gait. [a]Baseline differences present, despite random assignment

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
Halvarsson et al. (2011)	Progressive balance group exercise (practice of activities required for independent daily living, e.g., balance while sitting, standing and walking; Single (ST) and Dual (DT) conditions at 5 levels of demand) vs. Wait-list control	45 min/session; 3 sessions/week for 12 weeks	Step Execution Test under ST and DT conditions Gait parameters at usual and fast speed measured by GAITRite system: velocity; cadence; step length; double support	Compared to controls, under preferred walking speed conditions, the intervention group improved walking cadence during ST ($p = .03$) and trended toward decreased double support during ST ($p = .052$). Relative to controls, under the fast velocity conditions, the intervention group increased walking velocity ($p = .004$) and cadence ($p = .001$), and trended toward decreased double support ($p = .051$).	Swedish adults aged ≥ 65 ($N = 59$) with fear of falling or falling experience within the past year
Hartmann et al. (2010)	Walking, dancing, balance exercises, resistance training, stretching, and relaxation exercise Insole group (IG) (wore MedReflex shoe insoles during exercise) vs. Training group (TG) (same exercise program without insoles) vs. No-treatment control (C)	Both intervention groups: 2 sessions/week for 12 weeks (session duration not specified)	Gait analysis (single and dual task conditions) at typical speed Muscle power measurements (knee, ankle)	The IG and TG groups significantly improved gait parameters 1–12% and 1–8%, respectively ($p < .05$). IG and TG groups trended toward significant gains on measures of knee and ankle muscle power (15–79% and 20–79%, respectively). The intervention groups did not differ significantly in their improvements, while controls showed a trend toward deterioration (0–75% for gait parameters and 7–714% for muscle power).	Adults aged 65–91($N = 28$)
Alfieri et al. (2010)	Strength training (ST) (chest press, rowing, leg press, calves, abdominal, and lumbar extension, with varying resistance at 50%, 75%, and maximum load) vs. Multisensory training (MT)[a] (games with balls, stretching, and resistance exercises; standing or lying down, on varied surfaces, with obstacles, with eyes open or eyes shut)	60-min sessions; 2 sessions/week for 12 weeks	Timed Up and Go Guralnik Test Battery (static balance, chair stand, walking speed) Force Platform Testing	The MT group showed significant reduction in Timed Up and Go completion time ($p = .002$), anterior-posterior ($p = .03$) and latero-medial displacement of the center of pressure ($p = .02$), and significant improvement on the Guralnik measures ($p = .009$). The ST group only improved significantly only on speed of foot displacement ($p = .03$). The only significant difference between the groups was found on timed up and go, with the MT group improving relative to the ST group ($p = .03$).	Brazilian adults aged 60–75 ($N = 46$)
Manini et al. (2010)	Physical Activity (PA) (walking, strength, flexibility, and balance training) vs. Attention/education control (EC) (weekly group presentations on health topics)	Weeks 1–8: 40–60-min sessions; 3 supervised sessions/week Weeks 9–24: 40–60-min sessions; 2 supervised sessions/week; home activity increased Weeks 25–52: home-based PA 5 days/week; goal time = 150 min/week; 1 supervised session/week	400 m walk test Short Physical Performance Battery (SPPB)	At 12 months, non-obese participants in the PA group were approximately 0.052 m/s faster than controls, a significant difference ($p = .003$). Non-obese participants in the PA group also improved SPPB scores by 0.56 points, significantly more than the control group ($p = .035$). Obese subjects in the PA group showed a decline in gait speed similar to controls, however they made significant gains, similar to non-obese PA participants, on the SPPB relative to controls ($p = .042$)	Adults aged 70–89 ($N = 424$) Sedentary, obese and non-obese individuals, at-risk for disability

VanSwearingen et al. (2009)	Walking, Endurance, Balance and Strength (WEBS) (program for gait and balance retraining) vs. Progressive timing and coordination training (TC)[a] (motor learning to enhance smooth, automatic movement control)	Both groups: 60-min sessions; 2 sessions/week for 12 weeks	Energy cost of walking Gait Abnormality Rating Scale (GARSM) Gait speed and variability Gait efficiency Short Physical Performance Battery (SPPB) Self-reported Gait Efficiency Scale (GES)	Change in energy cost of walking was significantly different between WEBS and TC groups ($p = .0001$), as the energy cost of walking decreased in the TC group ($p = .027$) but did not change in the WEBS group ($p = .66$). Compared to WEBS, the TC group showed a reduction in the metabolic cost of transport ($p = .0003$). While the GARSM decreased significantly in both the TC group ($p < .001$) and the WEBS group ($p = .0025$), the TC group decreased their scores significantly more ($p = .02$). Compared to WEBS, the TC group improved on the GES ($p = .008$).	Adults (M age = 77.2 y) ($N = 45$) with slow and variable gait [a]Baseline differences present, despite random assignment
Resnick et al. (2008)	Senior Exercise Self-Efficacy Project (SESEP) (aerobic/dance, balance and resistance strength training exercise based on NIA recommendations + efficacy enhancement + nutrition education) vs. Attention control	Exercise: 60–90 min sessions; 2 sessions/week for 12 weeks Efficacy enhancement: 30 min at beginning of 1st session each week Nutrition education: 60–90-min classes; 2 classes/week	Tinetti Scale Chair Rise Time	Performance on chair rise time and the Tinetti mobility scale approached significance in the SESEP group relative to controls ($p = .05$).	Adults aged ≥ 60 ($N = 103$) primarily urban-dwelling minorities
Baker et al. (2007)	Multi-component training: (MT): progressive resistance (knee, hip flexion/extension, hip abduction, chest press, seated rows, lat pull down) + Aerobic endurance (semi-recumbent stepper) + Balance (8 static and dynamic exercises, e.g., side-to-side weight shift, heel walk) vs. Wait-list control	2 sets of 8 repetitions of each resistance exercise/session; 3 sessions/week 2 aerobic sessions/week for 20 min 1 day/week of balance exercises	1RM of all progressive resistance exercises 6 min walk test Static and dynamic balance Habitual gait velocity Chair stand Stair climb Short Physical Performance Battery (SPPB)	Compared to the control condition, MT led to significantly greater gains on 1RM measures of right hip flexion ($p = .01$), right and left hip abduction ($p = .01$; $p = .02$), and chest press ($p = .04$). Lower baseline strength was related to greater load progression ($r = -.758$, $p < .01$).	Australian adults aged 58–92 ($N = 38$)
Shumway-Cook et al. (2007)	Multifaceted intervention (MI) (group exercise classes including aerobic, progressive strength, and balance components + falls prevention education) vs. Education control (given brochures on fall prevention)	60-min sessions (10 min flexibility and balance; 20 min progressive strength training; 30 min moderate aerobic exercise); 3 sessions/week for 12 months 6, 60-min fall prevention classes	Repeated Chair Stands Test Berg Balance Test Timed Up and Go Test	After adjustment for baseline scores, participants in the MI group made small but significant improvements relative to EC on repeated chair stands ($p < .001$), the Berg Balance Test ($p < .001$), and the Timed Up and Go Test ($p = .005$).	Adults aged 65–96 ($N = 429$)
Tsourlou et al. (2006)	Aquatic Training (AT) (shallow-water exercise and water resistance training; target heart rate increased from 65 to 80% over course of training) vs. Usual activity control	60-min sessions; 3 sessions/week for 24 weeks	Timed Up and Go Test Maximal vertical squat jump 3RM: chest press, knee extension, lat pull down, leg press Isometric peak torque of leg extension/flexion	The AT group improved relative to controls on peak isometric knee extension ($p < .0125$), isometric torque ($p < .0125$), leg press ($p < .0125$), chest press ($p < .0125$), squat jump ($p < .0125$), and timed up and go ($p < .0125$).	Greek women aged 60–75 ($N = 22$)

Appendix A (*continued*)

Article	Intervention type	Time frame	Mobility measures	Results	Sample
King et al. (2002)	Exercise group intervention (EG) (Strength, aerobic endurance, balance, flexibility) vs. Home control exercise (HC)[a] (moderate aerobic exercise encouraged; balance, strength exercises not allowed)	EG: 3, 6-month phases: Phase 1: 75-min sessions; 3 sessions/week; First 3 months strength and endurance training; second 3 months balance and flexibility training + maintenance strength and endurance Phase 2: 1 session/week at center; 2 home sessions/week following Phase 1 protocol Phase 3: 3 sessions/week at home; 1 home-visit, monthly phone call HC: 1 instructional session on nutrition, how to work up to 180 min of exercise/week; received monthly phone calls	MacArthur Battery Physical Performance Test (PPT-8) 6-min walk test	Compared with the HC group, the EG group significantly improved their MacArthur battery scores at 3, 6, and 12 months ($p < .05$), but not at 18 months. PPT-8 and 6-min walk test performance did not improve in either group.	Adults aged ≥ 70 ($N = 155$) with mobility impairments
Buchner et al. (1997)	Aerobic endurance training (ET) (stationary bicycling) vs. Strength training (ST) (upper and lower body resistance training on weight machines) vs. Combined aerobic endurance and strength training (ET+ST) vs. Wait-list control	60-min sessions; 3 sessions/week for 24–26 weeks	Muscle strength 6-m walk on wide and narrow balance beam Standing ability on tilt boards Average usual gait speed, stride length Stair climbing speed	There were no significant effects of exercise on any measure of gait or balance. Relative to controls, the ST group showed significant increases in isokinetic strength at 6 months in all muscle groups except the ankle (hip, knee, elbow extension and flexion, hip adduction, $p < .01$; hip abduction, $p < .05$). Relative to controls, the ST+ET group increased knee flexion and extension strength ($p < .01$) and the ET group knee extension strength ($p < .01$) at 6 months.	Adults aged 68–85 ($N = 105$) with strength and balance deficits
Vibration exercise					
Rees et al. (2007)	Whole body vibration training (WBV) (low-intensity walking, static and dynamic squats, calf raises, performed on oscillating platform) vs. Exercise without vibration (EX) (same exercises as WBV but on static surface) vs. Low intensity walking control (LIW)[a]	2, 4-week blocks; 3 sessions/week (session duration not specified) All groups expected to participate in walking 3 times/week	Sit to Stand Test Timed Up and Go Test 5- and 10-min fast walk Stair Mobility Test Isokinetic strength	WBV and EX groups decreased their 5-min fast walk time significantly more than LIW ($p = .044$, $p = .045$, respectively). WBV and EX groups also improved significantly more than controls on knee-extension torque ($p < .001$) and sit to stand ($p < .05$) but were not significantly different from each other. WBV decreased 10-min fast walk time ($p = .008$) and timed up and go ($p < .05$) relative to LIW. The WBV group improved significantly more than EX and LIW on right ankle plantar flexion torque ($p < .001$).	Adults aged 66–85 ($N = 43$)

Furness and Maschette (2009)	0 sessions whole body vibration (WBV)/week vs. 1 sessions WBV/week vs. 2 sessions WBV/week vs. 3 sessions WBV/week[a] Participants stood with legs at 110° knee extension and feet equidistant. Vibration frequency progressively increased over the course of the study	Each session consisted of 5, 1-min WBV trials; 1-min rest between trials; At least 24-h between sessions Study duration: 6 weeks	5 Chair Stands Test Timed Up and Go (TUG) Tinetti Test	Overall, the study cohort significantly reduced time taken to complete the 5-Chair Stands Test ($p \leq 0.05$) and the TUG test ($p \leq 0.05$). Tinetti test scores also significantly improved ($p \leq 0.05$). On the 5-Chair Stands Test, the 3 sessions WBV group was significantly faster than the 0 sessions group ($p \leq 0.05$). On the TUG test, the 3 sessions group was significantly faster than the 2 sessions group ($p \leq 0.05$). On the Tinetti Test Total, the 3 sessions group was significantly better than all other groups ($p \leq 0.05$).	Australian adults aged >65 ($N = 73$)
Mikhael et al. (2010)	Whole body vibration (HBV) with: Flexed Knees (FK) vs. Locked Knees (LK) vs. Placebo control	20-min sessions (1-min WBV: 1-min rest); 3 sessions/week for 13 weeks	Muscle function (power, velocity, strength) 2-m maximal and habitual gait speed Stair Climb Power Chair Stand 6-min walk	No significant effects of WBV were found for any functional performance test. Upper body contraction velocity improved significantly more after WBV with FK compared to LK ($p = .01$). Relative upper body strength increased significantly following WBV (LK, $p = .02$; FK, $p = .04$) compared to control. Absolute ($p = .05$) and relative ($p = .03$) lower leg strength improved significantly in both LK and FK positions, and the LK group had significant leg strength gains relative to controls ($p = .02$).	Adults aged 50–80 ($N = 16$)
Machado et al. (2010)	Whole body vibration training (WBV) (lower body exercises, e.g., squats, calf raises, performed on vibrating platform) vs. No-treatment control	10-min aerobic and stretching warm up, followed by WBV intervention (duration not specified); progressively longer duration and faster vibration over 10-week intervention	Timed Up and Go Maximal leg extensor power at 20%, 40%, and 60% Maximal Voluntary Isometric Contraction (MVIC)	Relative to controls, WBV significantly improved on timed get up and go ($p < .01$). MVIC increased significantly in the WBV group ($p < .05$), while the control group showed significant reduction in muscle power over time ($p < .05$).	Spanish adult women aged 65–90 ($N = 26$) Sedentary

[a] *Note*: Indicates that one training group was compared to another training group rather than a no-contact or social-contact control condition.

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