Gait & Posture 38 (2013) 637–642

Contents lists available at SciVerse ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

The effects of aging on the rambling and trembling components of postural sway: Effects of motor and sensory challenges

Nejc Sarabon [a,b,*], Andrej Panjan [b], Mark Latash [c]

[a] University of Primorska, Science and Research Center, Institute for Kinesiology Research, Koper, Slovenia
[b] S2P Ltd., Laboratory for Motor Control and Motor Behaviour, Ljubljana, Slovenia
[c] The Pennsylvania State University, The College of Health and Human Development, Department of Kinesiology, Motor Control Lab, PA, USA

ARTICLE INFO

Article history:
Received 20 July 2012
Received in revised form 25 October 2012
Accepted 9 February 2013

Keywords:
Postural control
Aging
Sway
Rambling
Trembling

ABSTRACT

The effects of healthy aging on postural sway and its rambling and trembling components were studied. Young and elderly subjects stood quietly for 1 min in different postures, and with eyes open and closed. We found that age-related changes in postural sway and its components were similar to those observed in young participants in challenging conditions. These changes may therefore be viewed as secondary to the increased subjective perception of the complexity of postural tasks. Contrary to our expectations, stronger effects of age were seen in characteristics of rambling, not trembling. The commonly accepted hypothesis that older persons rely on vision more was not supported by this study: we found no significant interaction effects of age and vision on any of the sway characteristics. It was concluded that the reported higher reliance on vision in older persons may be task-specific. The results are compatible with the ideas that much of the age-related changes in postural sway emerge at the level of exploring the limits of stability and using the drift-and-act strategy. Our results suggest that the dominant view on rambling and trembling as reflecting supraspinal and peripheral mechanisms, respectively, may be too simplistic.

1. Introduction

In this paper, the control of the vertical posture during quiet standing and its changes with healthy aging was examined. Traditionally, quiet standing has been quantified using characteristics of postural sway and shifts in the center of pressure (CoP). Recently, however, it has been suggested that sway represents a superposition of two signals, rambling (Rm) and trembling (Tr) that reflect processes at the supraspinal and spinal–peripheral levels respectively [1,2]. Rm approximates an equilibrium trajectory of the center of mass of the body, while Tr reflects deviations from the equilibrium trajectory due to mechanical properties of the body and possibly spinal reflex and reflex-like mechanisms. In other words, the body oscillates (Tr) not about a fixed point but about a time-varying equilibrium trajectory (Rm).

Even during healthy aging, many age-related changes in the neuromuscular and sensory systems contribute to the challenges of maintaining vertical posture in the field of gravity. Problems in the peripheral structures involve sarcopenia, progressive death of alpha-motoneurons, and associated changes in the composition of motor units and muscle properties [3]. The number of neurons at higher levels of the central nervous system also shows a decline [4,5] that may lead to problems with synergic control of large muscle groups involved in postural tasks [6,7]. Maintaining vertical posture is dependent on proper sensory function of the visual, vestibular, and somatosensory systems. With advancing age, all these systems decline (reviewed in [8,9]). These factors can potentially lead to increased postural sway and its fractions, Rm and Tr. As of now, little information is available on age-related changes in Rm and Tr. This makes the current study, at least partly, exploratory.

In this study, we used two approaches to age-related changes in sway. First, we compared changes in CoP, Rm and Tr with age to those that are seen in young persons in challenging conditions such as standing with closed eyes (sensory challenge) and standing on one leg (motor challenge). Our first hypothesis is that age-related changes in CoP, Rm and Tr will be similar to those observed in young persons under the two challenging conditions.

Aging has been associated with increased agonist-antagonist co-contraction, in postural tasks in particular [10]. By itself,

* Corresponding author at: University of Primorska, Science and Research Centre, Institute for Kinesiology Research, Garibaldijeva 1, SI-6000 Koper, Slovenia. Tel.: +386 40 429 505; fax: +386 5 66 37 710.
E-mail addresses: nejc.sarabon@zrs.upr.si, nejc.sarabon@s2p.si (N. Sarabon).

0966-6362/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gaitpost.2013.02.007

increased co-contraction may be expected to affect both peripheral mechanical properties of the joints as well as reflex effects. Hence, our second hypothesis is that aging will have stronger effects on Tr as compared to Rm.

As far as supraspinal mechanisms of sway are concerned, one of the recent hypotheses has suggested that postural control may be viewed as a sequence of drift-and-act episodes [11,12]. The body deviates from the vertical until sensory signals inform the central nervous system that a correction is necessary, and then a corrective action is facilitated. Two age-related factors, the impaired sensory function and the reduced capacity to generate muscle force, suggest that in older persons, triggering a corrective action make take longer and the action process will then be slower. This gives rise to our third hypothesis that sway, particularly Rm, will be characterized by lower frequency content in older persons.

In another manipulation, we studied the effects of challenging conditions, such as closed eyes and semi-tandem stance, on the CoP displacement, Rm, and Tr. It is well documented that elderly persons rely on visual information more than younger persons. Hence, we expected that closing eyes (a sensory challenge) would have stronger effects on sway, particularly on Rm, as compared to the semi-tandem stance (a motor challenge).

2. Methods

2.1. Participants and quiet stance tasks

Two groups of young subjects (n = 28 and 29) and one group of older subjects (n = 21) volunteered to participate in the study (Table 1). The first young group (young-1) performed challenging tasks that were too complex for the elderly group; the second young group (young-2) was used as controls for the elderly group. The young subjects were recruited from university students, while the elderly group included fully independent volunteers. Both groups of subjects were not involved in any regular physical conditioning programs. Neurological diseases, major orthopedic lesions, vestibular or visual disturbances were used as exclusion criteria. After explaining the purpose and potential risks of the study, written informed consent was obtained. The study was approved by the National Medical Ethics Committee.

2.2. Procedures

Each subject performed a set of the quiet stance tasks as indicated in Table 1. The subjects were instructed to stand as still as possible for 60 s. Altogether, the following stance conditions were tested: (i) parallel stance, feet at hip–width, with eyes open and closed, (ii) single-leg stance on the dominant leg, with eyes open; and (iii) semi-tandem stance, feet together and toes of the non-dominant foot level with the inside arch of the dominant foot, with eyes open. For vision elimination, opaque goggles were used. In all cases the hands were placed on the hips and knees extended without locking the joint (i.e. avoiding hyper-extension of the knee). In tasks with eyes open subjects, were instructed to focus on a reference point marked on the wall at 1.5 m in front of them. In the case of single-leg stance, the subjects were instructed to keep the thigh of the non-dominant leg parallel to the thigh of the supporting leg, to avoid its active use, and to keep the left knee at about 90° flexion. All tasks were repeated three times for 60 s with 3-min breaks between trials. Foot position was marked on the force plate and repeated across trials. Each subject performed two 20-s practice trials before the test started.

2.3. Methods and data analysis

Three components of the ground reaction force (vertical (F_Z), horizontal (F_X and F_Y) – right handed coordinate system) were measured using a Kistler force plate. The signals were sampled at 1000 Hz. Pre-processing of the signals consisted of filtering: (a) F_{hor}, 10 Hz low-pass, zero-lag Butterworth second-order; and (b) CoP components, 0.04–10 Hz band-pass, zero-lag Butterworth second-order. Decomposition of the medial-lateral (ML) and anterior-posterior (AP) components of the CoP into Rm and Tr was done as described by Zatsiorsky and Duarte [1,2]. Briefly, instantaneous equilibrium points were defined as CoP coordinates when $F_{hor} = 0$. Rm was estimated as the interpolation of those points using a cubic spline function. Tr was estimated as the difference between CoP and Rm. The data were acquired and processed using Labview-based software. CoP, Rm and Tr trajectories were quantified by computing the following parameters: (i) root mean square (RMS), (ii) mean frequency on power spectrum of the signal (power spectrum was estimated using the fast Fourier transform), and (iii) mean velocity calculated as total distance divided by the duration of the measurement. All the parameters were computed for AP and ML direction.

2.4. Statistical analyses

Mean values of the main outcome variables calculated from the three 60-s trials at each of the balance tasks were included for further statistical analysis. For statistical analyses, SPSS 13.0 software (SPSS Inc., Chicago, USA) was used. Obvious outliers were excluded from further analysis using the Chauvenet criterion (one from young-1 PS-OE and elderly PS-OE, two from young-2 PS-CE). For testing statistical significance of differences the following tests were applied: (i) comparing young and elderly, independent t-test, (ii) comparing stance or vision conditions, paired t-test, and (iii) testing the interaction effects (*Age* × *Stance* and *Age* × *Vision*) 2-way repeated measures analysis of variance. All posturographic parameters values are presented as mean ± standard error. The level of statistical significance was set conservatively at 0.01. Effect size was calculated as $r^2 = t^2/(t^2 + \text{df})$, where t is the t-test statistics and df is the degrees of freedom (r^2 = 0.01 – small effect; r^2 = 0.09 – medium effect; r^2 = 0.25 – large effect).

3. Results

During parallel stance with open eyes, elderly subjects showed a general tendency to move the center of pressure (CoP) at higher velocity, over larger amplitude, and at a higher frequency. This general trend was more pronounced in the AP direction as compared to the ML direction. It is illustrated in Fig. 1, which shows 15-s segments of the three sway trajectories (CoP, Rm, and Tr). Specifically, mean velocities of CoP, Rm and Tr were significantly

Table 1
Means (standard deviations) are presented for the elderly group and the two young groups (young-1 and young-2) as well as the tasks the subjects performed.

	N (female, male)	Age (years)	Body mass (kg)	Body height (cm)	Task (stance-eyes)
Elderly	21 (20, 1)	81 (9)	67 (16)	163 (8)	PS-OE, PS-CE, STS-OE
Young-1	29 (12, 17)	24 (10)	70 (14)	172 (9)	PS-OE, SLS-OE
Young-2	28 (18, 10)	22 (4)	67 (13)	170 (11)	PS-OE, PS-CE, STS-OE

PS, parallel stance; STS, semi-tandem stance; SLS, single-leg stance; OE, open eyes; CE, closed eyes.