

Analysis of Leg Muscle Activity on Different Balance Training Devices

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ABSTRACT

Balance training is the one of the methods used to improve muscle strength and restore posture balance due degeneration of body function or injury. Currently, there is no particular guidance on selection of balance training device that can be used in the rehabilitation process. Lack of guidance especially in term of physiological effect may delay the recovering process. The purpose of this research is to compare the effect of different balance training devices on leg muscles activity and identify the difficulty level of balance training device based on muscle activity. In this research, surface EMG (sEMG) was used to record tibialis anterior and gastrocnemius muscle activities. Seventeen healthy subjects were required to stand on four different types of balance training device such as wobble board, balance cushion, bosu ball and the hover board. They were asked to maintain their standing position on each devices for two minutes. Time domain and frequency domain analysis were used to identify the features of the EMG signal. Time domain analysis measurement involved average rectified value (ARV) and root mean square (RMS) meanwhile, for frequency domain, median frequency of the signal were measured. The results shows that, the RMS is differs significantly between the balance training devices ($p < 0.05$). Meanwhile, no significant interaction between the devices in ARV and median frequency of the muscle ($p > 0.05$). Besides that, the findings show that less stable devices increased muscle activity. Finally, the balance training device were ranked based on the RMS value. These results highlighted the training intensity produced by each device and classify them based on rehabilitation and sports training programs so that a better rehabilitation programme can be provided.

INTRODUCTION

Human balanced is 'inherent ability' of a person to maintain, attain and reinstate of balance. Inherent ability depends on the sensory and motor system of a person. A proper spatial orientation and posture also affect the balance of the human (Azaman & Yamamoto, 2014). Balance ability affected by deterioration of vision, vestibular and somatosensory inputs. Besides, it also affected by weakened muscle strength. There are a few devices that use for balance training and therapy which are wobble board, passive robotic wobble board, basu ball and balance cushion (Latip, Omar, Shahrom, Azmi, & Ridhwan, 2015; Wolburg, Rapp, Rieger, & Horstmann, 2016). Training or exercise for balance and muscle strength training often conducted in gym or other indoor setting. These 'indoor' type of training device may delay the improvement stage as patient easily get bored. Gamification of exercise or training increased self-motivation and enjoyment of exercise (Goh & Razikin, 2015). Other than that, outdoor exercise accumulated more physical activity compared to indoor exercise (Kerr et al., 2012). Thus, an alternative exercise device for balance training with gamification and outdoor feature is needed.

Hover board is a fictional levitating board used for personal transportation. The boards are generally depicted as resembling a skateboard with lateral wheel. It generates the self-balance of the user. Nowadays, hover board has become a phenomenon. They use hover board as daily exercise during leisure time. Besides, compared to other self-balance devices, hover board suitable for both indoor and

outdoor environment. Thus, this device has a promising feature to be used for posture balance training. Hover board apply almost a similar approaches like balance training device as mentioned previously where a person required to maintain their balance position and initiate a movement at their foot in order to move to their desired direction. But less research has been conducted to investigate the therapeutic feature of hover board. Other wheels type board such as skateboard war reported improved cardiovascular health and fitness (Loch, Butte, & Todd, 2013). Besides, a recent article claimed that skateboarding may have therapeutic effect on children with autism, but no scientific evidence recorded yet (Nieratko, 2010).

Most of the balance training device focused on the ability to maintain balance position and least concern on physiological part especially muscle activation. Electromyography (EMG) is widely used as evaluation tool for muscle activation. It allows analysis of muscle in ergonomic studies, muscular performance, and helps to train muscle (Rainoldi, Melchiorri, & Caruso, 2004). The simplest way to record the EMG signal is apply the electrode to the surface of skin covering the muscle that called Surface EMG (SEMG). A sufficient amount of muscle activation generates from the training activity will benefit rehabilitation and training session and ensure a better recovery process.

This study aims to compare the effect of different balance training devices on leg muscles activity. The effect of hover board to the physiological activities also be identified to investigate either it can be therapeutic device or not. Besides, based on muscle activity the difficulty level of balance training device have been identified.

METHODOLOGY

Subject Preparation

In this study, 17 healthy subjects were involved (age: 23.35 ± 0.17 years old; weight: 61.12 ± 3.57 kg and height: 159.59 ± 1.24 cm). 7 of them were men and the rest were women. They were recruited from general student population. Each subject was fully briefed regarding the experiment and possible risk. They were provided with the consent form participation that followed the Declaration of Helsinki. Subjects were excluded from the experiment if they have any health problem or history of fall. Before started, the balance screening did follow Stork Balance Stand Test. The subject needed to stance one leg with their arm across the chest for 2 minutes and the total is recorded. The rating of the test is shown in Table 1. They were given training sessions on how to use hover board to help them familiarize with the devices.

Table 1 Rating Stork Balance Stand Test

Rating	Score (seconds)
Excellent	> 50
Good	40 – 50
Average	25 – 39
Fair	10 – 24
Poor	< 10

Data Recording

The muscle activity was recorded using EMG (TMSI, Porti 7, Nederland). Bipolar surface electrodes were placed on tibialis anterior and lateral gastrocnemius muscles. The recording area was shaved and alcohol swabs was used to remove the top layer of skin to reduce skin impedance.

Subject was asked to maintain their standing position on the wobble board, balance cushion, bosu ball and hover board for 2 minutes as shown in Figure 1. They were needed to do 3 trials for each device. They were given 2 minutes rest between the trials. The different stability was achieved by different structural design and material properties as shown in Table 2.

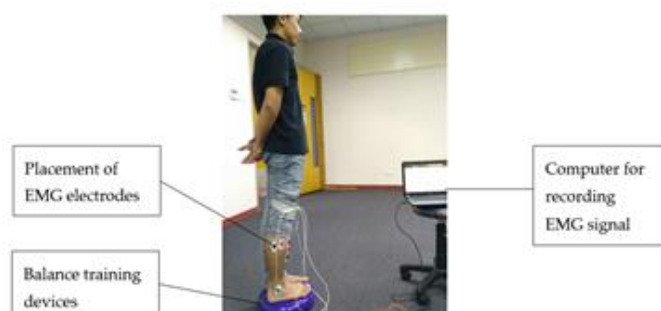


Fig. 1 Experiment Set Up

Table 2 Characteristic of Balance Training Devices

Devices	Surface Material	Dimension	Remark
Wobble board	Wood	Diameter: 20 in. Tilt angle: 15 deg	Unstable

Balance Cushion	Plastic with concentric groove surface	Dimension: 6cm W x 35cm L x 36cm H	Very stable
Bosu Ball	Plastic	Diameter: 25 in. Height: 10 in.	Very unstable
Hover Board	Plastic	Dimensions: 24.5" L x 9" W x 8.75" H	Slightly unstable

Data Analysis

The signal of EMG was processed by Matlab software. The preprocessing started by detrend process. The signal was detrended to remove data that cause the distortion. Then, the signal was rectified to find the absolute of the data point. The filtering was did by using Butterworth Band Pass filter between 50 to 400 Hz to remove motion artifact and unwanted high crosstalk.

The time domain analysis for this signal were the average rectified value (ARV) and root mean square (RMS). The ARV was measured by averaging the filtered signal which commonly used to indicate the amount of muscle contribute for each devices.

Based on the mean value calculation, another modification used to compare innervation ratios between balance training devices is using Input Percentage Value (Konrad, 2005). The formula to calculate Input % Value is shown in Eq 1.

$$\text{Input percentage (Input \%)} = \frac{\text{ARV}}{\sum \text{ARV}} \times 100\% \quad (1)$$

The frequency domain analysis was done by measuring the median frequency of the signal. Fast fourier transform (FFT) was applied to the filtered signal to get the power density spectrum. Half of the total power spectrum then calculated to get the median frequency as shown in Eq 4 [6]. The decreasing of the median frequency will indicate the muscle fatigue. The decreasing of the muscle conduction velocity is the one that causes the median frequency is decrease (Cifrek, Medved, Tonković, & Ostojić, 2009; Stirn, Jarm, Kapus, & Strojnik, 2013).

All the statistical analysis and test were performed in the Excel Software. Data for all the subjects were averaged. One-way analyses of variance (ANOVA) were used to detect the differences of muscle activity between each balance training devices with the significance level $\alpha=0.05$ was selected.

RESULTS AND DISCUSSION

Muscle Activity and Fatigue

The ARV in this studies indicates the muscle contribution for each devices. The ARV of the tibialis anterior muscle for all the balance training devices is almost same. There was no significant interaction of ARV between the balance training devices ($p=0.9798$). The highest ARV for tibialis anterior is balanced cushion as shown in Figure 2. The ARV value for the bosu ball and hover board is almost same. For the gastrocnemius muscle, there was no significant difference of the ARV between the balance training devices ($p>0.05$). The highest contribution of muscle for gastrocnemius muscle was recorded by bosu ball. The height of the bosu ball which is 55cm off floor affect the muscle contribution. More muscle strength need to keep the stability of people on the bosu ball.

Figure 3 showed the percentage of the contribution of the muscle for each devices that used to compare innervation ratio between the training devices. For the wobble board and bosu ball, the used of the antagonist muscle (gastrocnemius) is more that agonist (tibialis anterior). This different with balance cushion and hover board that

used more agonist muscle. The highest contribution of tibialis muscle to the balance training devices is balanced cushion which contributed 28.06% followed by wobble board (25.16%), hover board (24.08%) and bosu ball (22.71%). For gastrocnemius muscle, the highest contribution is bosu ball which is 41.65%, followed by wobble board (27.58%), balance cushion (19.11%) and hover board (11.66%).

The RMS of the muscle shows that there was significant difference between the balance training devices for tibialis anterior muscle which is $p=0.0004$ ($p<0.05$). The RMS for gastrocnemius muscle was no significant different between the balance training devices ($p=0.0932$). The wobble board is the highest RMS for both muscles. The RMS which indicates the level of muscle activation increased from hover board, bosu ball, balance cushion and wobble board for both muscle as shown in Figure 4. The RMS of the hover board and bosu ball for gastrocnemius muscle is different $0.57\mu V$ only.

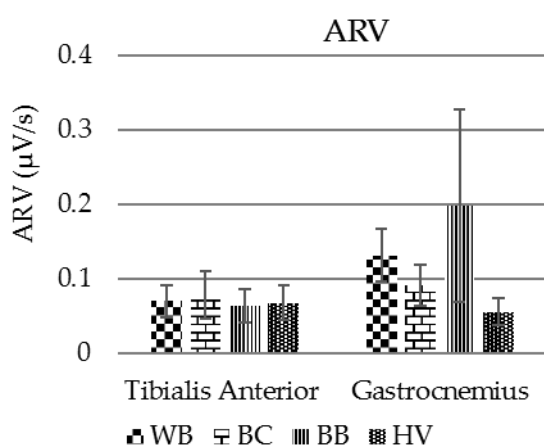


Fig. 2 The average rectified value (ARV) of the tibialis anterior and gastrocnemius muscle for balance training devices

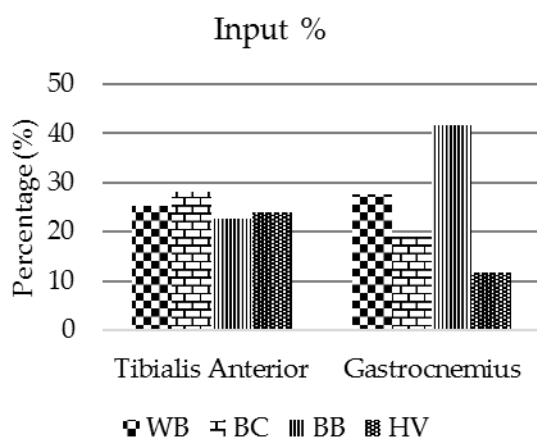


Fig. 3 The percentage input contribution of the muscle to the balance training devices

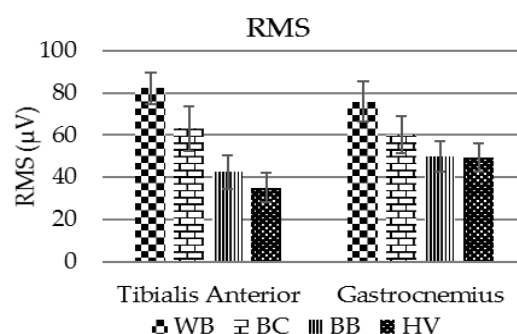


Fig. 4 The root-mean square (RMS) of the tibialis anterior and gastrocnemius muscle for balance training devices

Figure 5 show that the value of the median frequency is not too different between the devices. From the ANOVA analysis, the p-value between the devices for the tibialis anterior is 0.8539 and gastrocnemius muscle is 0.9651. There was no significant different between the balance training devices for both muscle ($p>0.05$). Besides that, the highest firing rate of motor unit for tibialis anterior is balance cushion while for the gastrocnemius muscle is bosu ball. Generally, the firing rate for all the balance training is almost same.

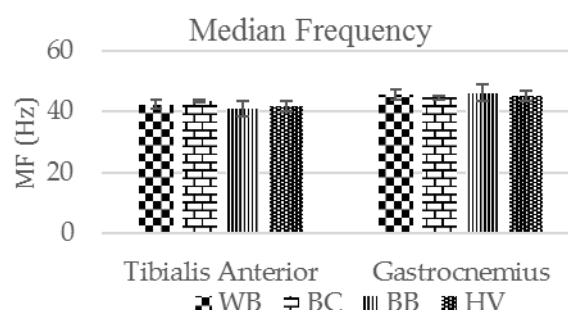


Fig. 5 The median frequency (MF) value of the tibialis anterior and gastrocnemius muscle for balance training devices

According to the previous research, the less stable balance training devices required more muscle activity than the more stable devices (Wolburg, et al., 2016). The muscle contribution of agonist (tibialis anterior) and antagonist muscle (gastrocnemius) is balanced for all balance training devices. The bosu ball contributes more amount of muscle for the antagonist muscle because the device is high and people need more antagonist muscle to keep balance. From the RMS results, the level of muscle activation was increased from hover board, bosu ball, balance cushion, and wobble board. This finding similar to the previous study where force is directly proportional to the EMG signal (Fukuda, Thiago Yukio et al., 2010). This shows that the muscle needs more strength to keep stable on the most unstable devices.

From the median frequency for 120 seconds of the training, the firing rate of a motor unit was increased for all the devices. The more the strength of muscle used, the more the firing rate (De Luca & Hostage, 2010). The differences of the bosu ball and hover board is not too significant for all the parameter. This show that the hover board has a potential to be the therapeutic device.

Based on the previous study, the wobble board, bosu ball and balance cushion are suitable for people with ankle injuries. In addition, wobble board can improve the upper limb injuries and balance cushion for general strength training (Latif, et al., 2015). From this research, the difficulty of the balance training devices affected the muscle activity. Based on the results, training devices were rank based on their effected to muscle activation (RMS) as shown on Figure 6. This rank can be a guide for recovery or rehabilitation purpose. For the pre-recovery ankle injuries, the patient is suggested to use the hover board, but they need to be trained, so they can use this board for a safely reason. Then, they can move to

bosu ball, balance cushion and lastly, the wobble board. People can use this guideline to improve their balance ability from time to time.



Fig. 6 The median frequency (MF) value of the tibialis anterior and gastrocnemius muscle for balance training devices

CONCLUSION

The findings show that less stable devices increased muscle activity. These results highlighted the training intensity for each device and classify which balance training devices suited in rehabilitation and sports training programs so that a better rehabilitation intervention can be provided.

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