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Exercise training can improve spatial characteristics of time-critical obstacle avoidance in elderly people

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ABSTRACT

Fall prevention programs have rarely been evaluated by quantitative movement analysis methods. Quantitative movement analyses could provide insight into the mechanisms underlying the effects of training. A treadmill obstacle avoidance task under time pressure has recently been used to evaluate a fall prevention exercise program for community-dwelling elderly people and it showed that participants improved their obstacle avoidance success rates. The mechanism, by which the increased success rates were achieved, however, remained to be determined. Participants were elderly who had fallen at least once in the year prior to participation. They were assigned to either the exercise or the control group. The control group did not receive any specific treatment. The exercise group was administered a five week exercise program, which consisted of exercises on a functionally oriented obstacle course, walking exercises, and practice of fall techniques. Pre- and post-intervention laboratory obstacle avoidance tests were conducted. Three possible determinants of success were investigated, namely avoidance reaction times, the distribution of avoidance strategies, and three spatial parameters (toe distance, foot clearance and heel distance). Analysis yielded significant Time × Group interactions in heel distances. The exercise group increased heel distance, while the control group did not. Increased heel distance may result in reduced risk of heel contact with the obstacle and, consequently, larger success rates. The remaining parameters showed no effect of training. In conclusion, the training program was effective in improving time-critical obstacle avoidance skills. In every day life, these effects of training may contribute to less obstacle-related fall

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incidents in elderly. In addition, these findings could indicate that the execution of other time-critical events, like an actual fall, could also be improved by training.

1. Introduction

In daily life, independent and safe locomotion requires the ability to continuously adjust the locomotor pattern in response to environmental demands. Avoiding obstacles in the travel path is a frequently studied example of this adaptive locomotion. The characteristics of obstacle avoidance have repeatedly been shown to be negatively affected by the normal ageing process (Chen, Ashton-Miller, Alexander, & Schultz, 1991; Chen, Ashton-Miller, Alexander, & Schultz, 1994a; Chen, Ashton-Miller, Alexander, & Schultz, 1994b; Hahn & Chou, 2004; McFadyen & Prince, 2002; Weerdesteyn, Nienhuis, & Duysens, 2005; Weerdesteyn, Nienhuis, Geurts, & Duysens, 2007; Weerdesteyn, Nienhuis, Mulder, & Duysens, 2005). This may contribute to the high fall rates of elderly, since many fall incidents are caused by tripping over obstacles (Tinetti, Speechley, & Ginter, 1988). This suggestion is also supported by the finding that obstacle avoidance skills in recurrent fallers are substantially deteriorated compared to elderly people who had no or only one fall during a six month period prior to an obstacle avoidance assessment (Weerdesteyn et al., 2005).

Treatments or interventions in these groups of people are often aimed at improvements of walking abilities in daily life and the prevention of falls. However, only a few studies have investigated the effect of a treatment or intervention on the performance of obstacle avoidance, even though the importance of adequate obstacle avoidance for safe locomotion is widely accepted. Jaffe, Brown, Pierson-Carey, Buckley, and Lew (2004) reported improvements in stroke patients on the maximum size of obstacle they could clear after they had received six sessions of obstacle avoidance training. Three studies have used an observation-based obstacle course to evaluate the effects of an exercise program for community-dwelling (Means, Rodell, & O'Sullivan, 2005; Means, Rodell, O'Sullivan, & Cranford, 1996) or institutionalized elderly (De Carvallo Bastone & Filho, 2004; Means, Rodell, & O'Sullivan, 2005). Significant improvements on the obstacle course could be demonstrated after an exercise intervention to improve functional performance (De Carvallo Bastone & Filho, 2004). Finally, avoidance of fixed obstacles on a walkway with quantitative motion analysis has been used to evaluate the effects of strength training in elderly people (Lamoureux, Sparrow, Murphy, & Newton, 2003). A number of parameters associated with safe obstacle negotiation were found to improve as a result of training, such as foot clearance and the distance from the heel to the back of the obstacle (heel distance; Lamoureux et al., 2003).

In studies on avoidance of fixed obstacles, however, people could see the obstacle during multiple steps prior to obstacle crossing and they rarely contacted the obstacle (Chen et al., 1991; Hahn & Chou, 2004; McFadyen & Prince, 2002). A more challenging locomotor task is the avoidance of obstacles under time pressure. Typically, the available response time (ART) is manipulated in such experiments. ART is the time between obstacle presentation and the instant that the foot would have contacted the obstacle had no step adjustment occurred. Research has shown that very few contacts of the foot with an obstacle occurred when the ART is more than 450 ms, but when the ART was less than 450 ms, the number of foot contacts gradually increased (Chen et al., 1994a; Chen et al., 1994b; Patla, Prentice, Rietdyk, Allard, & Martin, 1999; Weerdesteyn et al., 2005; Weerdesteyn et al., 2005; Weerdesteyn et al., 2006). The next question was whether effects of training could also be demonstrated in such time-critical obstacle avoidance. A treadmill obstacle avoidance task under time pressure has recently been used to evaluate the effects of a fall prevention exercise program for community-dwelling elderly. Avoidance success rates improved as a result of training, especially at short ARTs (less than 350 ms), in conjunction with a 46% reduction in the number of falls (Weerdesteyn et al., 2006). The mechanism, by which the increased success rates were achieved, however, remained to be determined.