Research Article

Differences in Responses on the Modified Clinical Test of Sensory Interaction and Balance on Medium Firm and Medium Density Foam in Healthy Controls and Patients with Vestibular Disorders

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What Is It about?

Many clinicians use unstable foam to test standing balance. Although norms were developed using a particular type of continuously compliant medium density foam, clinicians often use other types of foam. We tested healthy adults and adults with vestibular (inner ear) disorders on the type of medium density foam used to develop the norms and on medium firm foam, which is less compliant. When the dependent measure was trial duration (s), scores were different on the 2 types of foam. Therefore, if balance scores are going to be compared to published norms, then balance tests should be given on the same type of foam with which the norms were developed.

Keywords

Postural control · Vestibular screening · Romberg · Therapy assessment · Balance test

Abstract

Purpose: To determine whether foam density affects modified Romberg balance test performance. **Materials and Methods:** Controls and patients with vestibular disorders performed Romberg tests on medium and medium firm foam, with their eyes closed and the head still and moving in yaw and pitch. The trial duration and number of head movements were measured. **Results:** Subjects aged >60 years performed longer and with more head movements on medium firm foam than on medium foam. Older controls did not differ between medium firm and medium foam. Older patients had higher scores on head-still and head-yaw trials on medium firm foam versus medium foam but pitch trials did not differ. Females, controls, and patients had longer trial durations and more head movements on medium firm foam than on medium density foam; male controls did not differ by foam density. Male patients differed in

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yaw trials. **Conclusion:** Foam density affects scores. Clinical decision-making may be adversely affected if the clinician uses foam of a density that is not the same as that of the foam that was used in the studies that developed descriptive statistics, sensitivity, and specificity.

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Introduction

Since Shumway-Cook and Horak [1] updated the Romberg balance test [2] as the Clinical Test of Sensory Interaction and Balance (CTSIB) as a non-computerized alternative for computerized dynamic posturography [3], it has become widely used for screening standing balance skills (D Wrisley, PhD, PT, personal communication) and it is recommended as part of an educational program in vestibular rehabilitation by therapists around the world [4]. Initial descriptive statistics were published a few years later without regard to age. [5] Those data have been updated since then and age-related differences have been shown to occur [6, 7]. Those tests all used medium density foam from the same manufacturer. Many clinicians use other foam types, however.

The finding of age-related differences has been confirmed by other investigators [8]. Other investigators have also shown that different types of foam from different manufacturers affect the score [8–12]. Different levels of elasticity and thickness yielded different scores on postural control velocity, torque variances, and other measures. Nevertheless, many clinicians seem to be unaware of these findings. In essence, the firmer the foam, the easier it is to stand on it. This problem has not previously been tested using the foam with which Shumway-Cook and Horak [2] developed the CTSIB.

Although several measures differentiate patients from healthy controls [13], many of them are not useful for quick screening in the clinic. The simplest measure is trial duration and, during trials that are sharpened with head oscillations, the number of head movements. Those measures can be obtained with the use of a hand-held stopwatch or an app on a smart phone or tablet computer and simple observation. Therefore, those measures may be most useful for screening in rehabilitation clinics and environments with limited resources. Surprisingly, however, no previous studies have examined the problem of differences in trial duration by foam density.

The goal of the present study was to determine whether scores are different in asymptomatic healthy control subjects and patients with vestibular disorders when they are tested on the same type of foam, from the same manufacturer, but with different densities. This problem has important implications for clinical care, particularly for seniors, who are more likely than young adults to have vestibular and balance impairments. We used the same foam as in the original description by Shumway-Cook and Horak [2] and as in the studies describing sensitivity and specificity [6, 7] because that is the foam that clinicians should use if they intend to compare their clinical findings to published data.

Materials and Methods

Subjects

Two groups of adult subjects were recruited. The 63 control subjects were asymptomatic, with no history of vestibular or other otologic, neurologic, or musculoskeletal disorders. The control group included 54 females and 9 males, aged 21.4–81.2 years (mean $\pm$ SD: 45 $\pm$ 18.4 years). They were recruited from among staff, students, and visitors to our clinic waiting room. The 23 patients included 13 females and 10 males, aged 46.6–84.4 years (mean $\pm$ SD: 63.9 $\pm$ 11.8 years). All of the patients had been diagnosed with peripheral vestibular impair-

ments by board-certified otolaryngologists and neurologists based on clinical examination and the results of objective diagnostic tests including unilateral weakness on bi-thermal caloric testing of at least 20% (mean weakness 46%, range 22–100%). All of the subjects were able to walk independently without a cane.

Procedure

All of the tests were performed in a well-lighted room with a vinyl tile floor. All of the trials were performed on Sunmate compliant foam with a 2-mm polyurethane (Skinsoft) coating on one side (Dynamic Systems, Leicester, NC, USA: sunmatecushions.com). Two pieces of foam were used (both 71 × 62 × 10 cm; medium density foam, PSI = 0.85–0.95; medium firm density foam, PSI = 0.97–1.11). To standardize footwear and maintain hygiene, the subjects wore socks but no shoes.

Control subjects were all tested initially on the medium firm foam. Later, when we realized the manufacturer's mistake in sending us foam of a different density than we had ordered, the subjects were invited to return for testing on the medium foam. Thus, they were all tested more than 1 month later on the medium foam. The patients were tested on both types of foam in the same visit in random order so that half of the patients first stood on the medium density foam and half of the patients first stood on the medium firm foam. On both types of foam the subjects stood with their feet together, arms crossed, and eyes closed. Each trial lasted a maximum of 30 s. A trial was ended when the subject opened his eyes, took a step, or lost his balance. For safety, the foam slabs were placed near a corner and a staff member guarded the subject.

In trial 1 the head was stationary (head still). In trial 2 the subject shook his head from left to right (yaw) $\pm 30^\circ$. In trial 3 the subject nodded his head up and down (pitch) $\pm 30^\circ$. To cue head motions during head movement trials, an auditory signal generated by an app on a tablet was used. The signal oscillated at 0.33 Hz, with the sound varying between 170 and 450 Hz at a comfortable intensity level. The subjects were trained to oscillate their heads in pitch and yaw while standing on the floor with their eyes open, prior to the head movement trials. They were given verbal cues about the range of motion of the head movement as needed. This procedure was used previously to develop the published norms [6, 7]. Dependent measures were: trial duration, timed with a stopwatch, and the number of head oscillations made in yaw and pitch trials. A head oscillation was scored as complete when the head moved right-left-right/left-right-left, or up-down-up/down-up-down. It was scored as half an oscillation when only half the cycle was made. When less than half of an oscillation was observed it was scored as no head movement. After obtaining informed consent, the typical session lasted 10 min.

Statistical Methods

General linear mixed methods (Proc Glimmix) were used to examine the association of the study's primary outcomes with the type of foam (medium firm, medium) with various head movements (head still, head moving in yaw, head moving in pitch). For patients and controls, analyses were performed overall and they were then stratified by subjects' gender and age (≤ 59 or ≥ 60 years). $p < 0.05$ was considered statistically significant. All analyses were performed using SAS statistical software (version 9.4; Cary, NC, USA).

Results

Control Subjects

For control subjects the time elapsed to retest varied from 35 to 608 days (median: 227 days), depending on subjects' schedules. Many of them returned when they had another visit

Table 1. Scores for the total cohort

	Head still	Head yaw		Head pitch	
	duration	duration	head rotations	duration	head rotations
Medium firm foam					
Controls	22.5 (11.2)	20.47 (11.8)	5	19.6 (11.6)	5
Patients	10.5 (10.7)	8.2 (8.2)	1	6.7 (8.1)	0.5
Medium foam					
Controls	19.7 (11.4)	17.1 (11.7)	2.5	16.1 (11.6)	2
Patients	5.4 (6.1)	4.3 (4.19)	1	1.2 (1.2)	1

Mean trial durations (SD) and median head rotations for medium and medium firm foam are shown.

Table 2. Scores by gender

	Head still	Head yaw		Head pitch	
	duration	duration	head rotations	duration	head rotations
Medium Firm Foam					
Male controls	26.5 (7.6)	20.8 (13.7)	5	20.2 (11.9)	5
Female controls	21.8 (11.6)	20.4 (11.6)	5	19.5 (11.7)	4.75
Male patients	11.0 (11.6)	6.1 (4.4)	1	5.0 (7.1)	0.75
Female patients	10.2 (10.3)	9.8 (10.1)	1.5	8.0 (8.9)	0.5
Medium foam					
Male controls	24.2 (9.6)	18.1 (11.8)	2.5	19.3 (11.9)	4
Female controls	18.9 (11.6)	16.9 (11.8)	2.5	16.2 (11.6)	2
Male patients	6.3 (8.5)	3.0 (1.3)	0.75	6.2 (8.5)	1.25
Female patients	4.7 (3.5)	5.2 (5.3)	1	3.8 (2.1)	0.5

Mean trial durations (SD) and median head rotations for medium and medium firm foam are shown.

to the Medical Center with a family member. With all of the control subjects combined trial durations were significantly longer on the medium firm foam than on the medium foam (head still, $p = 0.03$; head yaw, $p = 0.004$; and head pitch, $p = 0.01$). Similarly, the number of head oscillations was slightly but significantly greater on the medium firm foam compared to the medium foam (Table 1).

For control females, trial durations were all significantly longer on the medium firm foam compared to the medium foam for head still ($p = 0.04$), head yaw ($p = 0.006$), and head pitch ($p = 0.007$). They had more significantly more head oscillations on both head movement trials on the medium firm foam than the medium foam (head yaw, $p = 0.04$, and head pitch, $p = 0.005$). For control males trial durations did not differ significantly between types of foam in any of the trial conditions and they did not differ on the number of head oscillations during head movement conditions, either (Table 2).

To test for age-related differences among the subjects, the age range was split at 59 years, per previous evidence showing a difference between younger and older subjects [6], yielding 47 subjects in the younger control group and 16 subjects in the older control group. Within the younger group, trial durations were significantly longer on the medium firm foam

Table 3. Scores by age for asymptomatic subjects

	Head still	Head yaw		Head pitch	
	duration	duration	head rotations	duration	head rotations
Medium firm foam					
Younger controls	26.7 (7.8)	24.4 (9.7)	5.5	23.4 (9.8)	5.5
Older controls	10.2 (10.6)	9.0 (9.8)	1	8.5 (9.4)	1
Younger patients	12.9 (11.3)	9.7 (9.7)	1.75	9.4 (11.3)	1
Older patients	9.3 (10.5)	7.4 (7.6)	1	5.3 (5.7)	0.5
Medium foam					
Younger controls	23.2 (9.9)	20.7 (10.8)	5	19.5 (10.9)	4
Older controls	9.2 (8.8)	6.4 (7.1)	1	8.2 (9.6)	1
Younger patients	7.6 (9.3)	4.6 (2.1)	1.4	7.5 (9.3)	1.3
Older patients	4.2 (3.1)	4.0 (5.0)	0.5	3.4 (1.6)	1

Values for younger (≤ 59 years) and older (≥ 60 years) subjects are shown as mean trial duration (SD) and median head rotations for medium and medium firm foam.

than on the medium foam (head still, $p = 0.016$; head yaw, $p = 0.009$; and head pitch, $p = 0.007$). In the older group, no significant differences were found for trial duration between types of foam in any of the trials. Similarly, for the number of head movements, younger subjects made significantly more head movements on the medium firm foam compared to the medium foam in head yaw ($p = 0.01$) and head pitch ($p = 0.003$). Older subjects did not differ on the number of head movements on medium firm or medium foam in pitch or yaw trials (Table 3).

Patients with Vestibular Disorders

With all of the patients combined trial durations were significantly longer in head-still ($p = 0.006$) and head-yaw ($p = 0.005$) trials on medium firm foam versus medium foam. Trial durations for pitch trials did not differ between the 2 types of foam (Table 1).

On head-still trials male patients did not differ in trial durations in head-still and head-pitch trials but they did perform head-yaw trials for significantly longer on medium firm foam versus medium foam ($p = 0.028$). Female patients performed head-still trials for significantly longer on medium firm than medium foam ($p = 0.01$) and approached significant differences in head-yaw trials ($p = 0.07$), but trial durations of head-pitch trials did not differ between medium firm foam and medium foam (Table 2).

Older patients performed head-still ($p = 0.05$) and head-yaw ($p = 0.01$) trials for significantly longer on medium firm foam than medium foam but did not differ in head-pitch trials. Subjects younger than 60 years of age performed head-still trials for significantly longer on medium firm foam than on medium firm foam ($p = 0.049$), but they did not differ between the two types of foam on head-yaw and head-pitch trials (Table 3).

The number of head movements did not differ significantly between the 2 types of foam overall or by the 2 age groups or the 2 genders (Tables 1–3). Therefore, we do not recommend counting the number of head movements. The perturbation in postural control caused by the head movement is sufficient to disturb balance and may affect the complexity of the sway pattern but the actual number of movements generated does not seem to be relevant.

Discussion/Conclusion

Scores on medium firm and medium foam differ. These data suggest that maintaining balance on firmer foam is easier. Therefore, therapists should be careful which type of foam they use for screening balance. If they want to challenge the patient then the less firm foam should be used.

Furthermore, the published descriptive statistics and data on sensitivity and specificity for CTSIB are based on medium, not medium firm, foam [5–7]. If the therapist plans to compare a patient's data to published data in order to decide whether the patient's scores are within the normal range for that age group, then medium foam should be used. More specifically, the clinician should use foam with characteristics that match those of the foam used in the published studies. This problem is important if the clinician will use the results of the balance screening to determine the need for further testing or for therapy or to determine whether the outcome of therapy leads to age-appropriate balance skill.

If a patient can perform the head-still trial for the usual expected length of time, that clinical outcome does not mean that the patient's standing balance skills are normal. It might indicate that the trial was too easy to stress that patient's system. Therefore, the head-moving trials should also be used. The destabilizing effects of head movement are particularly clear in the head-yaw trials. Younger patients with vestibular disorders, in particular, who have more physical resources than older patients may be able to perform head-still trials easily. Nevertheless, they may be unable to perform one or both of the head movement trials.

If the clinician uses a different type of foam than that used in the published studies the clinician will be able to determine whether the patient has improved from the initial assessment to a later assessment date but the clinician will not be able to determine whether the patient's scores fall within the normal range for that patient's group. Thus, the therapist risks making an incorrect decision about care.

Previous evidence shows that these tests are more challenging for older subjects than for younger ones. Therefore, we tested 2 age groups separately. The finding that both age groups performed the head-still trial for longer on the firmer foam supports the idea that the density of the foam used for testing is an important parameter and affects the outcome.

The problem of male/female differences in balance has yet to be resolved. This study showed some differences. Previous research on CTSIB showed no differences between males and females [6]. Some other studies, however, have shown sex differences [14–17]. The problem of postural control and aging may be more related to the complexity of postural sway than to any single factor, however [18].

The relatively low scores for healthy controls with the head still are probably related to age-related changes in balance skill.

Study Limitations

The order of foam tests was not randomized or counterbalanced for control subjects because of the serendipitous manner that the design came about; we received the medium firm foam rather than medium foam when we ordered new foam for an experiment and did not realize the mistake initially. When we realized what had happened, we invited participants in the on-going study to return for retesting on the medium foam. The order of testing might have affected the outcome but, given the relatively long time in between tests, that possibility is low. We ensured that there was no order effect in the patients by randomizing the order of testing.

As in the previous studies [6, 7] we had subjects wear socks, for good hygiene and to match the design of the previous studies. Clinicians may test patients who are not wearing

socks. Although we advise wearing socks to maintain good hygiene, we realize that some patients may not wear socks and the clinic may not have extra socks available. It is possible, though unlikely, that testing with and without socks might result in significant differences in the scores. We are unable to perform such a study to find out, however.

The study cohorts had fewer males than females. The clinical services at our institution have more female than male non-faculty staff. Also, the family members, friends, and paid caregivers who accompany patients to our clinic are predominantly female, consistent with the evidence that most caregivers are female [19, 20]. To recruit an equal number of males and females would have taken longer than our study schedule allowed. Due to the differences between the male and female sample sizes, results about only males, especially control males, should be interpreted with caution.

The study had more young controls than old controls. Ideally, we would have had the sample sizes in both groups, but finding seniors who met the inclusion criteria and would return to the Medical Center was challenging. That difference might have affected the outcome. The number of older subjects was high enough, however, that we are not concerned that the sample size affected the results. Also, we had more older patients than younger ones because of the nature of the patient population. The mean age of the control group was younger than that of the patient. Nevertheless, the findings in the 2 groups are similar.

As a sensitivity analysis we also examined the results in controls based on an age cut-off of 45 years to make the groups more equal in sample size ($n = 34$, younger than 45 years; $n = 29$, older than 45 years). We found similar results as before, i.e., only younger subjects had a significantly longer duration and head movements on medium firm foam than on medium foam. Thus, our results showing the lack of influence of foam type among the older subjects may not be due to the small sample size in that group but may indicate changes due to aging.

Summary

These data have important clinical implications for therapy. Standing balance is an important component of many activities. Also, balance impairments may indicate underlying problems that the therapist may need to address, or at least take into account during treatment planning. Therefore, therapists should assess standing balance as part of the initial evaluation. The CTSIB is inexpensive and easy to administer in virtually any clinical setting where physical and occupational therapists practice. Therefore, it has become widely used to screen standing balance. The norms published for CTSIB used medium density foam. Therapists who plan to use those norms for comparison with patients should use the same foam density as in the normative papers. Otherwise, the density of the foam will affect the results of testing, which may affect clinical decision-making.

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Statement of Ethics

All of the subjects gave written informed consent prior to participation. This study was approved by the Institutional Review Board for Human Subjects Research for our institution. This paper complies with internationally-accepted standards for research practice and reporting.

Disclosure Statement

The authors have no conflict of interests to declare.

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Author Contributions

Helen S. Cohen designed this study, recruited and tested subjects, interpreted data analyses, and drafted this paper. Haleh Sangi-Haghpeykar performed all statistical analyses, interpreted data, and drafted this paper.

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