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A water-based training program that includes perturbation exercises improves speed of voluntary stepping in older adults: A randomized controlled cross-over trial

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ABSTRACT

This study evaluated the effects of a water exercise training program that includes perturbation exercises (WEP) to improve the speed of voluntary stepping reaction in older adults. Speed of voluntary stepping considered as an important skill to prevent a fall when balance is lost. In a single-blinded randomized controlled trial with a crossover design thirty-six independent old adults (64–88 years old) were divided into two groups. Group A received WEP for the first 12 weeks, followed by no intervention for the second 12 weeks. Group B did not receive intervention for the first 12 weeks and received WEP for the second 12 weeks. Voluntary Step Execution Test and postural stability in upright standing (eyes open and closed conditions) were measured at baseline, 12 weeks, and 24 weeks. A significant interaction effect between group and time was found for the step execution, due to improvement in initiation phase and swing phase durations in the WEP group. Also significant improvement in postural stability parameters in eyes open and closed conditions is noted. The present results indicate that the primary benefit of WEP that include perturbations to induce stepping, was a reduction in voluntary stepping times. The WEP generalized to a better control of balance in up-right standing.

1. Introduction

In older adults (65 years old and older) about one out of three individuals fall at least once a year (Tinetti, Speechley, & Ginter, 1988). Falls may result in acute injuries, including traumatic brain injuries (Rutland-Brown, Langlois, Thomas, & Xi, 2006), spinal cord injuries (Kent & Pearce, 2006), hip fractures (Kannus et al., 1996), and even death (Masud & Morris, 2001). Consequently, there is a general need for developing cost-effective interventions that can prevent the occurrence of falls. However, fall prevention programs are usually directed toward high-risk populations although age-related deterioration of balance function that leads to an increased risk of falling affects all older adults. Therefore, a better way to decrease the number of fall-related injuries may be to also direct preventive efforts toward older adults who have not yet fallen.

A rapid step is the most important protective postural strategy since it can prevent a fall from occurring. It can arise from large perturbations (e.g., slips, trips and collisions), but is also frequently recruited at lower magnitudes of perturbation or as a consequence of volitional movement, self-induced perturbation such as turning, bending, and reaching (Maki & McIlroy, 1997). The time to complete voluntary stepping was found to be related to falls. It was found to be slower in older adults who reported falls retrospectively compared with non-fallers (Melzer, Kurtz, Shahar, Levi, & Oddsson, 2007), and in older adults monitored for one year prospectively (Melzer, Kurz, & Oddsson, 2010) and even older adults who were injured as a result of fall compared with non-injured fallers (Melzer, Kurz, Shahar, & Oddsson, 2009). Improving the ability to step quickly, to a loss of balance determines whether a fall occurs in older adults (Melzer, Kurtz, et al., 2007). Studies show that compared to young adults, older people also showed reduced step length (Luchies, Alexander, Schultz, & Ashton-Miller, 1994), an increased frequency of collisions between the swing foot and stance leg during lateral perturbations (Maki, Edmondstone, & McIlroy, 2000), and an increased frequency of multiple-step responses (Luchies et al., 1994; Maki et al., 2000; McIlroy & Maki, 1996), with a lateral second step following the forward or backward step (McIlroy & Maki, 1996). All the above results may suggest that targeting stepping speed may reduce the

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risk of falls in older subjects. Consequently, there is a clinical need for developing interventions to improve the stepping speed, thus reducing the risk for falls in older adults.

A common misunderstanding appears to be that strength training per se should improve balance function. A Cochrane Review (Latham, Anderson, Bennet, & Stretton, 2003) of 62 Randomized Control Trials including a total of 3674 subjects found no statistically significant effects of strength training on objective clinical measures of balance function, or on physical disability measures. The results are not surprising; according to the principles of training, training of balance or stepping as a skill must incorporate exercises that closely mimic and provide a challenge to the successful performance of functional tasks. Rogers, Johnson, Martinez, Mille, and Hedman (2003) showed that a three-week period of either voluntary or waist-pull-induced step training reduced step initiation time. Mansfield, Peters, Liu, and Maki (2010) used a balance-specific intervention that using a perturbation platform that moves suddenly and unpredictably during standing or walking in place. Their perturbation-based training led to reductions in frequency of multi-step reactions, foot collisions. However, the above-mentioned studies (Mansfield et al., 2010; Rogers et al., 2003) utilized expensive equipment (e.g., moving-platform or waist pulls) that would not be available to older adults or even in rehabilitation clinics. Recently, Melzer and Oddsson (2012) showed that functional balance training that includes perturbations can improve voluntary stepping in independent older adults. The present study aimed to test whether a water-based training program (WEP) that includes perturbation of balance specifically targeted compensatory and voluntary stepping skills are able to improve speed of stepping. To evoke stepping reactions during training, pushes were made by the instructors or classmates to evoke balance-recovery stepping reactions against the water resistance. The subjects were instructed to respond to the pushes by stepping as quickly as possible, if required.

To date, only a few studies have examined the effects of WEP on balance control in older adults. These studies demonstrated that following WEP training there was increased Berg Balance Score (Douris et al., 2003), improved leaning balance (Lord, Matters, & St George, 2006; Lord, Mitchell, & Williams, 1993) and Functional Reach (Simmons & Hansen, 1996), and improvement in the step test (step 7.5 cm high and return to the floor as many times as possible over a period of 15 s) and quality of life, but not fear of falling (Devereux, Robertson, & Briffa, 2005). To our knowledge, no studies have directly addressed the potential of using perturbation-based exercises to counter specific impairments in compensatory and voluntary stepping responses. Using deep-water-running exercise Kaneda, Wakabayashi, Sato, Uekusa, and Nomura (2008) in an elegant study were able to demonstrate improvements in postural-sway distance and tandem-walking time in a group of 15 older adults that appeared to counteract normal age-related balance deterioration. However, their study was not designed to improve the speed of stepping. To be functionally useful, balance-related strength should preferably be designed into the water balance training intervention, by training in a water environment; water resistance may produce overload for stepping and thus specifically improve the speed of stepping. We hypothesize that subjects who undergo a WEP that includes perturbation exercises will show greater improvements in the ability to step rapidly, compared to control subjects who undergo no training.

2. Methods

2.1. Study population

A randomized cross-over trial was conducted with 36 healthy volunteers, average age 69.5 (range 64–88 years, SD 4.8) who ambulate independently. Subjects were recruited from the community of the Sha'ar Hanegev council through the internal brochure of the Yahdav elderly center. The water-based exercise program (WEP) consisted of 24 sessions, each 40 min long; 8–9 subjects participated in each training group, twice a week over a period of 12 weeks. Using a concealed randomization method utilizing sealed envelopes, the 36 subjects were randomly allocated to 2 groups by investigators who were not involved in data collection, treatment implementation, or data analysis. A senior physiotherapist from Community Physiotherapy Services enrolled the participants and coordinated the randomization and allocation. Subjects in group A started with a 12-week WEP program, followed by a 12-week control no training period. Group B subjects began with an initial 12-week control period without training, followed by 12 weeks of WEP intervention (Fig. 1). Baseline assessments were done before randomization (t0); subjects then performed assessments after 12 weeks (t1), and after 24 weeks (t2).

A short interview examined whether the subjects met the inclusion–exclusion criteria. Participants were excluded if they had received physiotherapy, hydrotherapy, or attended community exercise classes in the past six months, had orthopedic surgery within the prior year, showed an indication of cognitive impairment (Mini-Mental Score < 24), score of 45 and over on the Berg Balance Scale, this range of Berg scale score corresponded to individuals with low risk of falls (Shumway-Cook, Gruber, Baldwin, & Liao, 1997). The Berg Balance Test scores the participant on 14 tasks graded on a 0–4 scale (maximum 56) to evaluate balance under different conditions (Berg et al., 1989) had severe focal muscle weakness or paralysis, serious visual impairment, severe peripheral or compression/entrapment neuropathies, any neurological disorders causing balance or motor problems, or cancer (metastases or under active treatment). Prior to their inclusion, all subjects received medical clearance from their

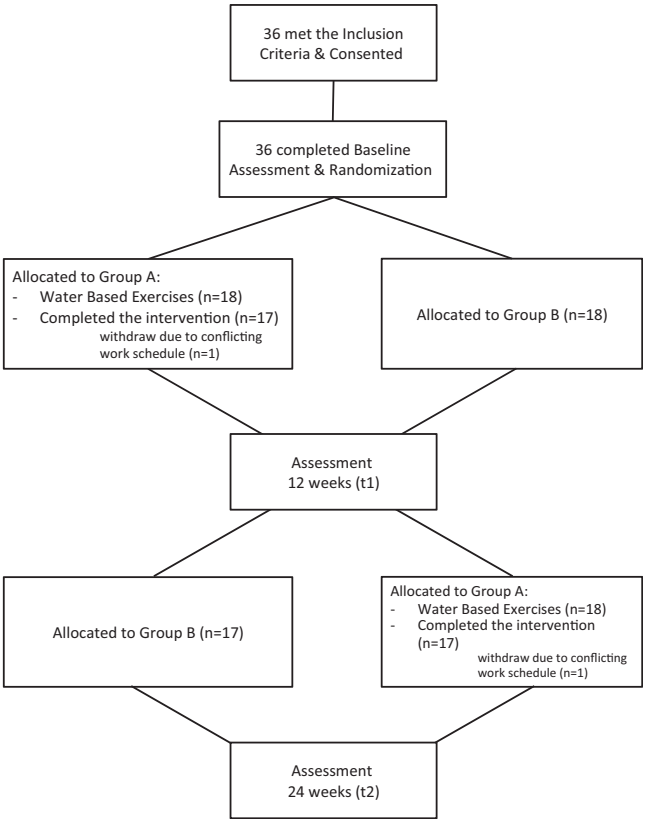

Fig. 1. Study design and flow of participants through each stage of the trial.