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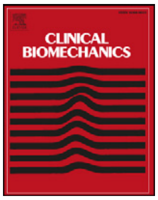

Motor-cognitive dual-task training improves local dynamic stability of normal walking in older individuals

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ABSTRACT

Background: Extreme levels of gait variability and local dynamic stability of walking are associated with risk of falling and reduced executive functions. However, it is not sufficiently investigated how gait variability and local dynamic stability of human walking develop in the course of a motor-cognitive intervention. As dancing implies high demands on (and therewith trains) executive functioning and motor control, it might increase local dynamic stability or reduce gait variability.

Methods: 32 older healthy participants were randomly assigned to either a health-related exercise group (age: mean = 68.33 years, standard deviation = 3.17 years; BMI: mean = 27.46, standard deviation = 2.94; female/male: 10/6) or a dancing group (age: mean = 66.73 years, standard deviation = 3.33 years; BMI: mean = 26.02, standard deviation = 3.55; female/male: 11/5). Based on angular velocity data of trunk kinematics, local dynamic stability and stride-to-stride variability in level overground walking were assessed prior to and after the specific intervention. The data were analysed by a blinded observer using two-way repeated measures ANOVAs. Based on one-way ANOVAs, time and group effects were determined.

Findings: Regarding the variability of trunk movements, no interaction effect was observed ($F_{1,30} = 0.506$, $P = .482$; $\eta 2 = 0.017$). For local dynamic stability of trunk movements, an interaction effect in favour of the dancing group was observed ($F_{1,30} = 5{,}436$; $P = .026$; $\eta 2 = 0.146$).

Interpretation: Our data indicate that a dancing programme (which combines cognitive and motor efforts) might increase local dynamic stability in older people.

1. Introduction

A healthy status and motor skills go along with an optimal level of movement variability while this variability has form and a chaotic structure (Stergiou and Decker, 2011; Stergiou et al., 2006). Older healthy individuals show higher levels of walking variability than a young and healthy cohort (Buzzi et al., 2003; Hamacher et al., 2011). Many efforts were also made to identify older people at risk of falling with the aid of linear and non-linear gait variability measures. In an older population, great amounts of variability, which quantifies the magnitude of trial-to-trial variations, and low local dynamic stability (lds, indicated by high values of Lyapunov Exponents), which quantifies the system's sensitivity to extremely small perturbations (Stergiou, 2004), derived from kinematic gait data are parameters that were positively correlated with risk of falling and might therefore predict future fallers (Rispens et al., 2015; Toebes et al., 2012; van Schooten et al., 2015; Weiss et al.). This, in turn, suggests that in older individuals, an increase in lds and a decrease of gait variability can be used to validate the efficacy of fall prevention programmes. To date, however, it is still unknown how different exercise programmes affect/improve these measures of gait. While most fall prevention programmes focus on physical exercise and sensorimotor training, Segev-Jacubovski et al. (2011) suggest that multimodality interventions which combine motor and cognitive training would be more effective with respect to reducing risk of falling. Also, the capability of executive functions is associated with increased gait variability (Beauchet et al., 2012) and demented people show lower magnitudes of lds (Ijmker and Lamoth, 2012). Furthermore, the risk of future falls can be predicted from the performance of executive functions and attention (Mirelman et al., 2012). Cognitive training programmes (not including any physical elements) can remediate executive functions and attention and positively affect gait speed in sedentary seniors (Verghese et al., 2010). Furthermore, pure cognitive interventions non-significantly reduce gait variability in patients with Parkinson's disease (Milman et al., 2014). Dancing, in particular, poses high demands on executive functions (updating and cognitive processing speed due to time pressure), on attentive functioning (remembering of dancing sequences) and on the sensorimotor system (Bläsing et al., 2012). Furthermore, regular participation in dancing lessons is accompanied

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with higher performance in cognitive functions (Kattenstroth et al., 2013). Thus, it can be inferred that dancing incorporates a cognitive element into a physical exercise programme (Pichierri et al., 2012a; Pichierri et al., 2012b) which demonstrates its motor-cognitive dual-task character. Given that dancing interventions are also reported to improve aerobic power, lower body muscle endurance, strength and flexibility, balance, agility, and gait in older individuals (Keogh et al., 2009), dancing could depict an efficient falls prevention strategy which might be superior to an intervention programme that only targets physical activity. If so, gait variability and lds in an older cohort would be improved in a higher extent by a dancing programme as compared to a pure physical exercise programme.

The participation in best practice exercise to prevent falls is relatively low (Merom et al., 2012), however, dancing seems to be a very feasible treatment, which could be easily implemented in senior centres. Therefore, the current randomized controlled trial aims to investigate whether an additional cognitive demand in an exercise intervention (6-months dancing programme), increases lds and decreases stride-to-stride variability of trunk movements in normal overground walking in older healthy individuals. It was hypothesised that the dancing intervention increases lds and decreases gait variability to a higher extent than a conventional health related exercise programme.

2. Methods

2.1. Participants

32 older healthy participants of a larger study (Hamacher et al., 2015a) were included. The subjects were randomly assigned to either a health-related exercise group (age: 68.33 (SD 3.17) years; BMI: 27.46 (SD 2.94); female/male: 10/6) or a dancing group (age: 66.73 (SD 3.33) years; BMI: 26.02 (SD 3.55); female/male: 11/5). The research protocol complied with the principles of the Declaration of Helsinki. The contents of the study were reviewed and approved by the ethical committee of Otto von Guericke University Magdeburg, Germany (No.: 22|12).

2.2. Experimental task

For 6 months, the dancing and the health-related exercise intervention took place twice a week, lasting 90 min each. We controlled training conditions with respect to intensity, frequency and duration. To control for the physical conditional loads of participants in both intervention groups, the participants trained at predefined heart rates, which were set at 70% of net maximum oxygen uptake which was predicted with the Karvonen formula (Davis and Convertino, 1975). The focus of the dancing programme was on learning and remembering specific dancing skills, making sure that the participants learned something new in each session. The intervention comprised choreographies of 5 genres: Line Dance, Jazz Dance, Rock 'n' Roll, Latin-American Dance and Square Dance. In the last 2 weeks of the dancing programme, participants were asked to recall the learned choreographies. The health-related exercise training included endurance training, strength-endurance training and flexibility training. The endurance training was performed on bicycle ergometers with the intensity of each subject's individual training heart rate. The strength-endurance part involved training with equipment (barbells, rubber band, gymnastic stick, gymnastic ball, etc.).

2.3. Instrumentation

The subjects walked on a 25 m long track (back and forth for 4 min) at their preferred walking speeds. Using an inertial sensor (MTw, Xsens Technologies B.V., Enschede, The Netherlands), the 3 dimensional (3D) angular velocity of the trunk motion was recorded with a sample rate of 75 Hz.

2.4. Outcome measure

Dingwell and Cusumano (2000) were the first who evaluated gait stability in humans using lds. Local dynamic stability quantifies the sensitivity of a system to very small perturbations which occur due to internal (neuromuscular) or external (wind, etc.) sources (Bruijn et al., 2013). Data derived from each first and last 2.5 m every time the participants changed directions were removed. To evaluate gait variability, the Euclidean norm of the 3D angular velocity of the trunk was calculated (Hamacher et al., 2015b). Then, each stride was individually time-normalized to 99 data points and at each increment of time the standard deviation over all strides was calculated. As measure of gait variability, the average of these standard deviations was determined (Dingwell et al., 2001). The method of lds calculation in human walking was described comprehensively in another study (Dingwell et al., 2001). In brief, 3D angular velocity of the raw data time-series of 100 strides per participant were time normalized to 10,000 data points. The gait dynamics were analysed in a 6 dimensional state space (according to the false nearest neighbours analysis) considering a time delay of $\tau = 12$ (according to the first minimum mutual information analysis). For each point in the state space, the nearest neighbour was determined and the succeeding Euclidean distances were tracked as long as the participants remained within the middle 20 m of a bout. Then, lds was defined as the linear fit through 0–0.5 strides of the log of the mean divergence curve (λ). Here, higher values of λ indicate lower local dynamic stability and vice versa (Buzzi et al., 2003).

2.5. Data analysis

The data were checked for normal distribution (Kolmogorov Smirnov Test). Using the Mann–Whitney-U-Test for independent groups, possible group differences regarding age and BMI were calculated. Two-way (factor groups: dancing group and exercise group, factor time: pre- and post-test) ANOVAs with repeated measures (IBM SPSS Statistics 20) were performed to identify interaction effects and main effects of time in gait variability or lds. In post hoc analyses, group effects (individually in both pre- and post-test) and time effects (for each group, individually), were determined with one-way ANOVAs. The level of significance was set to $\alpha = .05$.

3. Results

We did not find any differences regarding age ($P = .149$) and BMI ($P = .180$) between groups.

Regarding the variability of trunk movements (Fig. 1), no interaction effect was observed ($F_{1,30} = 0.506$, $P = .482$; $\eta 2 = 0.017$). We found a main effect of time (two-way ANOVA) indicating lower variability in the

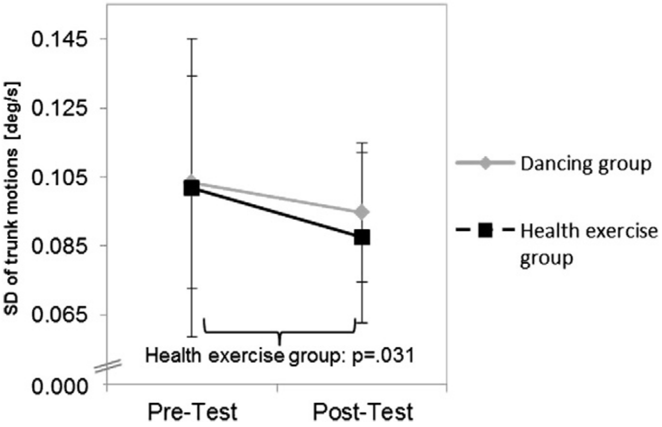

Fig. 1. Means and standard deviations of trunk movement variability while walking in the dancing group and the health-related exercise group in pre-test and post-test.