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Comparison between Romberg test with sensor-based balance assessment using electronic wobble board

Yvonne Khor Yee Woon[1], Eileen L. M. Su[1], Kang Xiang Khor[2], Muhammad Najib Bin Abdullah[2], Che Fai Yeong[1]

[1]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor, Malaysia
[2]Techcare Innovation Sdn. Bhd., Taman Perindustrian Ringan Pulai, Johor, Malaysia.

Email: eileensu@utm.my

Abstract. The number of fall-related injuries resulting in hospital admissions could place a significant load on hospitals. Prior research revealed that balance impairment is the most reliable indicator of future falls, and postural instability testing is expensive and tedious to be applied in clinical settings. This paper presents an objective based balance assessment method using an electronic wobble board to examine the balance ability among individuals, with minimal specialist intervention. The balancing assessment software modules provide visual feedback such as visual concentration, test procedure teaching, and time counting. Quick objective balance evaluation is facilitated by the software modules, which also can comprise visual feedback and provides instant biofeedback with objective measurements of user's progress. The balance assessment score obtained from this electronic wobble board was compared against physiotherapists' ratings using the Romberg test. The results indicated that the sensor-based balance score is comparable with the expert ratings using the Romberg test. Additionally, the sensor-based score provides higher sensitivity in differentiating among similar categories of subjects as compared to the conventional Romberg test.

1. Introduction

Falls are one of the common causes of injury in individuals with neuromuscular impairment and older adult population (persons aged 65 and older) [1]. Statistics show that 37.3 million people experience severe falls each year and approximately 684 000 people die from falls each year [2] [3]. Complication from falls, including hip fractures and fear, decreased quality of life from self-imposed activity restriction, social isolation and depressive symptoms [4] [5]. The increasing number of injuries may induce a huge burden to hospitals, therefore, a new, effective, and widely applicable strategy to prevent hip fractures and improve balance is urgently needed [6]. Previous studies showed that impairment of gait or balance is the most consistent predictor of future falls [1].

Even though there is the link between balance impairment and falls, the objective measurement of postural stability is rarely used in clinical set up due to expensive equipment and required expertise [7]. Previous studies have suggested that postural instability such as balance impairment can be evaluated using center of pressure (COP) movement. COP movement was used as the gold standard balance measurement for risk of fall [7]. Balance impairment was also evaluated by using motion capture cameras and stand-alone accelerometers to assess the fall risk [7].

Conventional balance tests such as the Berg Balance Scale (BBS), Romberg test, Times Up and Go test are common standing balances and used less costly tools for balance test assessment [7]. However, they tend to be subjective and may not always yield reliable and sensitive outcomes [1]. Hence, a quantitative balance assessment methodology with a sensor-based approach is needed for reliable balance assessment, and also for objective outcome measures in evaluation of treatments.

Balance is important to maintain body balance and avoid fall when walking, sitting up, standing, or playing sports [8]. There is evidence showing that balance training reduced the risk of fall and complication of injuries while improving body balance and motor performance. Generally, it is important to train and evaluate balance ability for overall well-being and preventing falls, particularly in adults aged 65 or above. This paper investigates a sensor-based balance assessment method for objective based measurement using an electronic wobble board called FIBOD [9]. The balance assessment score in the form of overall stability index (OSI) is then compared against the conventional Romberg test [10]. A sensor-based approach allows for less dependency on experts' availability to perform balance test and provided feedback.

2. Methodology

2.1. Experiment Setup

The categories of eyes open balance task and eyes closed balance task from the Romberg test [10][11] were incorporated into the sensor-based balance assessment test. The sensor-based balance assessment platform that were used in this study included an electronic wobble balance board called FIBOD, with its corresponding software assessment modules, a soft round sponge foam, a TV and TV box and a measuring tape. Figure 1 shows a user standing on the FIBOD during a balance assessment test. A set of sensors consisting of gyroscopes, accelerometers and inertial measurement units, were assembled into the FIBOD wobble board to provide motion measurement and feedback to the user. The readings from the sensors were integrated into an assessment algorithm to provide instant feedback to allow users to gauge their own balance score and to also increase motivation for training. By using the sensor-based wobble board, users received instant visual feedback to balance their bodies while playing on the wobble board. Figure 2 shows an example of game based FIBOD software training modules while Figure 3 shows the visual display for a FIBOD balance assessment test. The software modules were developed using the Unity engine for virtual reality visuals, which included a timer and instructions using animation to guide the users to stand on the sensor-based wobble board. Balance scores and biofeedback were used as rewards for their standing balance to motivate users and track their standing balance progressively. The software was also tested on Android-based devices such as phones or TV to validate its usage on different platforms [9][12].

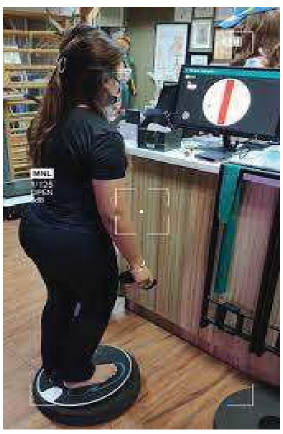

Figure 1. A subject using the FIBOD wobble board for sensor-based balance assessment

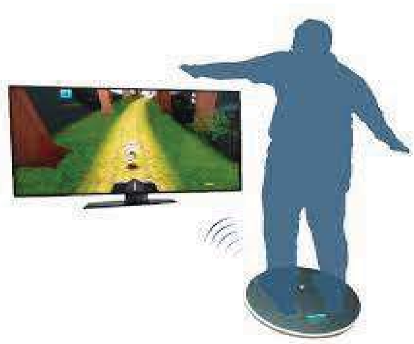

Figure 2. Game-based software modules with instant visual feedback provided by the FIBOD wobble board.

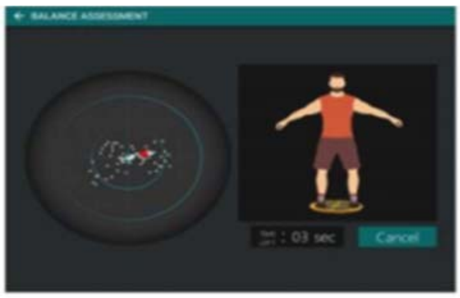

Figure 3. Visual display during a balance assessment test using the FIBOD sensor-based wobble board

2.2. Subject

All subjects must fulfil the inclusion criteria and the postural assessment was conducted by a professional physiotherapist. Three healthy subjects were chosen for this study. The inclusion criteria for subjects include age between 18-65 years old, able to stand independently without assistance, able to walk independently without limping and can understand instructions. Exclusion criteria outlined categories of persons who were not allowed to participate in this study. The exclusion criteria include those with neurological disorder, orthopaedic disorder such as an ankle injury, a knee ligamentous injury, a musculoskeletal injury, or a disorder involving the lower limb, cognitive impairment, unstable angina, pregnancy, uncontrolled diabetes mellitus, or visual and hearing impairment. Any persons with medical conditions that can cause problems with stability and balance, such as cerebellar dysfunction, vestibulocochlear dysfunction, were also ineligible to participate in this study.

2.3. Protocol

During the experiment, subjects went through a familiarization session followed by one trial of Romberg test and then one trial of sensor-based wobble board balance test [12]. The study began with a familiarization session, which consisted of maximum 120 seconds of practice standing on sensor-based balance test with wobble board. The subject was given 30 seconds' rest after familiarization before starting the Romberg test and 15 minutes' rest time between the two different balance tests.

For the Romberg test, the subject had to stand quietly with eyes open, and subsequently with eyes closed while trying to maintain his balance on a flat floor for about 30 seconds [10]. When the subject closed his eyes, he should not orient himself by light, sense or sound, as this could influence the test result and cause a false positive outcome.

For sensor-based balance test with wobble board, the distance between the TV and the electronic wobble board was fixed at 110 cm. Every subject was asked to stand on the wobble board, which was supported by a round foam sponge. The subject needed to maintain balance for 10 seconds. The subject had to stand with feet apart the same as shoulder width and hand at the side of the body touching the thigh while looking at a point on the TV.

The Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (MOH) has provided ethical approval for this study, with NMRR ID-23-01539-UOJ. The research was conducted in accordance with the principles embodied in the Declaration of Helsinki and in accordance with local statutory requirements. All participants gave written informed consent to participate in the study.

3. Data Analysis, Result and Discussion

The data analysis for this experiment focuses on comparing stability results obtained from the wobble board with the balance assessment categorization of subjects obtained from the Romberg test. Based on the results shown in Table 1, the assessment from the Romberg test categorised subject A and subject C as having normal balance with no failures during the test. However, subject B exhibited body sway when standing with eyes closed and hence, was considered to not have as good balance skill as subjects A and C. However, since the Romberg test was less sensitive and subjective, there were no further indicators to separate the levels of subjects A and C.

Table 1. The result of the Romberg balance test for subjects A, B and C.

	Eyes Open			Eyes Closed		
Subject	Increased Body Sway	Placing one foot in the direction of fall	Fall	Increased Body Sway	Placing one foot in the direction of fall	Fall
A	No	No	No	No	No	No
B	No	No	No	**Yes**	No	No
C	No	No	No	No	No	No

Table 2. The OSI from the wobble-board in the sensor-based balance test for Subjects A, B and C.

Subject	Open Eyes OSI	Close Eyes OSI
A	0.4	0.8
B	1.8	8.1
C	0.7	4.6

In comparison, the wobble board tests return overall stability score (OSI) based on sensor measurements during the eyes open and eyes closed movements. A higher value of the OSI indicates poorer balancing skill whereas a low OSI score on the wobble board represents good balance. As shown in Table 2, the OSI from the wobble board scored subjects A and C as having better stability than subject B. Subject A scored 0.4 in the eyes open balance task and 0.8 in the eyes closed task. Meanwhile, subject C scored 0.7 in the eyes open task and 4.6 in the eyes closed task. Subject B, who is ranked poorer in the Romberg test compared to the other two subjects, was also given a poorer score of OSI by the wobble board measurement modules. Subject B scored 1.8 in the eyes open task and 8.1 in the eyes closed task.

From these findings, the sensor-based balance assessment of the wobble board can discriminate between good balance with poor balance. The OSI scores showed a similar trend as that given by the Romberg balance assessment, where subjects that were rated well by Romberg would also score well in the wobble board OSI. Similarly, subject B who scored poorly in Romberg test also scored poorly in the OSI. Additionally, OSI had higher sensitivity in differentiating between subjects A and C who were both rated as normal in the Romberg test. This was due to the subjective and ceiling effect of the Romberg test, which can be overcome by the sensor-based measurements.

Previous studies have also attempted to use accelerometers in mobile phones or wearable inertial sensors to analyse the kinematics of the Romberg test. Results showed that acceleration increased when the balance test became more challenging [13], indicating that sensors can provide objective information that was indiscernible by human observation.

However, this is a pilot study with only three subjects. A larger sample size would be able to provide a more accurate trend and comparison between the conventional Romberg test and the objective based approach using sensor-based system. In general, the sensor-based systems can be a viable alternative or for balance skill assessment without depending on the availability of an expert observer and the experience level of the assessor. Sensor-based assessment can complement the current conventional approach to reduce reliance on manual labour and to increase the sensitivity in balance assessment.

4. Conclusion

This paper presented a pilot study comparing balance assessment of conventional Romberg test with the OSI results obtained from a sensor-based balance test using an electronic wobble board. The initial findings indicated that the sensor-based balance test showed comparable results with the assessment obtained through the conventional Romberg test, whereby subjects with good balancing skills as indicated by the Romberg test were appropriately and similarly scored with the wobble board OSI. In contrast, subject with low balance skill as indicated with the Romberg test was also scored with poor OSI with the wobble board. However, the conventional Romberg test has a ceiling effect whereby two subjects who did not fail any of the tasks would be rated the same. The wobble board exhibits higher sensitivity in that it was able to provide different scores to the two subjects rated as having good balance skill in the Romberg test. In conclusion, the sensor-based balance test would be able to provide an objective assessment with less reliance on expert ratings and a higher sensitivity to counter the ceiling effect of the conventional Romberg test.

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