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Sports activities are reflected in the local stability and regularity of body sway: Older ice-skaters have better postural control than inactive elderly

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ABSTRACT

With age postural control deteriorates and increases the risk for falls. Recent research has suggested that in contrast to persons with superior balance control (dancer's athletes), with pathology and aging, predictability and regularity of sway patterns increase and stability decreases implying a less adaptive form of postural control.

The aim of the present study was to determine, whether patterns of body sway of elderly (N = 13) who practice a sport which challenges postural control (ice speed-skating), are more similar to that of young subjects (N = 10) than to that of inactive elderly (N = 10). Trunk patterns were measured with a tri-axial accelerometer. Data were recorded during quiet upright stance with (1) eyes open, (2) limited vision, and (3) while performing a dual task. Anterior–posterior and medio-lateral acceleration time-series were analyzed. Differences in postural control were quantified in terms of the magnitude of the acceleration (root mean square), the smoothness (mean power frequency), the predictability (sample entropy) and the local stability (largest Lyapunov exponent). Postural control of ice-skating elderly differed from that of sedentary elderly. As anticipated, postural control of the ice-skating elderly was similar to that of young adults. For anterior–posterior accelerations, the skating elderly and the younger subjects had significant higher stability and lower regularity than the non-skating elderly in all tasks. These results imply that sport activities such as ice-skating are beneficial for elderly people. It might, at least partly, counteract the age related changes in postural control.

1. Introduction

Adequate postural control is essential for daily activities and requires the integration of visual, proprioceptive and vestibular information. The degree to which individuals rely on this information depends on task difficulty, cognitive load [1], motor skill [2,3], age [4,5] and pathology [6,7]. The integration of sensory inputs for postural control occurs normally without conscious attention and is considered a highly automatic process. Consequently people are routinely able to perform two tasks simultaneously, like talking and walking. The age-related loss of visual, proprioceptive, and vestibular sensitivity demands more attention for maintaining postural stability during standing and walking [8].

A number of studies clarified that measures of movement variability and stability can detect age-related postural control changes [9–11] and can also be used to quantify automaticity of postural control [3,12]. During quiet stance, even without any external perturbation, apparently random and irregular small fluctuations in the body sway are continuously present [3,13]. With pathology and aging, loss of complexity, increased regularity and variability in these fluctuations are suggested to reflect a less automated form of postural control, which is unstable, lacks adaptability and is susceptible to perturbations [6,7]. Individuals with excellent balance skills (e.g., gymnasts) have sway patterns that are more complex and irregular and less variable, characteristics that are suggested to be indicative of a more automatic, stable and adaptive form of postural control robust to external perturbation [3,12]. These findings are in line with the theoretical concept that health is characterized by 'organized' variability, while disease is defined by loss of complexity, e.g., increased regularity, decreased smoothness, decreased stability, and vanishing of the correlation structure of time series [14]. Based on this notion, it is suggested that normal 'healthy' postural control is positioned in the middle between the extremes of a continuum; with pathological sway patterns located at one end of the continuum and sway patterns obtained from individuals with superior balance skills, located at the other end of the continuum [2,3,12]. This view is similar to the suggestion that complexity can

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be described as an inverted U-shape with optimal complexity at the apex [15]. However the continuum allows for including expert behavior which exhibit increased adaptive behavior and is characterized by higher complexity, variability and local stability. In accordance with this concept, Lamoth et al. [3] found that young adults who differed only in athletic skill level, showed significant differences in postural control during quiet standing. As gymnastic skill level increased, regularity of postural sway decreased, and variability and local stability increased, suggesting a more automatized, efficient and more adaptive form of postural control that is resilient to external perturbations.

Aging has a detrimental effect on postural control either due to a specific pathology affecting a particular component of sensory and neuromuscular control systems, and/or as a consequence of a more general age-related deterioration in these systems [4]. Poor postural control with loss of balance has been suggested to be a major risk factor for falls, implying that balance training is of utmost importance for elderly. However, results of intervention studies investigating balance programs are ambiguous. Some studies do report beneficial effects of exercise on balance performance of elderly [16,17], whereas others did not find effects, due to differences in the intervention programs between the reviewed studies [18]. Moreover, these studies are all based on setting up a training program for a limited amount of time. If postural control is reflected in athletic skill level in young subjects, these finding could be taken to imply that elderly who performed life-long sports activity will have a more efficient postural control than sedentary elderly: one shifted on the continuum line towards the level of postural control of young subjects. In former athletes, performance on physical tests is reported to be comparable to younger control subjects of 24–30 years of age [19]. Moreover, elderly who have been involved in sports activities during their life or became physically active more recently, have a better balance at older age than inactive elderly [20,21]. Yet, scarce information is available about the effect of sport activities of elderly on postural control. Therefore, the aim of the present study was: (1) to examine if elderly who have been and still are engaged in sports activities on a regular basis, differ in postural control from age matched elderly who are not involved in sports activities; (2) evaluate difference in postural control between sportive elderly and young subjects. We examined if task difficulty had a differential effect in the three groups, by measuring trunk accelerations during quiet standing with eyes open, limited vision, and while performing a dual task. The sportive elderly who participated in the study practiced a sport activity which requires a high level of balance skills, namely speed ice-skating. Based on previous research [3], we expected that trunk acceleration patterns of non-skating elderly showed greater regularity, lower local stability and decreased smoothness than trunk acceleration patterns of skating elderly and young subjects. Furthermore, we expected the skating elderly to exhibit trunk acceleration patterns more similar to that of the young subjects.

2. Methods

2.1. Subjects

Three different groups participated in the experiment. One group of 13 elderly, (mean = 66.3 years ± 6.3, 11 male) who practiced ice-speed skating for more than 5 years and trained at least once a week. The other groups consisted of 10 age-matched elderly, (mean = 66.3 years ± 4.9, 8 male) and 10 young adults (mean = 22.6 - years ± 1.4, 7 male) with no ice-speed-skating experience or regular practice in sports activities. All subjects were healthy and had no orthopedic or neurological problems that could affect postural control. All subjects provided written informed consent to participate in the study.

2.2. Instrumentation

Accelerations during standing were measured with a tri-axial accelerometer (DynaPort®MiniMod, McRoberts, The Netherlands). The acceleration module (64 × 64 × 13 mm) was fixed with an elastic belt near the centre of mass at the level of lumbar segment L3. Data were sampled at 100 Hz.

2.3. Procedure

Subjects performed an upright standing task while (1) standing with eyes open; (2) performing a dual task (DT); (3) standing with limited vision. The DT consisted of the Brooks spatial matrix task [22]. While standing, subjects listened to a series of sentences that described the location of seven numbers in a 4 × 4 grid. The first sentence was always "put a 1 in the square in the second row of the second column". Subsequent sentences indicated the placement of numbers such as "In the next square to the right (down, up or left), put a 2.". Sentences were recorded in advance and played by a computer. Each sentence was followed with a silent period of 3 s. The person had to visualize the matrix with the numbers, and wrote at the end of the trial the numbers down on a paper in a matrix. For each trial a different matrix was used. An advantage of this spatial memory task is the absence of any motor activity that could interfere with postural control. In the limited vision condition the subjects wore 'dust' goggles which allowed for very blurred limited vision. Each trial was performed twice and lasted 45 s. The average of the values of the two trials was used for data-analysis.

2.4. Data analysis

Anterior–posterior and medio-lateral acceleration time-series were analyzed. All data were corrected for horizontal tilt [23] and a high pass 3th order Butterworth bidirectional filter was applied with a cut-off frequency of 0.016 Hz to correct for slow drifts and one of 20 Hz to eliminate low amplitude measurement noise [23]. The magnitude of trunk accelerations was quantified by calculating the root mean squares (RMS) of the acceleration time-series. The smoothness of the time-series was determined by calculating the mean power frequency (MPF). Higher MPF values indicate smoother accelerations. Postural sway dynamics was quantified by means of the sample entropy (SEn) [24] and the largest Lyapunov exponent (λ_{max}) [25], which are briefly described below. See for applications [7,26,27].

SEn indexes the regularity or predictability of a time-series and is used to analyze complex stochastic system. SEn is defined as the negative natural logarithm of an estimate of the conditional probability that epochs of length m (in this study $m = 3$) match point-wise within a tolerance r also match at the next point [24]. Small SEn values are associated with great regularity and large SEn values signify a smaller chance of similar data being repeated, that is, great irregularity. Before calculating the SEn the data were normalized to unit variance, rendering the outcome scale-independent. The system's resistance to small internal perturbations, such as the natural sway fluctuations present while standing upright was assessed by means of λ_{max} [25]. If λ_{max} is negative, then any perturbation exponentially damp out and initially close trajectories remain close. In contrast, for positive λ_{max}, nearby points diverge as time evolves and produce instability i.e., the distance between trajectories increases exponentially.

2.5. Statistical analysis

Statistical analysis was performed using SPSS version 14.0. Group, condition and interaction effects were tested for significance using Kruskall–Wallis tests followed by pairwise group comparisons with Mann–Whitney U-tests with Bonferroni correction for multiple comparisons. The group by task and group by vision interaction were tested by comparing the groups on the differences between single task with eyes open and respectively single task with limited vision and DT condition. Level of significance was set at $p < 0.05$.

3. Results

3.1. Dual task performance

A significant effect of group was found on the number of faults made in the Brooks spatial memory test ($\chi^2 = 11.3$, $p = 0.003$). Average number of faults for the skating elderly was 3.5 ± 3.8, for the non-skating elderly 3.1 ± 2.6 and 0.1 ± 0.31 for the young subjects. The young subjects made significant fewer faults than the skating and non-skating elderly ($U = 22$, $p = 0.004$; and $U = 11$, $p = 0.001$, respectively).

3.2. Single task normal vision

Table 1 provides an overview of significant main effects of group and condition and Fig. 1 shows the values of the variables. A main group effect in the single task condition was observed for the regularity of medio-lateral and anterior–posterior accelerations.