Time to maintain standing balance on NeuroCom and AIREX foams during the Modified Clinical Test of Sensory Interaction and Balance (mCTSIB) in elderly

ระยะเวลาในการควบคุมการทรงตัวระหว่างโฟมนิวโรคอมและแอเร็กที่ใช้ในการทดสอบ Modified Clinical Test of Sensory Interaction and Balance (mCTSIB) ในผู้สูงอายุ

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Abstract

A common clinical tool for balance assessment in the elderly is the modified clinical test for sensory interaction and balance (mCTSIB). This test is used for assessing the ability to appropriately organize sensory information for stance control by timing the stance duration. The mCISIB composes of four conditions; stand with eyes open and eyes closed on a firm surface and foam surface. Types of foam pad used in the mCTSIB test can affect accuracy of the test results. The NeuroCom® foam is the standard foam used for the mCTSIB testing but it is expensive. At present, the AIREX® Balance-Pad is a cheaper foam that is widely used in both clinical and laboratory settings but there is no report on its appropriateness for the mCTSIB. Therefore, this study aimed to compare time to maintain stability between AIREX® Balance-Pad foam and the NeuroCom® foam when standing on conditions of the mCTSIB in elderly. Sixty-eight healthy elderly persons were asked to maintain stability under four conditions of mCTSIB: firm and foam surface (AIREX® and NeuroCom®) with eyes open and eyes closed for 120 seconds each condition. Participant's time to maintain stability during the mCTSIB test was recorded using the stop watch. Combination of the time to maintain stability on four conditions of the mCTSIB (composite score) and standing time on each foam condition was compared between AIREX® and NeuroCom® foams. Paired samples t-test was conducted to compare between two types of foams at a level of p-value < 0.05. The composite score measured during the mCTSIB test was significant higher ($p = 0.000$) when using the AIREX® foam (431.78 $\pm$ 64.37 seconds) compared to the NeuroCom® foam (424.06 $\pm$ 67.66 seconds). Significant difference of time to maintain stability between two different types of foam pads was found for eyes closed condition ($p = 0.001$), but not eyes open condition ($p = 0.099$). A composite score for the mCTSIB on the NeuroCom® foam differs from the AIREX® foam, especially under eyes closed condition. Using different types of foam in balance test may lead to the wrong interpretation of balance performance of elderly persons.

บทคัดย่อ

เครื่องมือทางคลินิกที่ใช้กันมากที่สุดสำหรับการประเมินการทรงตัวในผู้สูงอายุ คือ การทดสอบ modified clinical test for sensory interaction and balance (mCTSIB) ซึ่งใช้ในการประเมินความสามารถของระบบประสาทส่วนกลางในการจัดการข้อมูลจากระบบรับความรู้สึกสู่การควบคุมการทรงตัว mCTSIB ประกอบด้วย 4 เงื่อนไข ได้แก่ ยืนลืมตา และหลับตาบนพื้นและโฟม ชนิดของโฟมที่ใช้ในการทดสอบ mCTSIB ส่งผลต่อผลการทดสอบการทรงตัว โฟม NeuroCom® เป็นโฟมมาตรฐานที่ใช้สำหรับการทดสอบ mCTSIB แต่มีราคาแพง ปัจจุบัน โฟม AIREX® เป็นโฟมที่ใช้กันอย่างแพร่หลายทั้งในทางคลินิกและห้องปฏิบัติการ แต่ยังไม่มีรายงานถึงความเหมาะสมของการนำโฟม AIREX® ไปใช้ในการทดสอบ mCTSIB ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อเปรียบเทียบระยะเวลาที่ผู้สูงอายุสามารถยืนทรงตัวได้ระหว่างการยืนบนโฟม AIREX® และโฟม NeuroCom® ภายใต้เงื่อนไขการทดสอบ mCTSIB ผู้สูงอายุสุขภาพดีจำนวน 68 คน ถูกขอให้ยืนทรงตัวภายใต้ 4 เงื่อนไข เป็นเวลา 120 วินาทีในแต่ละเงื่อนไข ผลรวมของเวลาที่อาสาสมัครสามารถยืนทรงตัว (composite score) และระยะเวลาของการยืนในเงื่อนไขที่ใช้โฟม ถูกนำมาใช้ในการเปรียบเทียบความแตกต่างระหว่างโฟม AIREX® และ NeuroCom® โดยใช้สถิติ paired samples t-test ผลรวมของระยะเวลาในการยืนทรงตัวขณะทดสอบด้วย mCTSIB ในกรณีที่ใช้ โฟม AIREX® (431.78 $\pm$ 64.37 วินาที) มีค่ามากกว่าอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับการใช้โฟม NeuroCom® (424.06 $\pm$

67.66 วินาที) (p = 0.000) และพบความแตกต่างของระยะเวลาในยืนทรงตัวบนโฟมทั้งสองชนิดนั้นพบเฉพาะในขณะที่ยืนบนโฟมร่วมกับหลับตา (p = 0.001) ผลรวมของระยะเวลาในการยืนทรงตัวในเงื่อนไขของ mCTSIB โดยใช้โฟม NeuroCom® แตกต่างจากการใช้โฟม AIREX® โดยเฉพาะอย่างยิ่งเมื่อยืนพร้อมกับหลับตา ดังนั้น การใช้โฟมที่แตกต่างกันในการทดสอบการทรงตัวอาจนำไปสู่การตีความที่ไม่ถูกต้องเกี่ยวกับความสามารถในการทรงตัวของผู้สูงอายุ

คำสำคัญ: พื้นผิวที่ไม่มั่นคง, การทรงตัว, ผู้สูงอายุ
Keywords: compliant surface, postural stability, older persons

Introduction

Postural control is the foundation of our ability to stand and to walk independently (Tinetti et al., 1988). An age-related degeneration of the multiple systems in elderly people may contribute to falls, fear of falling and decreased physical activity that subsequently lead to impaired health-related quality of life (Scheffer et al., 2008; Young et al., 2015) and the ability to live independently (Tinetti et al., 1995). Important degenerative change in the elderly relating to the occurrence of falls is balance. Declined functions of sensory systems and central system as a result of advancing age lead to problems of integrating sensory information for balance control (Buchanan et al., 2003; Nodehi-Moghadam et al., 2015)

One of the most commonly used clinical tool for balance assessment in elderly is the clinical test for sensory interaction and balance (CTSIB) (Boulgarides et al., 2003; Whitney et al., 1998). This test is used to assess the ability of the central nervous system to appropriately organize and select sensory information for stance control under the situation that alters visual, vestibular or somatosensory information (Buchanan et al., 2003; Horak, 1987; Mahoney et al., 2015; Nodehi-Moghadam et al., 2015). The CTSIB includes six conditions that vary sensory available for balance control; standing on firm and foam surface with eyes open, eye closed, and wearing visual conflict dome (Shumway-Cook et al., 1986). Total duration for remaining stable (maximum 30 seconds) and acceleration of the body's center of mass (CoM) measured under those test conditions have been used to determine balance performance (Cohen et al., 1993; Wrisley et al., 2004). Results from this test can be interpreted as having normal sensory organization or having sensory selection problems, for example, highly dependent on visual or somatosensory information to control balance (Cohen et al., 1993).

Although CTSIB is a reliable test with excellent test-retest reliability (r = 0.75) (Anacker et al., 1992), the administration time is still lengthy as it takes approximately 30 minutes to complete the test. In addition, a previous study found redundancy among test conditions of the CTSIB when using in healthy elderly aged over 65 years such that balance duration during the visual conflict dome conditions did not differ from eyes closed conditions (Cohen et al., 1993). Therefore, visual conflict dome conditions are eliminated and a shorter version of CTSIB, the modified CTSIB (mCTSB) has been developed to determine the balance performance (Whitney et al., 2004). The mCISIB composes of four conditions of CTSIB; stand with eyes open and eyes closed on a firm surface and foam surface (Cohen et al., 1993; Wrisley et al., 2004). Time to administer the mCTSIB is about 10 minutes that cover a 30 seconds-trials of 4 conditions, repeated 3 times with additional time for setup and explanation (Wrisley et al., 2004). The reliability of the mCTSIB has been evaluated previously. All four conditions have excellent test-retest reliability (ICC = 0.91 to 0.97) (Hageman et al., 1995) and have moderate to high intrarater reliability (kappa = 0.31 to 0.81) (Loughran et al., 2005). Balance performance on the mCTSIB is easy to evaluate using a stopwatch to time how long person can maintain stability in a standing position (Wrisley et al., 2004). The mCTSIB is frequently used to assess balance performance in many populations (Boulgarides et al., 2003; Trueblood et al., 2001; Weber et al., 1993) including elderly (Boulgarides et al., 2003; Trueblood et al., 2001).

In aging, the ability to maintain standing balance during different conditions of CTSIB is varied, indicating the

deterioration of specific sensory system or the integration of several of sensory systems. Cohen et al. (1993) reported that elderly people have similar ability to stand on firm surface conditions when compared to younger persons. Both age groups could complete 30 seconds of firm surface conditions (Cohen et al., 1993). However, elderly persons demonstrated shorter duration to remain stable, compared with younger adults (Cohen et al., 1993), indicating that foam condition was more sensitive than firm surface condition to detect age-related decline in standing balance. Summation of duration to maintain standing position of all conditions of the CTSIB (composite score) has been used to indicate balance performance in elderly (Di Fabio et al., 1996). Although the CTSIB can be used to assess elderly's balance ability, this test is not practical in everyday practice due to the complexity of equipment required in the dome conditions. Therefore, the mCTSIB (4 conditions without dome) is a substitute test for administering in the clinical setting.

A variety of foam types, ranging in their density, have been used among different studies of mCTSIB (Boulgarides et al., 2003; Cohen et al., 1993; Mulavara et al., 2013; O'Sullivan et al., 2009; Shumway-Cook et al., 1986). Different types of foam affect test results differently and may lead to the wrong interpretation of the balance test. Previous study showed that the sway characteristics were largest when standing on NeuroCom® foam, a foam which has high density and high compliance property (e.g. Young's modulus) when compared to Ethylene Vinyl Acetate foam, sponge foam, and memory foam (Chaikeeree et al., 2015). At present, the AIREX® Balance-Pad is another foam that is widely used in both clinical and laboratory settings (Lin et al., 2015; O'Sullivan et al., 2009; Rugelj et al., 2015). However, there was no report on the time to maintain stability of using AIREX® Balance-Pad to assess balance performance. Therefore, this study aimed to compare the time to maintain stability between AIREX® Balance-Pad foam and the NeuroCom® foam when standing on mCTSIB in elderly. Different results of balance test under the two types of foam was hypothesized.

Methodology

Subjects

Male and female elderly persons age over 60 years who could walk with or without walking aids for at least 6 meters and no history of neurological diseases were recruited from the suburban communities in Pathum Thani, Thailand. They were excluded from this study if they were on medications affecting balance (Chen et al., 2014; Vandervelde et al., 2007), had disorders signs or symptoms of vertigo, nystagmus, blindness, uncontrolled cardiovascular conditions, neuropathy, and severe musculoskeletal problem affecting balance performance. They were also excluded from the study if they had comprehensive problem indicating by a score less than 24 out of 30 on the Mini-Mental State Examination-Thai version 2002 (MMSE-Thai) (Boonkerd et al., 2003; Institute of Geriatric Medicine, 2008) and had body mass index (BMI) of equal or more than 30 kg/m^2 (World Health Organization, 1998). All participants were signed informed consent forms before participated in this study. Study's protocol was approved by the Human Research Protection Committee, Faculty of Physical Therapy, Srinakharinwirot University, Thailand (PTPT2017-010).

Procedures

Sixty-eight elderly persons were recruited based on the inclusion and exclusion criteria. Subject's characteristics and general health status including strength of lower extremity muscles (using standard manual muscle test), body weight, height, and BMI) were gathered before starting other tests. Subject's cognitive function and comprehension were examined using the Mini-Mental State Examination-Thai version 2002 (MMSE-Thai) (Boonkerd et al., 2003; Institute of Geriatric Medicine, 2008), which assess 5 components; orientation, memory, language, calculation, and attention. A person who had the MMSE score of below 24 points, indicating cognitive impairment, was excluded from the study. Functional balance performance and fear of falling of subjects were determined using the Time Up and Go test (TUG) and Falls Efficacy Scale (FES) - Thai version (Tinetti et al., 1990), respectively.

The present study tests the utility of two types of foam pad the NeuroCom® foam (Natus Medical Incorporated, Inc.) with dimensions of 0.46 x 0.46 meters and AIREX® balance - pad foam (Legal Notice, Airex AG, Inc.), with dimensions of 0.50 x 0.41 mater (Figure 1). We used two pieces of the AIREX® balance - pad foam to make to types of foam have similar thickness. Standing balance during four conditions of mCTSIB: floor - eyes open, eyes closed, foam eyes open and closed was examined on two types of foam (Figure 2). This resulted in 6 conditions per each participant, 2 on floor and 4 on foam conditions of the mCTSIB: NeuroCom® (foam - eyes open, eyes closed) and of the AIREX® foam (eyes open, and eyes closed).

During each condition, participants were instructed to stand barefoot with feet shoulder width apart, arm crossed touch on the shoulder, looking forward at a picture hang at eye level of each individual during eyes open trials for as long as possible up to 2 minutes, performed once for each condition (Figure 2). Prior to the test, participants received the instruction and were allowed to practice the task until they became familiar with the task. A few minutes of rest period was allowed between each trial to prevent fatigue. The evaluation was performed in the same setting and all participants received the same verbal instruction. The total duration of testing was approximately 45 minutes for each participant. Time to maintain stability during each condition was recorded using the stop watch (Figure 1A).

This study extended the time to maintain standing balance from 30 seconds (used in the original protocol of the mCTSIB test) to 2 minutes. This was because our pilot study of ten elderly persons indicated that all of the pilot's participant could stand for more than 30 seconds under all conditions of the mCTSIB, but they could not remain stable for longer than 2 minutes. To ensure participant's safety, vital sign and blood pressure were monitored prior to and after the test and closed guarding during the tests were administered.

(A) NeuroCom® foam (B) AIREX®Balance-pad foam

Figure 1 Equipments used in the study

(A) (B) (C) (D)

Figure 2 Study setting, starting position for four conditions: firm (A) and foam (B) with eyes open and firm (C) and foam (D) with eyes closed condition.

Data analysis

The demographic and clinical characteristics of the subjects were described using a descriptive statistic. The recorded time to maintain stability during all trials for the four conditions; eyes open and closed on floor and on foam, i.e. NeuroCom® foam and AIREX® foam, was combined to determine a composite score (summation of 4 conditions of

120 seconds trials for mCTSIB). Total possible score of the composite score for each type of foam is four hundred and eighty seconds. The percentage of the composite score for each types of foam was calculated to determine performance related to total possible score. The lower composite score indicates lower balance performance. Time to maintain stability on the foam - eyes open and eyes closed conditions were separately determined for each type of foam. Total possible time to maintain stability on each foam is one hundred and twenty seconds. The composite score and time to maintain stability on foam pad were compared between AIREX® Balance-Pad foam and the NeuroCom® foam using paired samples t-test. The SPSS software version 16 was used to perform statistical analysis. Statistical significance difference was set at a level of p-value of less than 0.05.

Results

Sixty-eight elderly (38 male and 30 female) participated in this study. All of them had normal leg muscle strength, normal BMI, no comprehension problem, no fear of fall and could walk independently. Characteristics of the participant were shown in the Table 1.

Mean composite score of the NeuroCom® foam was 424.06 ± 67.66 seconds (88.35 % of maximum possible score) and AIREX® foam was 431.78 ± 64.37 seconds (89.79 % of maximum possible score) indicating declined balance performance in elderly. The composite scores for all 4 conditions when standing on the AIREX® foam was significantly longer than when standing on the NeuroCom® foam (p = 0.000), indicating that participants can maintain stability on the AIREX® foam longer than on the NeuroCom® foam (Figure 3).

When comparing only the time when standing on the foam (not the firm surface), average time to maintain stability for each type of foam was shown in the Figure 4. Under eyes open, participants showed similar time to maintain stability (p = 0.099) when standing on NeuroCom® foam (108.21 ± 24.30) and AIREX® foam (110.07 ± 21.17) (Figure 4A). In contrast, during eyes closed condition, time to maintain stability was significantly shorter (p = 0.001) on the NeuroCom® foam (82.12 ± 29.60 seconds) than the AIREX® foam (87.97 ± 38.52 seconds) (Figure 4B).

Table 1 Subject characteristics (n = 68)

Characteristics	Range	Mean ± S.D.
Age (years):	60 - 82	68.46 ± 5.79
LE Muscle strength (/5):	5	5
Weight (kg):	50 - 81	66.18 ± 8.58
Height (cm):	150 - 187	164.93 ± 8.26
BMI:	17.58 - 29.69	24.39 ± 3.09
MMSE Score (/30):	24 - 30	26.87 ± 2.02
FES (/100):	53 - 100	81.18 ± 15.53
TUG (seconds):	9 - 60	19.10 ± 11.94

Values are shown in mean ± S.D., except the LE muscle strength is presented as median, kg; kilogram, cm; centimeter, BMI; Body mass index, MMSE; The Mini Mental State Examination, FES; Falls Efficacy Scale, TUG; Time Up and Go test.

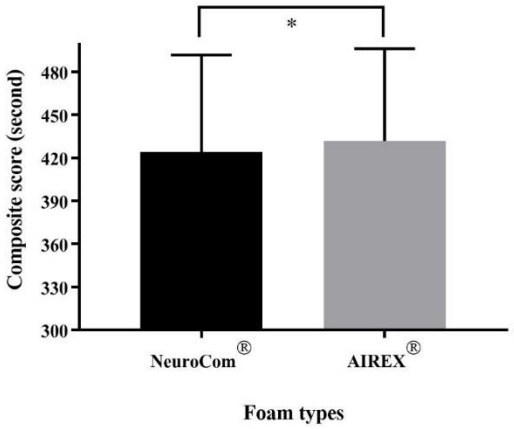

Figure 3 A composite score (summation of 120 seconds trials for each of 4 conditions trials for mCTSIB) for two types of foam pad *represent significant differences between NeuroCom® foam and AIREX® conditions (p = 0.000).

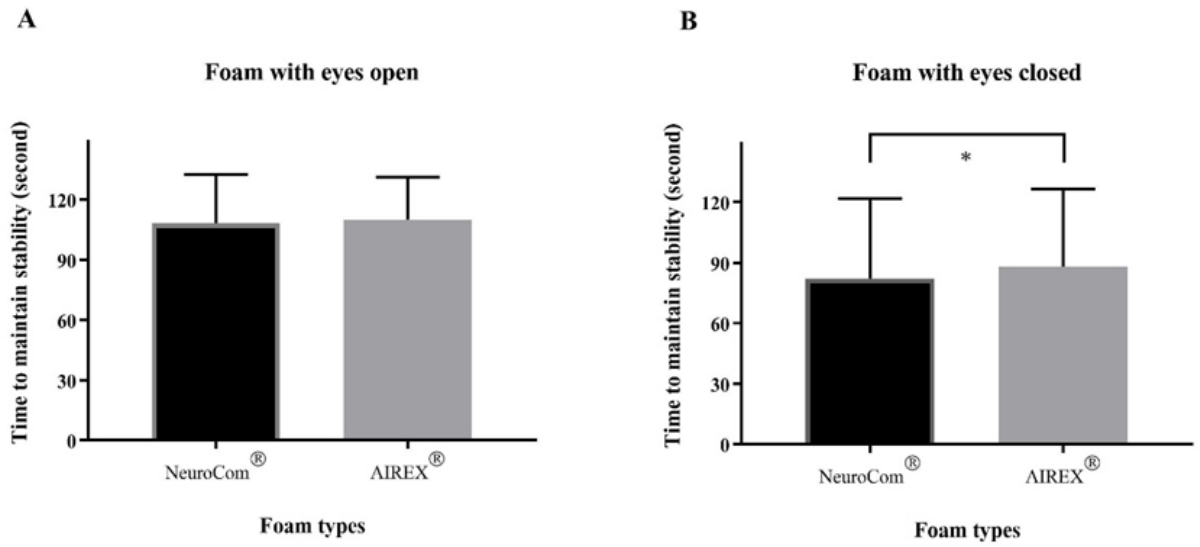

Figure 4 Average of time to maintain stability in foam conditions: (A) Standing on foam with eyes open condition, and (B) Standing on foam with closed condition. * represent significant differences between NeuroCom® foam and AIREX® foam (p = 0.001).

Discussion

Balance-Pad foam and the NeuroCom® foam during mCTSIB in elderly. Both foams demonstrated that the elderly persons were unable to maintain stance stability for the whole 120 seconds. In the present study, a wide range TUG performance, indicated that both types of foam had the ability to detect balance performance throughout wide range of mobility and balance performance. This result was in accordance with the previous study where they found that the elderly persons could not remain stable on the foam until the end of testing time and their time to maintain stability on foam was shorter than young adults (Cohen et al., 1993). Although the NeuroCom® foam is the standard foam used for testing sensory integration with the laboratory Balance Master system, this foam is not easily affordable in the clinic due to its high cost. The cheaper AIREX® Balance-Pad foam that is commonly used in the fitness centers is the potential alternative for mCTSIB purpose. However, our results showed significant difference in composite score between the NeuroCom® foam and AIREX® foam. Longer standing duration on the AIREX® foam indicated that the elderly persons can maintain stability better when standing on the AIREX® foam as compared to the NeuroCom® foam. This finding confirmed that types of foam influence the test result and raise the awareness on the selection of foam type to provide accuracy and consistency of the mCTSIB test.

In the present study, the difference between foam types was found during eyes closed condition, but not eyes open condition. Three sensory inputs, namely vision, vestibular and somatosensory systems function in maintaining standing balance on the firm and foam surfaces (Cohen et al., 1993; Wrisley et al., 2004). During the eye open condition, these three sensory systems are available for balance control whereas only two sensory systems are available during the eyes closed condition. Decrease in flexibility of the use of sensory systems for balance control is found in the ageing population, resulting in the increase in visual dependence during balance control. Therefore, the absence of visual system in the eyes closed condition results in difficulty in switching to other sensory systems for balance control which reflects in the larger sway during the eyes closed condition (Peterka, 2002). Therefore, the difference in foam types on time to maintain stance stability in the elderly persons was more evident during the eyes closed condition as seen in our study.

The difference in foam types on time to maintain stance stability may be partly due to the physical properties of the

foam. The NeuroCom® foam has the dimensions of 0.46 x 0.46 meters, density of 60.01 kg m^{-3}, indentation force deflection (IFD); 25% of 23.77 Newton (N) and 65% of 56.27 N and Young's modulus of 0.14 Mega Pascal (MPa) (Chaikeeree et al., 2015) and AIREX® foam has the dimensions of 0.50 x 0.41 mater (two pads foam), density of 55 kg m^{-3}, IFD; 25% of 43.87 N and 65% of 265.89 N and Young's modulus of 0.26 MPa (Lin et al., 2015). Foam density and elastic modulus are related to postural instability (Patel et al., 2008). The previous findings demonstrated that the NeuroCom® foam had high density and low firmness (IFD), causing this foam to induce instability (Chaikeeree et al., 2015) when compared to the AIREX® foam that had higher firmness.

This study has some limitations. The healthy and active older adults were recruited to participate in this study. Therefore, we extended the standing duration in each condition from the 30 seconds (in the original mCTSIB) to 120 seconds, as no difference was found during the first 30 seconds. One should be cautious when applying this results in the clinic where only 30 seconds are required for testing mCTSIB such that both types of foams do not differ in term of time to maintain stance stability during that short period of standing. In addition, before selecting the AIREX® foam for mCTSIB in the clinic, other group of participants with different functional capacities should be assessed on this foam.

Conclusion

The balance test result, composite score on the Modified Clinical Test of Sensory Interaction and Balance and time to maintain stability on compliance surface, derived from the AIREX® foam was lower than from the NeuroCom® foam. Precaution should be taken when evaluating postural control stability using foam surfaces with different compliance properties.

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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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