Influence of room lighting illuminance on postural control using an accelerometer measure among the individuals with transient ischemic attack

อิทธิพลของระดับแสงสว่างในห้องต่อความสามารถในการทรงท่าวัดโดย accelerometer ในอาสาสมัครที่มีภาวะสมองขาดเลือดชั่วคราว

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ABSTRACT

Background: Postural dysfunction among individuals with a transient ischemic attack (TIA) is inconclusive. Dim-light condition is commonly encountered in real-life situations. However, there is limited evidence on the influence of diminished room light on postural control in TIA.

Objective: To determine the influence of room lighting illuminance on postural control using the accelerometry measure under normal (NL) and diminished (DL) room light, and with the eye closed (EC) conditions in TIA.

Methods: Twelve participants with TIA and age-gender-matched controls were recruited. The accelerometer was used to quantify body sway or pelvic acceleration in anterior-posterior (AccAP) and medial-lateral (AccML), pelvic sway jerkiness (JERK), and standing time (ST). The testing tasks were standing on one leg (SOL), compensatory stepping to different directions, standing on a firm and a foam surface (Sfirm and Sfoam). Two-way mixed ANOVA with pairwise comparison was used for analysis.

Results: DL and EC affected Acc, JERK, and ST in TIA during SOL, compensatory stepping lateral (ComL), and Sfirm testing. DL significantly reduced ST, increased AccAP, AccML in SOL and Sfirm, and increased JERK in ComL when compared to NL only in TIA group. Despite room-light did not affect TIA in Sfoam, AccML in Sfoam was higher in TIA than the Con group.

Conclusion: TIA had subclinical balance dysfunction especially in DL and EC despite having no clinical impairments. This balance dysfunction was able to detect using an accelerometer. Therefore, postural assessment combined with accelerometer and light intensity adjustment are more sensitive to monitor postural control in TIA.

Keywords: Acceleration, Lighting, Movement, Postural balance

บทคัดย่อ

ที่มาและความสำคัญ: ยังไม่มีข้อสรุปที่แน่ชัดเกี่ยวกับความผิดปกติในการทรงท่าในผู้ที่มีภาวะสมองขาดเลือดชั่วคราว (TIA) ภาวะแสงไฟสลัวเป็นภาวะที่อาจพบได้บ่อยในการทำกิจกรรมในชีวิตประจำวัน อย่างไรก็ตาม ยังไม่มีหลักฐานการศึกษาเกี่ยวกับอิทธิพลของแสงไฟสลัวต่อความสามารถในการทรงท่าในผู้ที่มีภาวะ TIA

วัตถุประสงค์: เพื่อศึกษาอิทธิพลของแสงสว่างในห้องต่อความสามารถในการทรงท่าเมื่อวัดด้วย accelerometer ในภาวะแสงปกติ แสงสลัว และขณะปิดตา ในผู้ที่มีภาวะ TIA

วิธีการวิจัย: ผู้เข้าร่วมงานวิจัยที่มี TIA และผู้ที่มีสุขภาพดี (Con) ที่มีเพศและอายุตรงกันกลุ่มละ 12 คน ใช้

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อุปกรณ์ accelerometer วัดการแกว่งของร่างกายหรือความเร่งของเชิงกรานในแนวหน้า-หลัง (AccAP) และในแนวซ้าย-ขวา (AccML) ความเรียบลื่นในการแกว่งของเชิงกราน (JERK) และช่วงเวลาในการยืนขาเดียว (ST) ทำการทดสอบการยืนขาเดียว (SOL) การเคลื่อนไหวชดเชยในการก้าวขาไปทิศต่างๆ (Com) การทดสอบยืนบนพื้นแข็ง (Sfirm) และยืนบนพื้นนิ่ม (Sfoam) ทำการวิเคราะห์ผลโดยใช้สถิติ Two-way mixed ANOVA และการเปรียบเทียบระหว่างสองกลุ่ม

ผลการวิจัย: ภาวะแสงไฟสลัวและการปิดตาส่งผลต่อความเร่งของเชิงกราน ค่า JERK และค่า ST ของกลุ่ม TIA ในการทดสอบ SOL การเคลื่อนไหวชดเชยในการก้าวขาไปด้านข้าง (ComL) และ Sfirm โดยพบว่าเฉพาะใน TIA แสงสลัวทำให้ ST ลดลง และทำให้ค่า AccAP, AccML เพิ่มขึ้นในการทดสอบ SOL และ Sfirm และเพิ่มค่า JERK ในการทดสอบ ComL เมื่อเทียบกับแสงปกติ ถึงแม้ว่าระดับแสงจะไม่มีผลต่อ TIA ขณะทดสอบ Sfoam แต่พบว่า AccML ใน Sfoam ของ TIA มีค่ามากกว่าเมื่อเทียบกับกลุ่ม Con

สรุปผล: ผู้ที่มีภาวะ TIA มีความบกพร่องในการทรงตัวแบบไม่สามารถสังเกตเห็นได้เมื่อประเมินทางคลินิก แต่สามารถวัดการแกว่งของลำตัวได้เพิ่มขึ้นเมื่อประเมินด้วย accelerometer โดยเฉพาะในภาวะแสงไฟสลัวและปิดตา ดังนั้น การประเมินการทรงท่าร่วมกับการใช้ accelerometer และการปรับระดับแสงช่วยเพิ่มความไวของการประเมินในผู้ที่มีภาวะ TIA

คำสำคัญ : ความเร่ง แสงสว่าง การเคลื่อนไหว การทรงตัว

Introduction

Minimal movement impairments were evidenced in individuals with transient ischemic attack (TIA) (1). From the best of our knowledge, only one study evaluated the postural balance in TIA[1]. Batchelor et al.[1] found a significant differences in step test, timed up and go (TUG), and step and quick turn test between the TIA and matched healthy control[1]. However, other clinical balance tests and knee proprioception showed non-significant differences between the TIA and control[1]. Noted that all of the significant parameters were related to the speed of movement or related to the dynamic tasks[1]. Thus further study would require to promote a better understanding of the postural control among the TIA patients.

Control of balance is the result of an integration of various physiological processes, somatosensory, vision, and vestibular systems[2]. The roles of the visual system can be classified as central and peripheral vision[3]. The central vision is responsible for identifying the characteristics of an object such as color and shape with a good spatial resolution and visual acuity[4,5]. The peripheral vision informs location and spatial orientation of an object and takes a responsible part for the control of a stable stand[6-8]. It was found that the body sway was reduced more by the stimulation of the peripheral instead of the central visual field[5]. In contrast to the central visual field, peripheral vision can work in a dim-light condition[5].

Dim-light condition is commonly encountered in real-life situations, such as walking on a low lit street. However, the study on the influence of dim-light condition was rarely evidenced. The reduction of visual acuity may be related to the dim-lighting environment and influenced an increased risk of falls[9]. However, other studies found that contrast sensitivity rather than visual acuity is caused the postural stability[10,11]. Thus, visual dysfunctions like poor contrast sensitivity or poor visual environments or dim-light can reduce the postural stability and can influence the control of postural balance[12]. Interestingly, it was found that the greatest sway during standing and the slowest gait was found in dim-light and not in the no-light conditions in patients with diabetes[13]. Dim-light condition might cause false cues in patients with diabetes which could overload the other systems and cause more gait abnormalities[13]. From our knowledge, there was no study related to the postural control in dim-light among the TIA.

The Mini-BESTest incorporates the dynamic tasks which covers different balance systems; anticipatory and reactive postural control, sensory orientation, and gait stability[14]. For the present study, parts of the Mini-BESTest were selected due to the technical and time constraints. It is widely believed that the increased of postural sway during the postural tests manifests a reduced level of postural stability. However, most of the clinical tests using eye observation could measure only the gross characteristics of poor postural control.

Analyzing the postural sway with an accelerometer provides a sensitive analysis[15]. Inertial Measurement Units (IMU) were attached to the subjects to increase the sensitivity of the test. Acceleration of the body segments derived from IMU, such as at the pelvis in anterior-posterior (AccAP) or medial-lateral (AccML) directions and jerkiness represent the body sway[16]. Increasing of AccAP and AccML have been associated to the postural stability (16). Sway jerkiness (JERK) is the higher derivatives of acceleration (16). This parameter is used to measure the quality of smoothness of movement and can imply the frequent corrections of postural sway (16). From our knowledge, there was no quantitative measurement of postural control using IMU in TIA.

Consequently, the present study aimed to determine the influence of room lighting illuminance on postural control using IMU measure under three conditions including a normal room light (NL), diminished room light (DL), and with the eye closed (EC) conditions in individuals with TIA. The knowledge from this study can be used as helpful assessment protocol and the promotion of falling risk reduction such as environmental modification in household in individuals with TIA.

Methods

Study design

This was a cross-sectional study conducted at the Department of Physical Therapy, Chiang Mai University. Participants were recruited from the Stroke Unit, Department of Internal Medicine, Maharaj-Nakorn Chiang Mai Hospital. All participants received an informed consent approved by the ethics committee review board at the Faculty of Medicine, Chiang Mai University (NONE-2561-05655). All participants provided written informed consent prior to participate in the study.

Participants

The sample size calculation was performed based on the power of 0.95, the level of significance of 0.05 and the effect size of 0.35 Using the program G*power 3.0.10 for ANOVA repeated measures, within-between interaction calculation, the number of subjects needed for each group was 12.

Twenty-four participants (12-individual with TIA and 12-match healthy controls) aged 40-70 years were recruited. The diagnosis of TIA was confirmed by a neurologist according to the clinical presentation and the definition of the American Heart Association[17]. Duration of post-onset ranged from 3-24 weeks[18]. The inclusion criteria of all participants consisted of both gender, aged 40-75 years, normal visual field testing by visual confrontation test[19], having an inactive lifestyle confirmed with the screening questionnaire, independently walking ability without using an assistive device, comprehend instructions, and willing to participate in the study.

Exclusion criteria for individuals with TIA were as follows: cognitive impairment using the Mini-Mental State Examination (cut-off score<24), vestibular dysfunction such as vertigo, benign paroxysmal positional vertigo, diagnosed with other neurological lesions, impairment of touch and proprioception, musculoskeletal disorders (e.g. severe edema, pain) and lower extremity (LE) muscle strength less than 4/5 grade of manual muscle testing, severe deformity that restricted to less than 3 meters of walking distance, medications affecting balance and gait, and psychological disorder (e.g. anxiety or depression) by observation and general interview. The healthy control was matched by gender and age of the individuals with TIA.

Tasks

Participants performed the postural stability tasks that partially selected from the Mini-BESTest[14]. For the anticipatory postural adjustment, standing on one leg (SOL) test was conducted. For the reactive postural control, compensatory stepping correction in different directions was selected. For sensory orientation, only standing on the firm and foam surface (Sfirm, Sfoam) were tested. The detailed commands and procedures were followed as per the Mini-BESTest guidelines[14].

Experimental protocol

The first test was the SOL on either side of LE, for 20 seconds, followed by compensatory stepping correction-forward (ComF), correction-backward (ComB), and correction-lateral (ComL), and stand still (feet together) on a firm surface (Sfirm), and on foam surface (Sfoam) (38×46×5 cm balance pad) for 30 seconds. All the tests were performed under three light conditions (NL, DL, EC). To reduce the effects of light conditions, the randomization of the room lighting was provided. NL condition, light intensity was varied at 400-450 lux. A LED light bulb of 3-lux was used in DL condition. Therefore, the participants were able to read the Snellen's chart not better than 6/30 meters[20]. Two trials were completed for each side or each condition. At least two minutes of resting was provided after each light condition confirmed with rate of perceived exertion (RPE).

To increase the sensitivity of postural sway evaluation, the Inertial Measurement Units (IMU; STT systems Co, Spain) were used. This system included tri-axial accelerometers, magnetometers, and gyroscopes with wirelessly transmit raw data at 100 Hz to a laptop data collection system. The reliability and validity of this system has been tested[21]. Participants were asked to strap with 8-IMU which was attached on the bilateral thigh, both shanks, both ankles, thoracic, and L5-S1 spine. These IMU sensors were attached throughout the test.

Data processing

Data at the specific events, that is during SOL, at the beginning of stepping recovery to gaining the balance in compensatory stepping, and during 30-second of standing still on a firm and a foam surface, were exported for the further analysis. Custom automatic MATLAB® algorithms were elaborated to process the data from the IMU. The acceleration signals recorded from the pelvic sensor were transformed to a coordinate system and filtered using a third-order zero phase lag elliptical low pass filter, with a cut-off frequency of 0.25 Hz. The pass band ripple (0.01dB) and the stop band ripple (100dB) were used to perform gravity removal[22]. Pelvic root mean square acceleration in the anterior-posterior (AccAP) and medial-lateral (AccML) directions, as well as pelvic sway jerkiness (JERK) were calculated[16]. The standing time (ST) of SOL was also recorded.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 17. The distribution of all dependent parameters was tested using the Shapiro-Wilk test. A mixed model ANOVA was used, with the groups (TIA and control) as between the subject's factor and the room lighting conditions (NL, DL, and EC) as the within subject's factor. The significant level was set at p<0.05.

Results

The results showed that deprivation of visual information with DL and EC conditions resulting in an increased of postural instability among participants with TIA during the SOL, ComL, and Sfirm tasks. However, DL and EC affected the Con only in SOL. Room-light did not affect TIA in Sfoam, but the AccML in Sfoam was higher in TIA than the Con group.

1. Demographic characteristics

Twenty-four participants were recruited in this study: TIA (n=12), and matched healthy Con (n=12). Five participants (3 participants from TIA, and 2 participants from control) were removed from data processing due to technical error. The demographic characteristics of the participants are presented in Table1. There was no significant difference between the groups in respect of all variables. The average onset of TIA was 7.9±5.15 weeks, ranging from 3-24 weeks.

2. Standing on one leg

More individuals with TIA failed to stand for 20 seconds when compared to control in NL and DL. From 48 trials in each condition, a loss of balance occurred 25 vs 13 trials in NL and 42 vs 25 trials in DL for TIA and control, respectively. However, both groups were unable to complete SOL relatively similar in EC (47/48 vs 43/48 for TIA and control).

Table 1. Participants' characteristics

Characteristic	TIA (n=12)	Controls (n=12)	*p*-value*
Age, mean (SD), years	60.58 (7.29)	60.83 (7.44)	0.93
Gender (female %)	6 (50)	6 (50)	1.00
Weight, mean (SD), kg	66.42 (13.66)	63.03 (9.13)	0.48
Height, mean (SD), cm	160.92 (8.48)	161.00 (9.77)	0.98
Symptoms of TIA			
● Left side weakness/numbness	6 (50)		
● Right side weakness/numbness	2 (16.67)		
● Others			
- Dizziness	1 (8.33)		
- Visual disturbance	1(8.33)		
- Numbness	1(8.33)		
- Facial weakness	1(8.33)		

Note: **p*-value for the difference between TIA participants and healthy controls (match-pairs analysis), TIA = transient ischemic attack

2.1 Pelvic acceleration in anterior-posterior and medial-lateral direction

In SOL, combination the results of both legs was performed. The significant main effects of light and group on AccAP and AccML were found [$F_{(2, 72)}$=29.74, p<0.001, η^2=0.45, and $F_{(1, 36)}$=8.84, p<0.01, η^2=0.20, for AccAP, respectively] and [$F_{(2, 72)}$=22.44, p<0.001, η^2=0.38, and $F_{(1, 36)}$=4.57, p=0.04, η^2=0.11 for AccML, respectively]. However, there was no significant interaction effects of light and group [$F_{(2, 72)}$=1.41, p=0.25 for AccAP] and [$F_{(2, 72)}$=1.55, p=0.22 for AccML].

Pairwise comparison indicated that DL and EC induced a significant increase of AccAP compared to NL in both groups (Figure 1a). The AccAP was significantly higher in TIA than in control by means of all conditions (Figure 1b). Comparison within the group showed that the AccML was significantly greater in EC compared to NL in both groups (Figure 1c). Interestingly, DL significantly affected the AccML only in TIA group (Figure 1c). This parameter was larger among the TIA than the control group in all conditions, however it showed a significant difference only in DL (Figure 1d).

2.2 Pelvic sway jerkiness

Only the main effect of light in JERK was observed [$F_{(1.41, 50.70)}$=4.14, p=0.03, η^2=0.10]. There were no significant effects of group and no interaction effects of light and group in this parameter [$F_{(1, 36)}$=2.31, p=0.14 and $F_{(1.41, 50.70)}$=1.63, p=0.21, respectively]. Only the TIA group demonstrated a statistically increased JERK in EC compared to NL (p=0.05) but not in control (Figure 1e). Noted that JERK exhibited non-significant greater among the group in all conditions (Figure 1f).

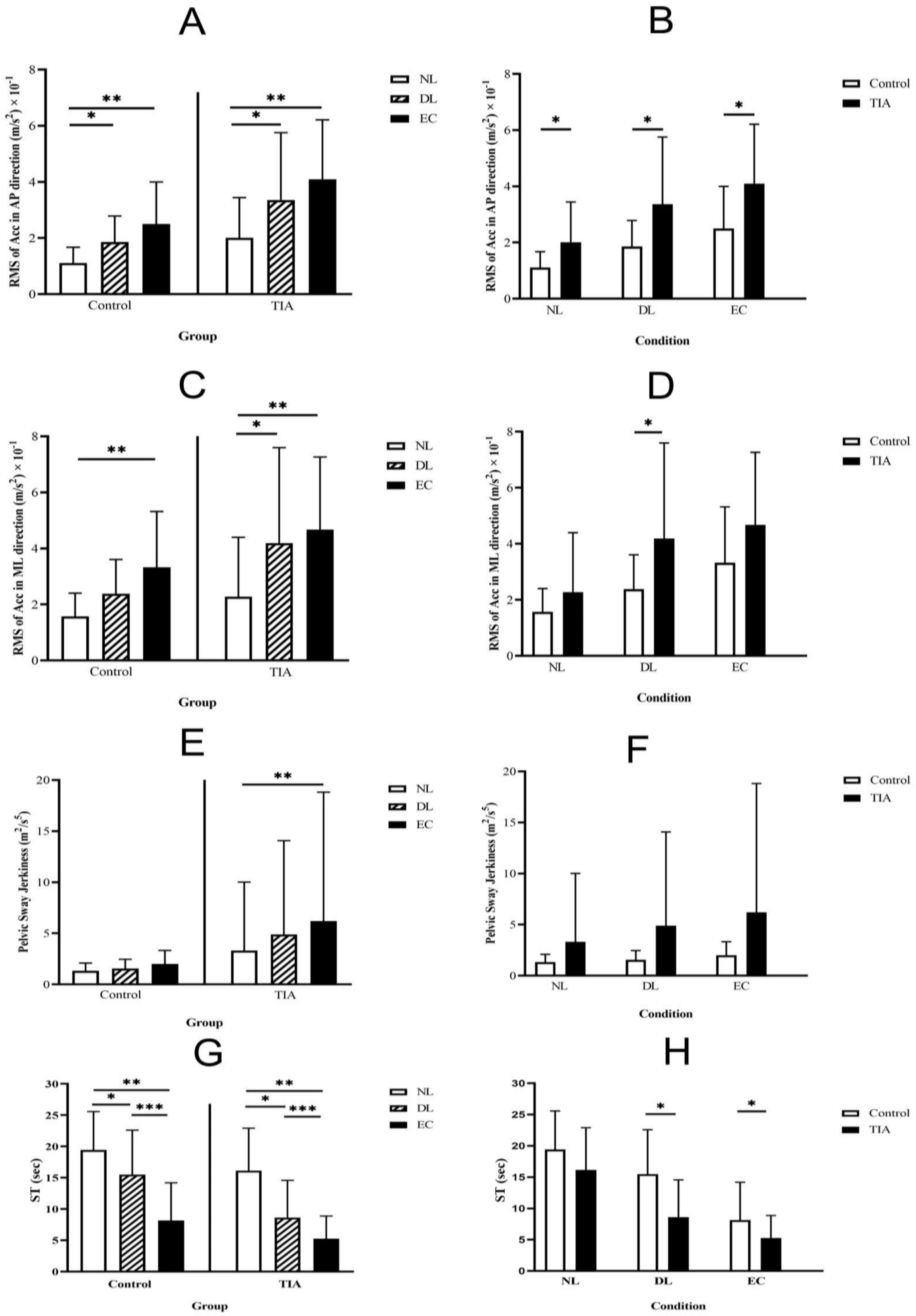

Figure 1 The effect of room lighting levels on acceleration in anterior-posterior (AccAP), acceleration in medial-lateral (AccML), pelvic sway jerkiness (JERK), and standing time (ST) during standing on one leg (SOL), *significant difference $p<0.05$

2.3 Standing time

The significant main effects of light and group but no interaction effects were found [$F_{(2,92)}$=70.96, p<0.001,η^2=0.61, $F_{(1,46)}$=314.75, p<0.01,η^2=0.87 and $F_{(2,92)}$=2.77, p=0.07, respectively]. Pairwise comparison showed the significant (p<0.01) longest ST in NL and the shortest in EC in both groups (Figure 1g). In addition, control group demonstrated a significantly longer ST only in DL and EC than TIA (p<0.01) but not in NL condition (Figure 1h).

3. <u>Compensatory stepping</u>

Both groups could recover from the ComF and ComB without fall. However, ComL was the only test that could illicit the fall pattern in both groups. The number of fall pattern gradually increased in DL and EC (3/48 and 11/48 trials) in TIA, but control showed a few fall pattern (3/48 trials) only in EC.

There were no significant main effects of light and no interaction effects of these conditions for AccAP and AccML in all directions of compensatory stepping. Only the JERK in ComL showed a significant results. Therefore, we presented only the results of JERK.

3.1 Pelvic sway jerkiness in compensatory stepping

Only JERK in ComL showed significant effects of light [$F_{(1.34, 48.15)}$=5.76, p =0.01, η^2=0.14] and group [$F_{(1, 36)}$=21.53, p<0.001, η^2=0.37]. However, there were no interaction effects of light and group [$F_{(1.37, 49.41)}$=0.92, p =0.37] in this parameter. TIA demonstrated a significantly increased of the JERK in DL and EC compared to NL (p=0.03, and p=0.03 respectively) (Figure 2a). However, the lighting condition did not create a significant difference of JERK in control (Figure 2a). Interestingly, JERK among the TIA was higher than the control group considering all lighting conditions (NL; p<0.01, DL; p=0.001, and EC; p<0.01) (Figure 2b). There were no significant interaction effects and main effects of group and light in JERK during ComF and ComB.

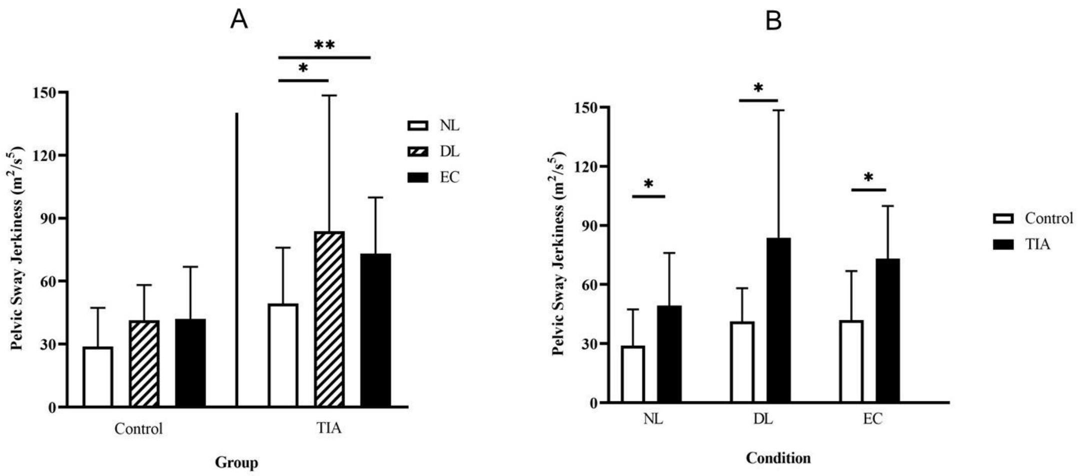

Figure 2 The effect of room lighting levels on pelvic sway jerkiness (JERK) during compensatory stepping sideway (ComL), * significant difference p<0.05

4. <u>Standing on firm surface</u>

All participants could complete 30-second stand in all lighting conditions.

4.1 Acceleration in anterior-posterior direction

A significant light and group interaction effects for AccAP was found ($F_{(2, 34)}$=3.53, p=0.04, η^2=0.17). In addition, there were significant differences in major effects of light and group ($F_{(2, 34)}$=12.32, p<0.001, η^2=0.42 and $F_{(1, 17)}$=15.61, p<0.01, η^2=0.48). Only AccAP under DL and EC among the TIA presented a significant increased as compared to NL (NL-DL: p=0.03; NL-EC: p<0.001) (Figure 3a). However, control group did not show any significant difference in AccAP in different conditions. Post-hoc analysis showed that TIA was characterized by a significant higher of AccAP than control in DL and EC (DL; p=0.049; EC: p<0.01) (Figure 3b), indicating that lighting levels affected the AccAP only in TIA (Figure 3a&3b).

4.2 Acceleration in medial-lateral direction

Neither the interaction effects ($F_{(2, 34)}$=0.53, p=0.60) nor the main effects of group ($F_{(1, 17)}$=1.62, p=0.22) were significant for AccML (Figure 3d). However, there was a significant major effects of light in AccML in Sfirm ($F_{(2, 34)}$=7.54, p<0.01, η^2=0.31). Only TIA showed that DL and EC induced an increase of AccML compared to NL (NL-DL: p=0.049; NL-EC: p=0.04) (Figure 3c).

4.3 Pelvic sway jerkiness

There were significant effects of light and group in the JERK ($F_{(2, 34)}$=6.05, p<0.01, η^2=0.26, ($F_{(1, 17)}$=12.80, p<0.01, η^2=0.43, respectively). However, there was no significant interaction effect of light and group ($F_{(2, 34)}$=0.88, P=0.43). Post-hoc analysis showed that EC caused an increased in the JERK compared to DL (P=0.046) only in TIA (Figure 3e). In addition, the markedly increased of the JERK in EC was presented in TIA compared to control (p<0.01) (Figure 3f).

5. <u>Standing on foam surface</u>

All participants could complete 30-second stand in all lighting conditions.

5.1 Acceleration in anterior-posterior direction

There was a significant effect of group in this variable ($F_{(1, 17)}$=13.78, p<0.01, η^2=0.44). However, neither the interaction effect of light and group ($F_{(1.46, 24.80)}$=0.05, p=0.91) nor the main effect of light ($F_{(1.46, 24.80)}$=1.85, p=0.19) were different significantly (Figure 4a). TIA had a significant higher of AccAP than control only in NL (p=0.03) (Fig4b). Noted that AccAP of TIA in DL and EC also increased but showed a non-significant difference compared to the control group (Figure 4b).

5.2 Acceleration in medial-lateral direction

The significant difference in the focal effect of light and group ($F_{(2, 34)}$=3.88, p=0.03, η^2=0.19), $F_{(1,17)}$=16.88, p<0.01, η^2=0.05, respectively) was found. However, there were no significant differences in the interaction effects of light and group ($F_{(2, 34)}$=0.11, p=0.90) in AccML. The lighting condition did not affect AccML in both groups (Figure 4c). Conversely, TIA had significantly higher of AccML than control in all conditions (NL; P=0.02, DL; p=0.04, and EC; p=0.049, respectively) (Figure 4d).

5.3 Pelvic sway jerkiness

There was a significant difference main effect of the group in this variable ($F_{(1,\ 17)}$=4.87, p=0.04, η^2=0.22). However, there was no significant main effect of light and interaction effect of light and group in the JERK in Sfoam ($F_{(2,\ 34\ )}$=2.70, p=0.08, and $F_{(2,\ 34)}$=0.17, p=0.84, respectively). Lighting condition did not affect JERK among both groups (Fig 4e). Noted that, JERK demonstrated a significantly higher in TIA more than the control group considered only in NL (p<0.001) (Figure 4f).

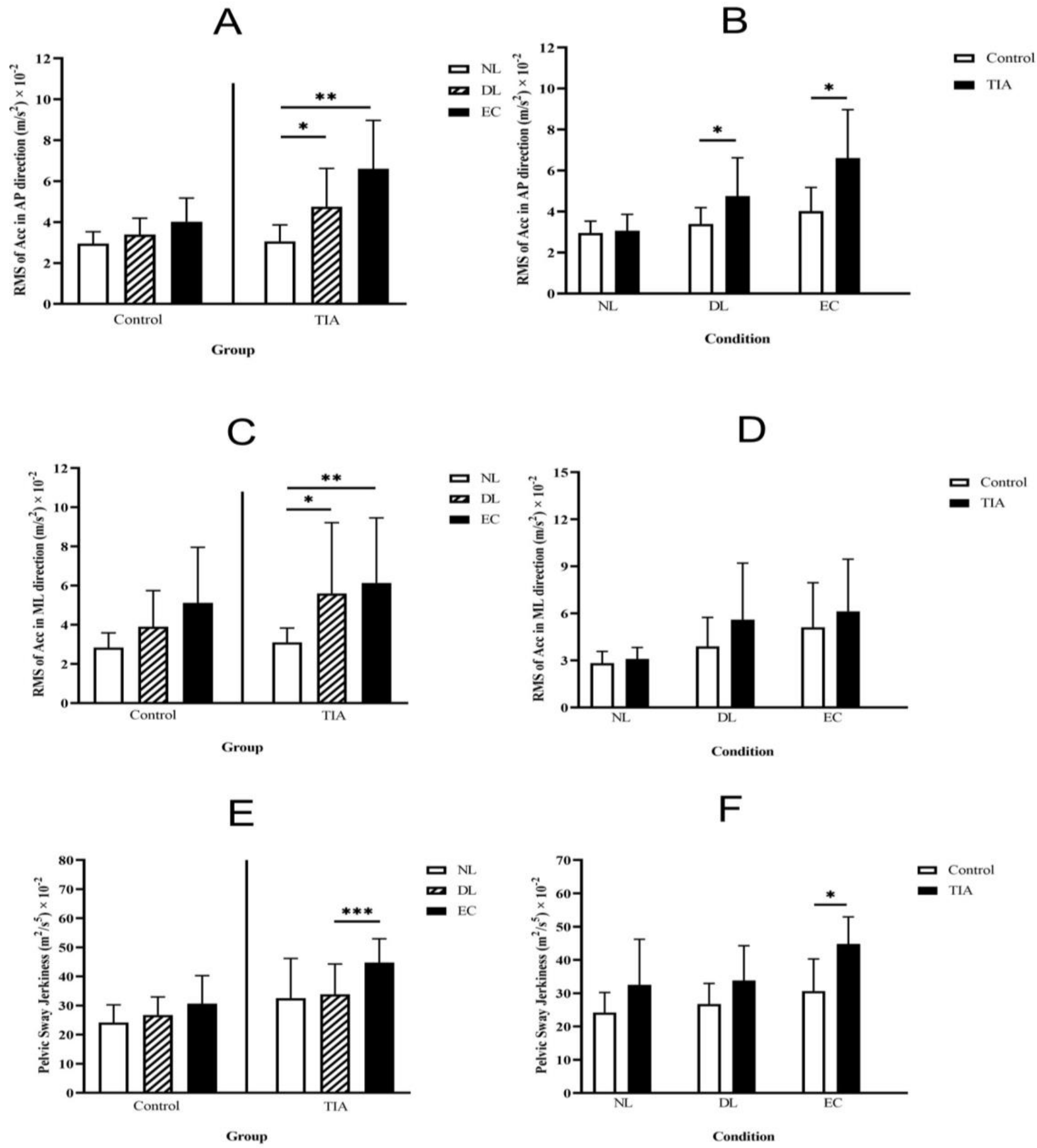

Figure 3 The effect of room lighting levels on acceleration in anterior-posterior (AccAP), acceleration in medial-lateral (AccML), pelvic sway jerkiness (JERK) during standing on firm (Sfirm),

* significant difference p<0.05

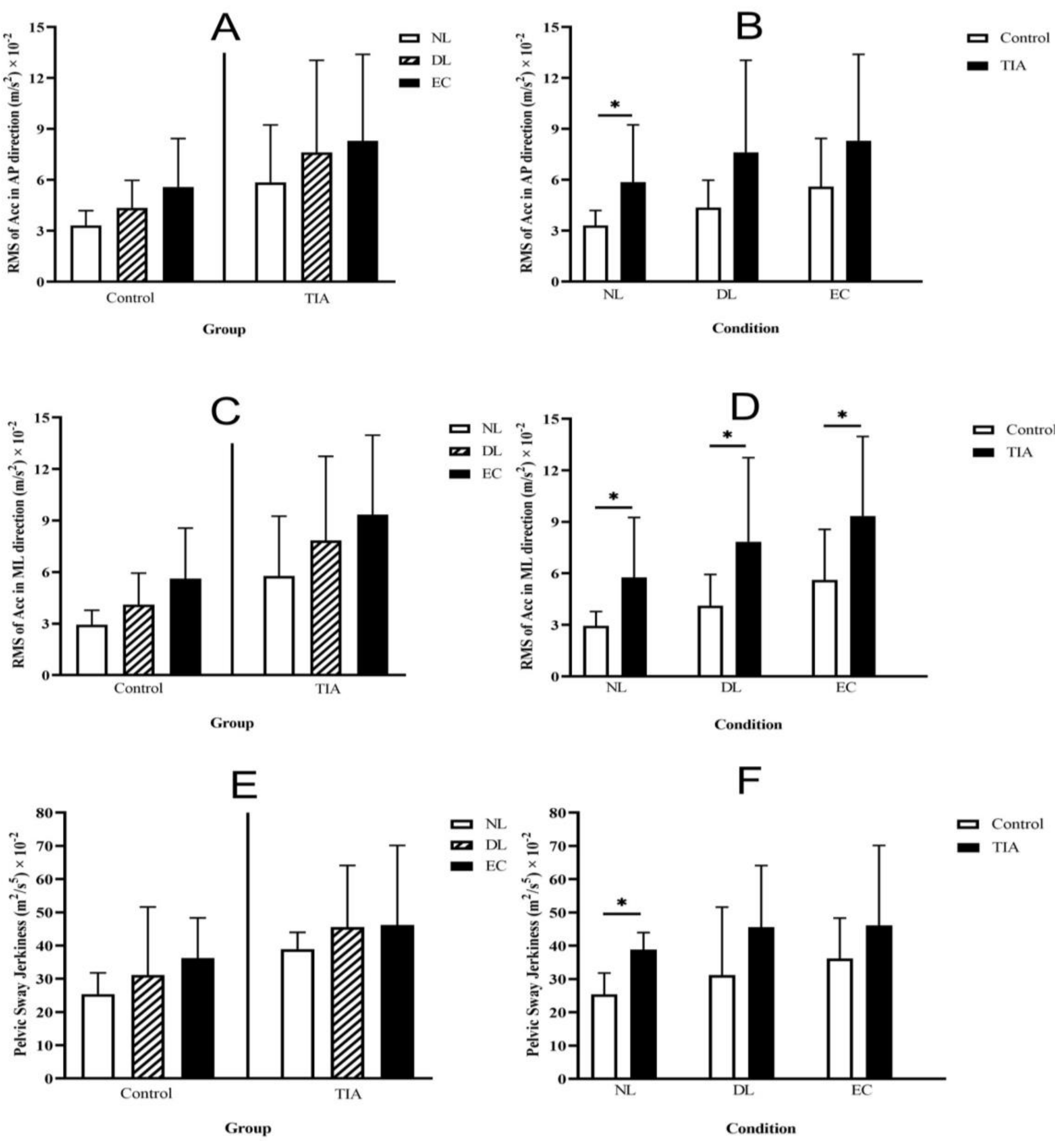

Figure 4 The effect of room lighting levels on acceleration in anterior-posterior (AccAP), acceleration in medial-lateral (AccML), pelvic sway jerkiness (JERK) during standing on foam (Sfoam), * significant difference $p<0.05$

Discussion

This study revealed that lighting intensity affected the ability to control balance in TIA. Deprivation of visual information by DL and EC conditions exhibited a slight dysfunction on balance in SOL, ComL, and Sfirm tasks among individuals with TIA. DL significantly reduced ST, increased AccAP, AccML in SOL and Sfirm, and increased JERK in ComL when compared to NL. Despite room-light did not affect TIA in Sfoam, AccML in Sfoam was higher in TIA than the Con group. In contrast to the TIA, DL and EC affected the Con group only in the SOL tasks.

From the clinical observation, we found that some participants in the TIA group loss balance in SOL before reaching 20-second and some demonstrated a fall pattern in ComL. However, a few subjects in the control also showed the same postural dysfunction. In contrast, the Sfirm and Sfoam tasks did not detect any different clinical observation that is all subjects could stand still for 30-second in all conditions. But data from the IMU exhibited a significant difference of AccAP, AccML, and JERK when compared between the group both in Sfirm and Sfoam tasks. Accordingly, it may be justified that the present findings revealed that the TIA had subclinical balance dysfunction compared to age- and sex-matched controls.

Therefore, we discussed our results based on the body sway in term of AccAP, AccML, and JERK. Balance dysfunction in TIA has been reported in the previous study[1], but Batchelor and co-workers used the different TIA definition and other balance tasks. To the best of our knowledge, this is the first study which combined IMU with different room-lighting conditions to assess balance ability in TIA. The effects of the room lighting condition have been reported in a limited population but not in the TIA[13, 23]. The present study used 3-lux LED and the participants were able to read the Snellen's chart not better than 6/30 meters[20]. This DL condition encouraged the participants to use their peripheral vision[5]. It was found that peripheral vision might be important for spatial orientation and control postural stability[24].

Body sway or AccAP and AccML in SOL (Figure 1b,d) showed a significant higher than the control group in DL. This result implied that TIA might be incompetent to use the peripheral vision to control body sway in the same way as the control group. Similarly, AccAP in TIA showed a significantly higher than the control in EC (Figure 1b). Results of body sway during SOL were comparable to the ST data in which TIA showed a shorter ST than control only in DL and EC (Figure 1h). Accordingly, the high demand of using visual system for better postural balance might be required in TIA. Our study found consistent results with the previous study in individuals with type2 diabetics which explored with higher AP-sway values during the standing in EC[25]. Another study demonstrated that, postural stability decreased among the participants after reducing visual acuity[24]. The large body sway as well as reducing in single leg standing time in TIA was a strong indication that participants with TIA had high risk of falling.

Compensatory recovery responses following a perturbation is one of the task specific for preventing a fall[26]. No previous research reported the compensatory stepping reaction in TIA. Our results showed a significant difference only in JERK in ComL. These results suggested that ComL might require more complex regulation than ComF and ComB. It was found that the elderly experienced difficulties to respond to effective lateral stepping reaction but not to forward and backward directions[26]. Only JERK showed significant results in ComL. This may be due to that JERK is more sensitive than AccAP and AccML parameters[16]. Amongst these, JERK can detect the sway correction or the smoothness of postural sway[16]. JERK was used to evaluate abnormal postural stability in vestibular disorder

(27) and to distinguish postural sway between the untreated-Parkinson and control group[16]. Only the TIA group showed significantly higher JERK in DL and EC than NL (Figure 2a) and higher JERK than control in all light conditions (Figure 2b). Because no fall pattern was presented during ComL in NL. These results imply that the sideway reactive postural control of TIA is sub-clinically compromised in NL but getting worst during the interruption of the visual ability.

For the Sfirm, both DL and EC creates significant increase of AccAP, AccML, and JERK (Figure 3a, c, e) only within TIA but not the control group. A comparison between the group found that AccAP (Figure 3b) and JERK in TIA (Figure 3f) were significantly higher than control in DL and/or EC. These results repeatedly confirmed the fact that TIA increases reliance on visual information to regulate postural balance. During quiet stance on the Sfirm, the ankle strategy is likely to occur to maintain balance[25]. The results of this study agreed with the previous study which showed higher AccAP and AccML in post-stroke participants during quiet stance [28].

Unlike Sfirm, we found that lighting conditions in Sfoam could not statistically affect postural sway within the group in both TIA and healthy control (Figure 4a, c, e). The lack of significance may be due to inter-subject variation as reflected by a large standard deviation. However, TIA showed greater AccAP, AccML, and JERK than control in NL (Figure 4b, d, f). The higher body sway of the TIA group in NL during Sfoam suggested that they may have sub-clinically degraded of somatosensory function. Therefore, postural control is based on the vestibular and/or the visual information. In addition, TIA demonstrated higher of AccML in DL and EC than control in Sfoam. This would reflect the fact that individuals with TIA increased reliance on visual information to control postural balance.

The study has several limitations: first, the test-retest reliability of the selected tests has not been performed. However, only one tester who had some experience in the protocol of testing executed all the tests. Furthermore, the standard protocol and commands were used[29]. Second, the sufficient resting period that might result in light adaptation ability should be concerned with each participant. However, the resting period (2-3 minutes) between testing conditions was provided in this study. The evidence showed that light adapting from EC or DL to NL only takes about one minute[30], but a dark adaptation from the NL to DL may take a longer time for full adaptation. In this present study, the light illuminance in our testing laboratory was not completely dark and the luminous does not require for the function of the peripheral vision. Third, the lack of previous evidence on the kinematic variables such as AccAP, AccML, and JERK in TIA among different balance aspects also suggested caution in data interpretation.

Conclusion

Postural stability is compromised when visual feedback is deprived in DL and EC in individuals with TIA. The results also indicated that individuals with TIA have sub-clinical somatosensory dysfunction as seen in higher JERK in ComL, and higher body sway and JERK in Sfirm because of room light affected only in the TIA. The impairment of the somatosensory system also complied with the higher number of TIA who showed the inability to do SOL for 20-second, or unable to recover from the ComL in DL and EC conditions. These results suggested that the peripheral vision of TIA may be compromised. However, there was no information regarding the effects of dim-light on postural control and peripheral vision function in TIA to compare with the present study. Therefore, further study is needed. Comparison with the Con, TIA confirmed the more dependent on visual information than Con in SOL, ComL, Sfrim, and Sfoam tasks. Perhaps, TIA may decrease or lose the ability to shift the sensory states for postural control. The mechanism contributing to the dysfunction is beyond the scope of this study.

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References

1. Batchelor FA, Williams SB, Wijeratne T, Said CM, Petty S. Balance and gait impairment in transient ischemic attack and minor stroke. J Stroke Cerebrovasc Dis. 2015;24(10):2291-7.
2. McCollum G, Shupert CL, Nashner LM. Organizing sensory information for postural control in altered sensory environments. J Theor Biol. 1996;180(3):257-70.
3. Gloriani AH, Schütz AC. Humans trust central vision more than peripheral vision even in the dark. Curr Biol. 2019;29(7):1206-10.e4.
4. Larson AM, Loschky LC. The contributions of central versus peripheral vision to scene gist recognition. J Vis. 2009;9(10):6.1-16.
5. Berencsi A, Ishihara M, Imanaka K. The functional role of central and peripheral vision in the control of posture. Hum Mov Sci. 2005;24(5-6):689-709.
6. Gautier G, Thouvarecq R, Didier C. Visual and postural control of an arbitrary posture: the handstand. J Sports Sci. 2007;25:1271-8.
7. Santangelo V, Spence C. Assessing the effect of verbal working memory load on visuo-spatial exogenous orienting. Neurosci Lett. 2007;413(2):105-9.
8. Sally SL, Poirier FJ, Gurnsey R. Orientation discrimination across the visual field: size estimates near contrast threshold. Percept Psychophys. 2005;67(4):638-47.
9. Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the Blue Mountains Eye Study. J Am Geriatr Soc. 1998;46(1):58-64.

10. Elliott DB, Whitaker D. Clinical contrast sensitivity chart evaluation. Ophthalmic Physiol Opt. 1992;12(3):275-80.
11. Lord SR, Menz HB. Visual contributions to postural stability in older adults. Gerontology. 2000;46(6):306-10.
12. Deshpande N, Patla AE. Dynamic visual-vestibular integration during goal directed human locomotion. Exp Brain Res. 2005;166(2):237-47.
13. Petrofsky JS, Cuneo M, Lee S, Johnson E, Lohman E. Correlation between gait and balance in people with and without type 2 diabetes in normal and subdued light. Med Sci Monit. 2006;12(7):273-81.
14. Horak FB, Wrisley DM, Frank J. The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. Phys Ther. 2009;89(5):484-98.
15. Brown H, Siegmund G, Guskiewicz K, van den Doel K, Cretu E. Development and Validation of an Objective Balance Error Scoring System (oBESS). Med Sci Sports Exerc. 2014;46.
16. Mancini M, Horak FB, Zampieri C, Carlson-Kuhta P, Nutt JG, Chiari L. Trunk accelerometry reveals postural instability in untreated Parkinson's disease. Parkinsonism Relat Disord. 2011;17(7):557-62.
17. Easton JD, Saver JL, Albers GW, Alberts MJ, Chaturvedi S, Feldmann E, et al. Definition and evaluation of transient ischemic attack: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association Stroke Council; Council on Cardiovascular Surgery and Anesthesia; Council on Cardiovascular Radiology and Intervention; Council on Cardiovascular Nursing; and the Interdisciplinary Council on Peripheral Vascular Disease. The American Academy of Neurology affirms the value of this statement as an educational tool for neurologists. Stroke. 2009;40(6):2276-93.
18. Lee KB, Lim SH, Kim KH, Kim KJ, Kim YR, Chang WN, et al. Six-month functional recovery of stroke patients: a multi-time-point study. Int J Rehabil Res. 2015;38(2):173-80.
19. Anderson AJ, Shuey NH, Wall M. Rapid confrontation screening for peripheral visual field defects and extinction. Clin Exp Optom. 2009;92(1):45-8.
20. Gronfier C, Wright KP, Jr., Kronauer RE, Jewett ME, Czeisler CA. Efficacy of a single sequence of intermittent bright light pulses for delaying circadian phase in humans. Am J Physiol Endocrinol Metab. 2004;287(1):174-81.
21. Mancini M, Salarian A, Carlson-Kuhta P, Zampieri C, King L, Chiari L, et al. ISway: a sensitive, valid and reliable measure of postural control. J Neuroeng Rehabil. 2012;9:59.
22. Lugade V, Fortune E, Morrow M, Kaufman K. Validity of using tri-axial accelerometers to measure human movement - Part I: posture and movement detection. Med Eng Phys. 2014;36(2):169-76.
23. Brooke-Wavell K, Perrett LK, Howarth PA, Haslam RA. Influence of the visual environment on the postural stability in healthy older women. Gerontology. 2002;48(5):293-7.

24. Friedrich M, Grein HJ, Wicher C, Schuetze J, Mueller A, Lauenroth A, et al. Influence of pathologic and simulated visual dysfunctions on the postural system. Exp Brain Res. 2008;186(2):305-14.
25. D'Silva LJ, Kluding PM, Whitney SL, Dai H, Santos M. Postural sway in individuals with type 2 diabetes and concurrent benign paroxysmal positional vertigo. Int J Neurosci. 2017;127(12):1065-73.
26. Maki BE, McIlroy WE. The control of foot placement during compensatory stepping reactions: does speed of response take precedence over stability? IEEE Trans Rehabil Eng. 1999;7(1):80-90.
27. Kim KJ, Gimmon Y, Millar J, Schubert MC. Using Inertial Sensors to Quantify Postural Sway and Gait Performance during the Tandem Walking Test. Sensors 2019;19(4):751.
28. Yu E, Abe M, Masani K, Kawashima N, Eto F, Haga N, et al. Evaluation of postural control in quiet standing using center of mass acceleration: comparison among the young, the elderly, and people with stroke. Arch Phys Med Rehabil. 2008;89(6):1133-9.
29. Mini-BESTest: Balance Evaluation Systems Test [Internet] [cited 2020 26 August]. Available from: http://www.bestest.us/files/7413/6380/7277/MiniBEST_revised_final_3_8_13.pdf.
30. Davson H. Light and dark adaptation [Internet] [cited 2020 16 August]. Available from: http://www.chm.bris.ac.uk/webprojects2003/white/light_and_dark_adaptation.htm.