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Short Communication

Interaction of age and foam types used in Clinical Test for Sensory Interaction and Balance (CTSIB)

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ABSTRACT

Clinical Test for Sensory Interaction and Balance (CTSIB) is a simplified method for investigating the organization of multiple sensory inputs in postural control. The accuracy of the test is based partly on the foam types. Several types of foam are available, but the validity of these foams on CTSIB and the interaction of age and foam types have not been addressed. In this study, postural sway of young (21.6 ± 3.3 years) and older (53.2 ± 4.9 years) participants were assessed while standing on four types of foam: NeuroCom®, sponge, Ethylene Vinyl Acetate (EVA), and memory foams. Postural sway during stance on solid floor and foams with eyes open and eyes closed were quantified by root-mean-square (RMS) of center of body mass acceleration in the mediolateral (ML) and anteroposterior (AP) directions using the acceleration-based OPAL system. Physical properties of foams including density, Young's modulus, and indentation force deflection (IFD) were determined. Results demonstrated that RMS-ML in older subjects was larger than younger subjects ($p \leq 0.001$), especially when standing on the NeuroCom® foam with eyes closed ($p = 0.001$). There was an interaction of age and foam types as larger differences in RMS-ML were observed between young and older subjects on the NeuroCom® and EVA foams, but not the other foams. The sway characteristics were largest when standing on the NeuroCom® foam which demonstrated high density and high compliance. Our findings suggested the importance of foam selection in CTSIB on accurate postural sway analysis and balance assessment.

1. Introduction

Somatosensory, visual, vestibular systems and their interactions are crucial for postural control [1,2]. Clinical Test for Sensory Interaction and Balance (CTSIB) is a clinical assessment for investigating the organization of sensory inputs in postural control [3]. Results from CTSIB can be interpreted as having normal sensory organization or having sensory selection problems such as highly dependent on visual or somatosensory information to control balance [4]. The ability to organize sensory inputs for postural control declines with increasing age. Various authors have shown that older adults have difficulty with fewer reliable sensory cues [5].

The accuracy of postural assessment is influenced by the physical properties of the foam block [6]. While several types of foam are commercially available for CTSIB, the validity of these foams used in CTSIB has not been established. Thus, this study aimed to validate the types of foam used in CTSIB with the recommended NeuroCom® foam and to determine whether the older adults respond to types of foam differently when compared with young subjects. Accordingly, we hypothesized that foam type will have varying effects on postural sway linked to the surface properties which may further differentiate older from younger adults.

2. Methods

Four types of foam pads; Ethylene Vinyl Acetate (EVA) foam yoga block (Fitness-Mad®), memory foam (SANTAS®), sponge coated with plastic sheath (custom-made furniture shop), and the NeuroCom® foam were used in this study. Four conditions of CTSIB; firm surface with eyes open and eyes closed, and foam

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surface with eyes open and eyes closed, were administered to 60 female young and older subjects (30 in each group). The foam and visual conditions were randomized in the order of testing. The average age of the young and older subjects was 21.6 ± 3.3 years and 53.2 ± 4.9 years, respectively. Groups did not significantly differ in weight and height. Ethical approval and informed consent were received.

All types of foam were covered with similar black clothing cover (0.1 mm thickness) to blind the subjects and assessor. Participants were asked to stand barefoot with feet shoulder width apart and arm crossed under the chest [7]. The same feet position was kept throughout all testing trials. Each trial lasted for 30 s and was repeated three times. Postural sways were measured by an acceleration based equipment, OPAL inertial sensor and Mobility Lab software (APDM, Mobility Lab™). Acceleration of the approximate position of the body's center of mass (CoM) was detected by a sensor strapped at the fifth lumbar spine (L5) at the sampling rate of 50 Hz [7]. Root mean square (RMS) of CoM acceleration in the anteroposterior (AP) and mediolateral (ML) directions (RMS-ML and RMS-AP) was calculated to represent body sway [7].

Density and compressive responses were assessed as the common physical properties of foam [8,9]. Compression test was performed using the Universal Testing Machine (Instron®, model 55R4502) at a speed of 0.85 mm s^{-1} [10]. Foam specimens with the dimensions of 50 mm × 50 mm and thickness of 127 mm, three from each type of foam, were tested. The force used to compress the specimens to 25% and 65% of their original thickness were used to indicate the indentation force deflection (IFD), a measure of foam firmness [9,10]. Compressive stress, strain, and Young's modulus were automatically calculated.

A two-way mixed ANOVA was used to examine the main effect of age and foam types during eyes open or eyes closed, and Tukey post hoc analysis was performed to quantify the effect of foam types (SPSS Version 18.0, SPSS Inc., Chicago, IL, USA). Statistical significance was set at $p < 0.05$, and Bonferroni was used to adjust the alpha during multiple comparisons.

3. Results

Both groups had larger excursions during eyes closed than eyes open in all tested conditions, and excursions of CoM acceleration were more prominent in the older group (Fig. 1). The largest excursion of CoM acceleration was found when standing on the NeuroCom® foam (Fig. 1).

Analysis of RMS of CoM acceleration in eyes open condition revealed that RMS-AP among five conditions was not different (Fig. 2A), whereas significant differences in RMS-ML were observed between NeuroCom® and memory foam, and between NeuroCom® and sponge foam ($p = 0.003$) (Fig. 2B). During eyes closed, differences in RMS-AP were seen between NeuroCom® and memory foam, and between NeuroCom® and sponge foam (Fig. 2C). Interestingly, NeuroCom® foam led to the largest RMS-ML when compared with all other tested foams ($p = 0.001$) (Fig. 2D), and an interaction of foam types and age was detected on RMS-ML ($F_{(4,290)} = 7.22$, $p \leq 0.001$), but not RMS-AP. The older group showed larger difference in RMS-ML than the younger group when standing on NeuroCom® foam and EVA foam, but the RMS-ML was not different between age group standing on memory and sponge foams (Fig. 2D). Table 1 shows that all foams were similar in dimensions and thickness but different in other physical properties, such as density, firmness (25% and 65% IFD), and elasticity (Young's modulus).

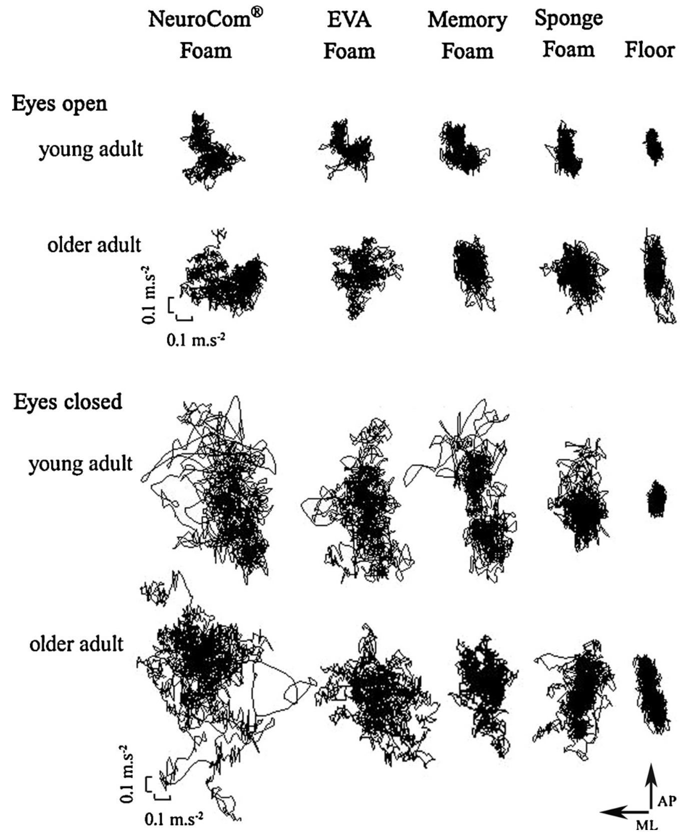

Fig. 1. Representative CoM acceleration excursions during standing on foams and floor with eyes open and eyes closed in young and old subjects. AP, anteroposterior; ML, mediolateral; m, meter; s, second.

4. Discussion

This study demonstrated an interaction between age and foam types on body sway. The difference in RMS-ML between two age groups was larger when standing on NeuroCom® foam and EVA foam. Such interaction observed in RMS-ML may be accounted for by the increase in hip and ankle stiffness with age, leading to the difficulty in maintaining postural stability in the ML direction [11]. In addition, the larger RMS-ML in the elderly was similar to that observed in the previous study which indicated that increased sway in the mediolateral direction was related to the density and elasticity of the foam [6]. Our finding on the age–foam interaction emphasizes the caution in CTSIB foam selection for accurate testing results.

In this study, we demonstrated that NeuroCom® foam had the highest Young's modulus and induced the largest body sway

Table 1
Physical properties of different types of foam.

	NeuroCom®	EVA	Memory	Sponge
Dimensions (m): width × length	0.46 × 0.46	0.48 × 0.40	0.56 × 0.41	0.46 × 0.46
Thickness (m)	0.13	0.12	0.13	0.13
Density (kg m^{-3})	60.01	42.36	69.35	37.67
25% IFD (N)	23.77	48.91	3.40	27.33
65% IFD (N)	56.27	322.77	24.65	87.97
Young's modulus (MPa)	0.14	0.08	0.01	0.06

IFD, indentation force deflection; m, meters; kg, kilograms; N, Newton; MPa, mega Pascal.

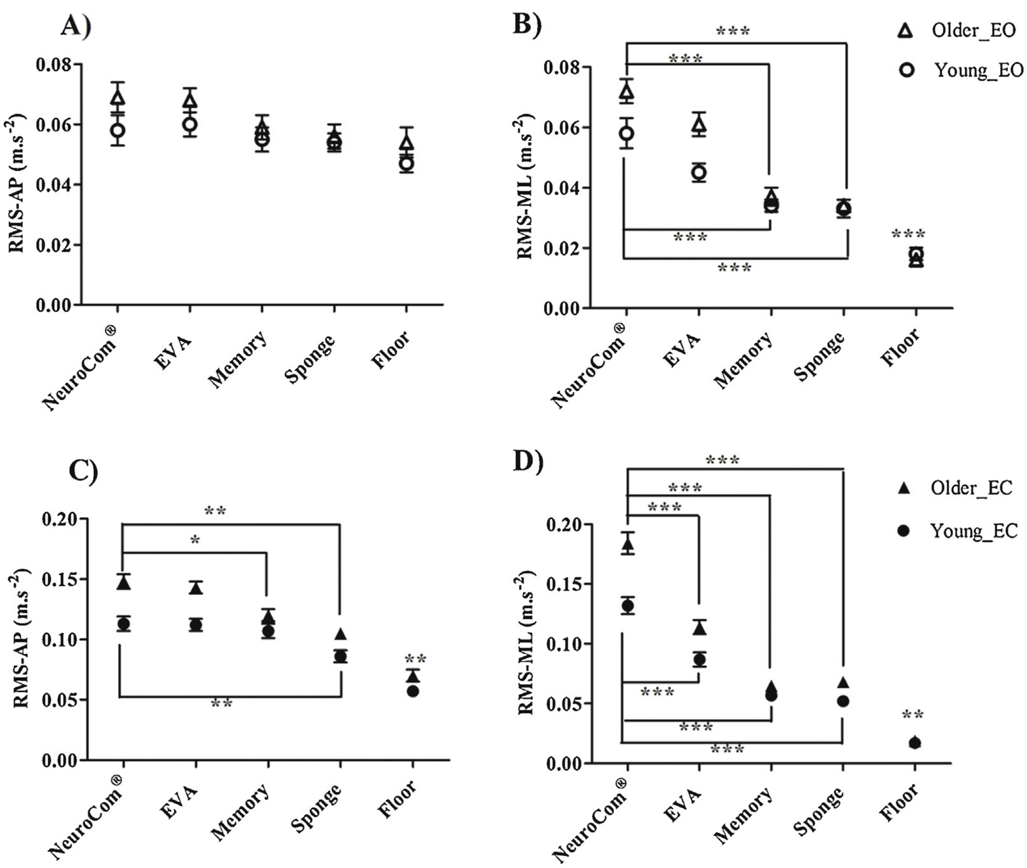

Fig. 2. Group average of root mean square (RMS) of CoM acceleration: (A) anteroposterior (RMS-AP) eyes open, and (B) mediolateral (RMS-ML) eyes open, (C) anteroposterior (RMS-AP) eyes closed, and (D) mediolateral (RMS-ML) eyes closed in young and older adults. $^{***}p < 0.005$, $^{**}p < 0.01$ and $^{*}p < 0.05$ represent significant differences between tested foams and NeuroCom® foam, and differences between different types of foam and floor.

compared to other foams. This result is in line with previous findings that demonstrated larger sway when standing on the foam with higher Young's modulus (0.049 MPa) as compared to the one with lower Young's modulus (0.029 MPa) [6]. This is supported by our observation that NeuroCom® foam had high density and low firmness (IFD), causing NeuroCom® foam to induce greater sways in both AP and ML directions. In comparison, EVA foam had higher firmness but lower Young's modulus than the NeuroCom® foam, causing less foam deformation. In addition, the hard texture of EVA foam may cause it to behave like a solid floor, increasing the reliability of the somatosensory inputs. Similarly, memory foam and sponge foam were soft so that they were deflated close to the floor, leading to the increase in the reliability of the somatosensory inputs.

In conclusion, the results from this investigation indicate that NeuroCom® foam is the most suitable foam type to be used in CTSIB due to its property to distinguish postural sway of young and older adults.

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Conflict of interest

There were no conflicts of interest. No authors have financial relationships with any research materials and equipment tested in this study.

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