ORIGINAL ARTICLE

ASSESSING STANDING BALANCE USING BALANCE REHABILITATION UNIT AND NINTENDO WII BALANCE BOARD IN YOUNG AND OLDER HEALTHY ADULTS

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ABSTRACT

Ageing is associated with changes in body balance mechanism. The gold standard assessment for body balance is posturography. However, because of the high cost constraints, not many health centers are equipped with the equipment. Nintendo Wii balance board (WBB) has been reported as a potential tool to be used to assess body balance and sway. Also, because WBB is more economical and portable, it has greater potential to be used in primary health centers and community settings. The objective of this study was to compare balance measures using BRU™ and WBB among young and older healthy adults during quiet standing. Thirty three young (26.9±5.6 years) and 33 older adults (65.6±4.4 years) were randomly tested on both equipments. Subjects performed 30sec trial for each of the four testing conditions: quiet standing on a firm or compliant surface (foam) with eyes-open and closed. The results showed significant differences in balance measurements between all four testing conditions and age groups using both equipments. This study also found significant positive correlations between the COP and sway velocity, SV (of the BRU™) and COB (of the WBB) in all test conditions. These results indicated that WBB coupled with its commercially available software could potentially be used as a screening tool for balance assessment in primary health centres.

Key words: Wii balance board (WBB), Balance Rehabilitation Unit (BRU™), centre of pressure (COP), centre of base (COB), sway velocity (SV)

INTRODUCTION

Many factors are known to influence human’s balance ability. Among them are: age, gender, height, weight, foot size, level of physical activity, fatigue, past injury to the lower body, cognitive function, existing diseases affecting balance, medication and alcohol intake1,2. Aging is associated with declined in human’s balance ability. Ni Scanaill et al.3 reported that reduction in overall human’s balance ability are due to decline in: (1) sensory input to the balance system, (2) the ability of information integration and processing related with the balance system and (3) musculoskeletal system in maintaining body’s stability.

The consequences of decreased balance ability among older adults may be debilitating. This process occurs in individual at different rates and it could increase the risk of falls. Lange et al.4 reported the possibility of falls are higher in those with history of falls as aging involved decrement in visual acuity, muscle strength, coordination and reflexes. It is believed that decrement in neurological function causes greater tremor in older than younger adults, in quiet standing. Balance disorders generally cause larger body sway while standing upright and it can be used as risk falling predictor, especially for older adults.

Balance assessment could improve the understanding of the central nervous system (CNS) that regulates muscle activity through muscle control and reflexes. Balance Rehabilitation Unit (BRU™) (Medicca, Monte-video, Uruguay) is a static posturography with virtual reality and game technology that is designed to assess balance and rehabilitation for patients with imbalance and/or
instability. It provides information on centre of pressure (COP) area and sway velocity (SV) which are used for diagnosing body balance and to monitor progress during rehabilitation.

Recently, written custom software interfaced with Wii Balance Board (WBB) (Nintendo Wii, Kyoto, Japan) has been reported as a potential tool to be used in assessing body balance as it is portable and cost-effective. It focuses on physical activities through WiiFit™ which incorporates WBB to record static and dynamic balance ability and provide relevant results of body mass index, centre of gravity (COG) and left-right symmetry.

However, WBB written custom software is not commercially available and it comes with higher cost and skill in developing it. Therefore, there is a need to assess the balance function with the use of commercially available software. To date, there is no comparative study on the differences in balance measurements between BRU™ posturography and WBB with the use of commercially available software. Therefore, the aim of this study was to determine the possible differences in the balance measurement obtained from both systems, by comparing the results in two different age groups.

METHODOLOGY

Participants
This was an experimental cross sectional study. Thirty-three healthy young adults and 33 healthy elderly (mean age 26.9±5.6 years and 65.6±4.4 years, consecutively) were recruited, based on the age classification by the Age of Majority Act 1971 and the United Nations. Before the study enrollment, brief case history was conducted. Subjects' selection criteria were: age between 18-40 years (for young adults) and 60-75 years (for elderly), weight less than 150kg (not exceeding maximum allowable WBB weight capacity), able to stand unsupported, no known balance problem, neurology, or any premorbid conditions that may cause balance problems and was not on any medications affecting equilibrium. Written informed consent was received from each subject and this study was conducted with the ethical approval from UKM (UKM 1.5.3.5/244/NN-076-2012).

Measurement setup
The BRU™ consists of a 40cmx40cmx15cm pressure sensitive platform with 4 inbuilt sensors, overhead safety harness and a foam cushion. It measures the area of a 95% confidence ellipse of the COP excursion in the anteroposterior and mediolateral directions and averaged SV of the COP during the 4 different conditions. The platform was marked with an 8cm horizontal line and 12cm vertical line for foot placement.

A commercially purchased Nintendo WBB was used to measure the centre of balance (COB). Its pressure sensitive platform, measuring 511mmx316mmx53.2mm was equipped with 4 sensors. It measures the vertical force at the bottom of each corner. The sensors worked together in detecting any body movement based on body weight changes on the board and eventually measure the COB. A marked for foot placement was made on the board for standardization in between trials. The WBB was interfaced with a TV monitor using the commercially available Physiofun Balance Training software (developed by Kaasa Solution) to display the real-time sensor signal. The setup for BRU™ and the WBB pressure sensitive platform are shown in Figure 1 (a) and (b).
Fig 1: (a) The study setup used for the BRU™. Marked for foot placement was made on the WBB pressure sensitive platform to ensure standardization in between trials (b).

Procedures
All subjects were instructed to stand with their arms by their side, facing forward, on the BRU™ platform and the WBB. Their feet were placed on the pre-marked foot placement area. The quiet standing tasks were: (a) standing on platform with eyes-opened (PEO), (b) standing on platform with eyes-closed (PEC), (c) standing on foam cushion with eyes-opened (FEO) and (d) standing on foam cushion with eyes-closed (FEC). The order of the four tasks and the sequence of BRU™ and WBB were randomised.

During each trial, the subjects were asked to stand unperturbed for 30sec. They were given 30sec resting intervals in between trials. An average of two trials were analysed. The measured parameters were COP area (cm²) and SV (cm/s) from the BRU™ and COB area (cm²) from the WBB.

Statistical analysis
All statistical analysis was performed using SPSS version 21.0. Three major assumptions made for the analysis were: normality assumption, equality of covariance matrices, and assumption of sphericity. To meet the normality assumption, a mixed design ANOVA was employed to determine the effect of the 4 standing tasks on the BRU™ and WBB recordings in the two groups. The Box’s Test was used to meet the equality of covariance matrices assumption. If the matrices were similar, this test should not be significant. A conservative alpha level of 0.001 was used for the Box’s Test. The assumption of sphericity was assessed using the Mauchly’s Test. If the sphericity assumption was not met (p<0.05), the Greenhouse-Geisser was used in order to assess the observed F-ratio. The correlation between the COP and COB areas were estimated with Spearman Rank’s correlation (rs) since normality could not be assumed.

RESULTS
All subjects successfully completed the tasks. There was gradual increment in the young and elderly subjects’ performance across all tasks, indicating consistent decreased ability in their standing balance tasks, from the simplest test condition (i.e. PEO) to the most difficult test condition (i.e. FEC), for both BRU™ and WBB.

Analysis of the BRU™s COP area indicated significant difference for both age groups [F (1,64) =12.41, p<.001,ŋ²=0.16]. The effect of testing condition was also significant [Greenhouse-Geisser adjusted F(1.38,88.49)=61.19, p<.001,ŋ²=0.49] and the interaction between four test conditions and groups were also significant; Greenhouse-Geisser adjusted F(1.38,88.49)=7.11, p<.05,ŋ²=0.10]. The BRU™s SV was also significantly different for both age groups.
[F(1,64)=24.35, p<.001, \eta^2=0.25] and the four test conditions [Greenhouse-Geisser adjusted F(1.68,107.67)=189.99, p<.001, \eta^2=0.75]. There was also significant interaction between testing conditions and age groups [Greenhouse-Geisser adjusted F (1.68,107.67) =5.89, p<.05, \eta^2=0.08]. The BRU™’s COP and SV results signify that the young subjects performed significantly better than the older subjects in all four standing tasks (Fig. 2 (a) and (b)).

Fig 2: Comparison of the young and older groups’ performance for the (a) BRU™ COP area (cm²), (b) SV (cm/s) and (c) WBB COB area (cm²) in four different standing tasks (eyes-opened and eyes-closed with and without the foam). There were significant differences (p< 0.001) in between the groups’ performance and also in between all four standing tasks (p< 0.05).
Analysis for the WBB's COB area also showed significant difference for both age groups [F (1,64) =22.65, p<.001,η²=0.26] and all test conditions [Greenhouse-Geisser adjusted F (1.56,99.63) =44.98, p<.001,η²=0.41]. The interaction between the test conditions and groups were also significant [Greenhouse-Geisser adjusted F (1.56,99.63) =13.28, p<.001,η²=0.17. The significantly better performance of the young versus older groups with the WBB is shown in Figure 2 (c).

Table 1 shows the COP area has a significant positive relationship to COB area, with moderate to good correlation strengths in all test conditions. COP area has a significant positive relationship to COB area, with moderate correlation strength for PEO and PEC (ρ(66) =0.253-0.254,p<0.05), and with good correlation strength for FEO(p(66)=0.498,p<0.001) and FECconditions (p(66)=0.410,p<0.05). It was also found that the SV also has a significant positive correlation to COB area, with moderate to good correlation strength, except in PEO condition. SV's variable has significant positive relation to COB's area, with moderate correlation strength for PEC(p(66) =0.315,p<0.05), while good correlation strength for FEO and FEC (ρ(66)=0.433-0.600,p<0.001). These findings indicated significant positive correlations between the COP and SV (of the BRU™) and COB (of the WBB) in all test conditions.

### Table 1: Spearman correlations between the BRU™'s COP and SV and WBB’s COB

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Pressure Centre Area</th>
<th>Sway Velocity (SV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEO</td>
<td>0.254*</td>
<td>0.165</td>
</tr>
<tr>
<td>PEC</td>
<td>0.253*</td>
<td>0.315*</td>
</tr>
<tr>
<td>FEO</td>
<td>0.498**</td>
<td>0.600**</td>
</tr>
<tr>
<td>FEC</td>
<td>0.410*</td>
<td>0.433**</td>
</tr>
</tbody>
</table>

(* Significance at p<0.05, ** Significance at p<0.001)

### DISCUSSION

Results from this study supported previous findings on balance changes associated with aging. The interaction between the four test conditions (PEO, PEC, FEO, FEC) and different age groups were significant (p<0.05). We showed that the COP and COB measurements and the SV performance for all four test conditions were significantly different among younger and older adults. This is evident from Figure 2 (a), (b) and (c) which demonstrated that all three measured parameters were...
significantly higher in older adults. The significant
decrease in their balance performance was likely
due to aging and this is evident by the measured
increment in the COP, SV and COB. It was
proposed that reduction in balance performance in
the older adults are generally due to age-related
deterioration in postural control system or may be
due to presence of underlying pathology in an
individual. Other possible reasons for this
significant findings were anatomical and
physiological changes that may results in balance
decrement in older adults. These include
impairments in cognitive function, reduction in
visual acuity, vestibular and somatosensory input,
motor responses, deterioration in sensory
integration system, muscles and nervous system
resulting in decreased muscle strength, muscle
volume and response time as well as decreased
movement efficacy. The amplitude of physiological
tremor when standing was greater among older
adults compared to younger adults. This was
believed to be due to deterioration in neurological
function associated with aging. In addition,
abnormalities in the peripheral and CNS also
contributes to increment in body sway. Changes
in blood circulation may reduce blood flow to the
brainstem, cerebellum or cerebrum that may
causel lesions to the nervous system or apparent
ischemic signs. Disorders affecting the inner ear
or vestibular organs, neurological diseases and high
blood pressure are reported among possible
factors contributing to imbalance. The use of
medications among older adults makes them
more susceptible to the possible side effects of the
drugs, such as dizziness and imbalance.Eventhough
for this study we have ruled out any premorbid
conditions or use of medications that may cause
imbalance among the subjects, this postulation
remains sparse to possibility of underlying
pathology that is unknown to the subjects.In
addition, the reflexive control strategies used by
older adults may contribute to this finding. They
are inclined to use hip strategy to maintain their
balance especially in the absence of visual cues or
when there is referenced support swayed. Hip
strategy involves movement of the head and hips
in opposite directions to overcome the weight
shifts from the COG or when the base of support
is small. For younger adults, the ankle strategy is
used if there is a slow perturbation in balance.
Therefore, the increased in body sway is smaller
than those who used hip strategy to maintain
balance. It was also reported that increment in
body sway performance are caused by inability
of older adults to ignore misleading sensory
signals or to effectively choose a reliable sensory
information to control their body posture and
weight re-shifting than younger adults.

Kalisch et al. concluded that WBB could detect
balance progressive increased with age-related
degradation in older adults by correlation analysis.
Older adults have the tendency for balance
impairment in a more demanding and challenging
tasks which may lead to fall. However, they
reported insignificant correlation between age and
balance performance for simple tasks such as
standing on WBB with eyes-opened and closed.
These findings were not in line with our study
which showed that WBB responses were
significantly different between younger and older
adults in all four test conditions, both in a simpler
(PEO) and demanding tasks (FEC). The
dissimilarity in the results may due to differences
in the research methods and data analysis. Kalisch
et al. used raw sensor data to transform to ‘xy’
Cartesian coordinate system for obtaining the COP.
This study used the value of COB, which is
obtained directly from the ‘Physiofun’ software.

Unlike static posturography system, WBB’s COB
measurement is based on the changes in the
percentage of body weight recorded on each force
footplate. WBB platform consists of two separate
force footplates for the placement of each foot.
Therefore, the relative pressure on the heel and
ball of foot could be determined. COB is
determined from measurements of vertical force
recorded by four sensors. This data was provided
in the ‘x’ and ‘y’ coordinates (COBx, COBy) which
represents the percentage change in the weight
distribution and the direction of that change.

We have found gradual increased in the COP and
COB areas and SV in the eyes-opened and closed
and in conditions with deficit or alteration of
sensory information. The influenced from
combined visual and altered somatosensory inputs
(when foam cushion is used) resulted in increased
in balance measurement parameters. This showed
that the body was more stable when doing simple
task or on firm surface. It is a well known fact
that visual input has significant role for balance
maintenance, where larger COP and body sway
was obtained during eyes closed. Poor vision leads
to imbalance and increased falls risk, specifically
among older adults because visual provides
information about the position and movement of
body segments.
Visual information was reported to be the most important input for body balance. However, it was argued that healthy individuals are more dependent on somatosensory information (70%), followed by vestibular (20%) and visual system (10%) [20]. This was based on relative increment in the number of body sway while standing on a compliant surface, compared to firm surface, with eyes opened. When they stand on compliant surface, there is increment insensory weighting to the vestibular and vision information, and simultaneous decrement to somatosensory input. However, Whipple et al. [21] agreed that visual system has influenced on the balance system and redundancy of this system’s input could compensate for other sensory deficits.

Our results also showed increased in the COP and COB areas and SV while standing on compliant foam surfaces. Foam surfaces changed the proprioceptive feedback which is obtained from standing on firm surfaced, and provide more dynamic and complex tasks. This method was reported to be suitable for measuring the dynamic balance while standing in healthy participants. The difficulties for the test parameter increased when two sensory inputs were altered; standing on a foam cushion with absence of visual input. In older adults, there was a significant decline in their balance ability when standing on a foam cushion with their eyes closed. This indicated that combined sensory deficits caused imbalance. Altered somatosensory information through the use of compliant surface affect ones balance control. Standing on a foam with eyes closed is a highly relevant test for determining the efficiency of the vestibular system because it is not only able to distinguish younger and older adults balance ability, but also differentiate between healthy individuals and patients with balance disorders regardless of their age. The dependency on vestibular information increased when standing on a foam. It reduces the relative contribution of somatosensory information to the balance system and improve the precision of the visual components measurement. Patients are more dependent on somatosensory input compared to vestibular input when on a firm surface. Woolacott [22] found that older adults could maintain balance when either visual or somatosensory input was reduced or eliminated, but the balance started to be affected when the input from both sensory systems decreased and the main source of vestibular input was used to maintain their balance.

Contrary to our study, Liaw et al. [23] found no significant difference between age groups during quiet standing. Older adults had lower average stability either with eyes opened or closed and on firm or compliant surfaces. They also reported no significant differences between three age groups; young, middle and older adults. Panzer et al. [24] concluded that quiet standing test did not produce evidence of postural instability associated with aging. The aging process was related with increased in body sway but it did not show stability deficits due to aging. It may occur as a result of lack of vigilance while maintaining upright position.

We have shown significant positive correlation between COP and COB area in all testing conditions. This linear relationship in which an increased in COP area has also resulted in higher COB area were in line with earlier researchers. Huurnink et al. [25] study using WBB, positioned on top of a force plate for real-time balance measurement. The result showed the WBB measurement is accurate in measuring the trajectory of the COP, amplitude and velocity while standing on one leg. Although there are limitations on WBB, they found very high correlation (r>0.99) between the force plate and WBB. The difference between this study and the study by Huurnink et al. [25] was the technique of data collection, in which this study performed separate measurements while they did real-time measurement. The technique differences were not an issue because they reported no difference in measurement's technique; either separate or real-time measurements. Other studies also showed high correlation between WBB and force plates. They concluded that the COB estimations obtained from WBB is almost similar to the COB obtained from the force plate [5, 15, 26, 27].

Our findings support and strengthen the theory of aging and provide information about the postural ability for healthy, young and older adults. We have also showed that both equipments were able to demonstrate that body sway increased with age and there were significant differences in balance measurements between the two groups.

CONCLUSION

Our findings added to the body of knowledge that one’s balance ability has a direct relation with age,
and this information could be used in tailoring to specific rehabilitation program. TheWBB coupled with its commercially available software has potential to be applied clinically as screening tool in the primary health centre as it is very cost effective, readily be used and portable as opposed to BRU™. However, BRU™ with the use of various visual stimulation, could be used for more complicated diagnostic assessment and rehabilitation in the secondary health centre.

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REFERENCES


