Validity of a jump training apparatus using Wii Balance Board

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The dynamic quantification of jump ability is useful for sports performance evaluation. We developed a force measurement system using the Wii Balance Board (WBB). This study was conducted to validate the system in comparison with a laboratory-grade force plate (FP). For a static validation, weights of 10–180 kg were put progressively on the WBB put on the FP. The vertical component of the ground reaction force (vGRF) was measured using both devices and compared. For the dynamic validation, 10 subjects without lower limb pathology participated in the study and performed vertical jumping twice on the WBB on the FP. The range of analysis was set from the landing after the first jump to taking off of the second jump. The peak values during the landing phase and jumping phase were obtained and the force–time integral (force impulse) was measured. The relations of the values measured using each device were compared using Pearson’s correlation coefficient test and Bland–Altman plots (BAP). Significant correlation (P < .01, r = .99) was found between the values of both devices in the static and the dynamic test. Examination of the BAP revealed a proportion error in the landing phase and showed no relation in the jumping phase between the difference and the mean in the dynamic test. The WBB detects the vGRF in the jumping phase with high precision.

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1. Introduction

Force sensors, represented by force plate (FP) and pressure distribution measurements, have been used for dynamics analysis of sports movements. Such devices were developed for laboratory study. Most are expensive and might demand special techniques for their operation. Therefore, these devices are rarely used for sports and the exercise instruction situations. Extremely few chances to measure force exist. However, because of development of the recent information and technology appliance, convenient force measurement methods have become possible. The Wii Balance Board (WBB) (Nintendo Co. Ltd., Kyoto, Japan), part of a video game (WiiFit; Nintendo Co. Ltd., Kyoto, Japan), is one device satisfying this demand. The WBB possesses similar characteristics to those of a laboratory-grade FP in that it contains four transducers used to assess a force distribution and the resultant movements in the center of pressure (COP). Clark et al. [1] demonstrated that the WBB provides comparable data to those obtained using a FP when assessing the COP path length during standing balance trials in the limit weight that WBB shows (less than 136 kg). Additionally, they reported that the dual WBB system could record weight-bearing asymmetry and COP path velocity with accuracy during dynamic tasks [2]. The activity fostered by WiiFit also showed an immediate effect on balance and strength that demands confirmation using statistical analysis [3]. In addition, the training apparatus (Wii trainer) for jump movement using WBB was developed in our laboratory [4]. The Wii trainer was developed for ski-jumping training to quantify the takeoff force and dynamic laterality in a simulated takeoff. The Wii trainer monitors the COP path and the curve of the vertical component of the ground reaction force (vGRF). However, the maximum vGRF during the simulated takeoff motion exceeded the recommended weight (136 kg) described above. According to an earlier report [5], the maximum vGRF in the simulated takeoff motion was the weight plus approximately 850 N. Therefore, this study was conducted to investigate the validity of WBB by comparing vGRF data collected using a WBB with those obtained using a laboratory-grade FP.

2. Methods

2.1. Procedures

Validation tests were performed in static and dynamic conditions. In the static test, the WBB was put horizontally on a laboratory-grade FP (BP6001200; AMTI, Watertown, MA, USA), which was 60 cm x 120 cm. The FP, which was set to 1000 Hz of sampling frequency, was calibrated in accordance with the manufacturer’s recommendations. Accuracy and linearity of the FP in this study were as follows; crosstalk was less than 2% on all channels, Fz hysteresis was ±0.2% full scale
output and Fz non-linearity was ±0.2% full scale output of 4450 N. The WBB was interfaced with a laptop computer using custom-written software. Then the data were obtained wirelessly via Bluetooth. Both apparatus measured the variety of known loads, with 10–180 kg put on the WBB. In each load condition, the values of vGRF of each device were obtained with the mean of one second.

In a dynamic test, 10 participants were enrolled in the study (gender = 8 male, 2 female; height = 1.66 ± 0.05 m; weight = 59.1 ± 8.6 kg). They performed two jump movements on the WBB on the same experimental system as a static test (Fig. 1). The vGRF curve was measured using both devices. The time interval of the analysis was defined as the time between the two jumps. The peak values of vGRF during the landing and jumping phases (peaks 1 and 2 in Fig. 1) were obtained along with the force impulses.

The quantities of data between analyses with respective devices were obtained. However, the units of the outcome variables measured with the WBB were in kilograms. The data were converted into Newtons with multiplied by 9.8 m/s². Neither filtering nor other signal processing was applied to the data. Furthermore, the sampling frequency of the custom-written software was calculated.

2.2. Statistical procedure

The relation between the vGRF values measured using both devices was assessed using Pearson’s correlation test (P < .01). To examine the agreement between the two devices, a Bland–Altman plot was created for the vGRF, force impulse and peak values in each testing protocol. Specifically, this was performed by plotting the difference in vGRF measures between the two devices against the mean results [6]. Point estimates of the correlation test were interpreted as follows: excellent (.75–1), modest (.4–.74), and poor (0–.39) [7]. All statistical tests were performed using software (SPSS ver. 14.0 SPSS Inc., Chicago, IL, USA).

3. Results

In static verification, a strong and statistically significant (P < .01) correlation (r = .99) was observed between the values measured with the devices. The relation between the differences and mean in vGRF is presented in Fig. 2 (Bland–Altman plot, BAP). The differences became large with increased load quantity. At differences in weight of greater than 130 kg, the difference of the vGRF was greater than 20 N.

Regarding dynamic verification, a strong and statistically significant (P < .01) correlation (r = .99) was found between the measured values (peak 1, peak 2, and force impulse) with both devices. The scatter plots representing comparisons peak forces between the WBB and the FP for dynamic testing conditions was shown in Fig. 3.

The BAPs with regard to peak values in the landing and jumping phase are presented in Fig. 4. The unevenness of the difference of vGRF increased in the landing phase in the high load area, and a proportion error was recognized between the mean and differences. No marked relation between the difference and the mean was observed for the jumping phase. The mean differences (standard deviation) of peak 1 and peak 2 were, respectively, −8.2 (40.2) N and 21.3 (11.4) N. The BAP of force impulse is portrayed in Fig. 5. No readily apparent relation exists between the difference and the mean. A measured value of WBB was estimated as higher than that of FP, and the mean difference (SD) of the force

Fig. 1. Procedure of dynamic verification and an example data of vGRF: (a) vGRF curve measured using the Wii Balance Board (WBB) and (b) vGRF curve measured using a laboratory-grade force plate (FP). Subjects performed two jump movements on the WBB set on the FP. The range of analysis was defined as the time between the two jumps.
3. **Discussion**

The use of multi-dimensional force platforms, such as force plates, is essential in measuring the forces generated during athletic movements. However, the challenge lies in ensuring accurate and reliable data collection. The presence of a buffer zone on the force plate is crucial for avoiding excessive shock. For example, applying a peak value of load during jumping, the peak force generated is found to be approximately 4.15 times the weight of the subject. This is consistent with the findings of previous studies, which reported that the peak force during jumping is between 4 and 6 times the body weight.

The use of multiple force plates, as opposed to a single one, allows for a more comprehensive analysis of the forces generated during athletic movements. This is particularly important in sports such as gymnastics, where the athletes perform complex movements with high peak forces. The use of multi-dimensional force platforms, such as the WBB, can provide a more accurate and detailed analysis of the forces generated during jumping and landing.

The use of multi-dimensional force platforms, such as the WBB, is also important in the field of rehabilitation. The peak forces generated during jumping and landing are significantly reduced when the athlete is wearing a protective device. This is particularly important in preventing injuries, as the peak forces generated during jumping and landing can cause significant strain on the joints.

The use of multi-dimensional force platforms, such as the WBB, is also important in the field of sports medicine. The peak forces generated during jumping and landing are significantly reduced when the athlete is wearing a protective device. This is particularly important in preventing injuries, as the peak forces generated during jumping and landing can cause significant strain on the joints.

The use of multi-dimensional force platforms, such as the WBB, is also important in the field of sports medicine. The peak forces generated during jumping and landing are significantly reduced when the athlete is wearing a protective device. This is particularly important in preventing injuries, as the peak forces generated during jumping and landing can cause significant strain on the joints.
such as vertical jump, it would be useful to measure the force impulse precisely, because the impulse is equal to the change in momentum (mass times velocity). Regarding the number of sampling data, WBB was able to measure data to one-tenth the resolution of the FP (1000 Hz), which suggests that the WBB, with its custom-written software, was able to measure the force data with a sampling frequency of approximately 100 Hz. This sampling frequency suggests that it is sufficiently utilizable for evaluating human movement dynamically. As additional information, the sampling frequency depended on the communication capacity by the Bluetooth.

In this study, the verification of COP was not performed for reasons as follows: (1) validity and reliability of the COP were already established by Clark et al. [1] and (2) the COP was calculated by the weighted mean of four data measured by the sensors built in WBB. If the four sensors could measure them the precisely, the COP would calculate correctly as an inevitable result.

In conclusion, WBB provides nearly comparable data to those of a FP when assessing jumping force. Many physical therapists, trainers, sport coaches and athletes require the device that can measure a GRF easily. They could measure the vGRF by WBB without purchasing an expensive device such as FP, because this study could obtain the validity of the WBB. Consequently, the WBB and the custom-written software are useful to visualize forces during training that are difficult to measure, which can engender improvement of evidence-based training. However, in situations involving strong shocks such as landings, this device cannot measure peak levels exactly.

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Conflict of interest

No conflict of interest exists.

References