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Validity of a jump training apparatus using Wii Balance Board

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ABSTRACT

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.

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 × 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

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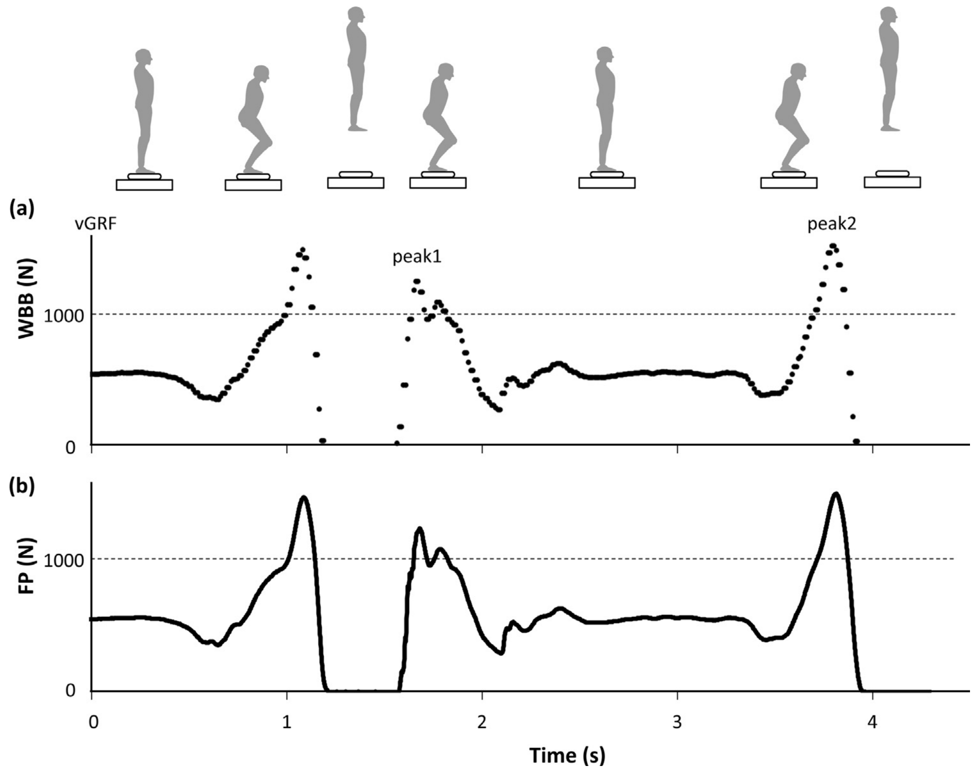

Fig. 1. Procedure of dynamic verification and an example data of vGRF: (a) vGRF curve measured using the Wii Balance Board (WBB) and (b) vGRF curve measured using a laboratory-grade force plate (FP). Subjects performed two jump movements on the WBB set on the FP. The range of analysis was defined as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

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/s^2. 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

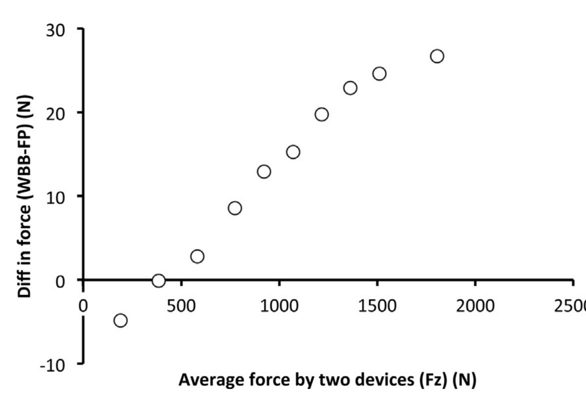

Fig. 2. Bland–Altman plots representing comparisons between the laboratory-grade force plate (FP) and the Wii Balance Board (WBB) for static testing conditions.

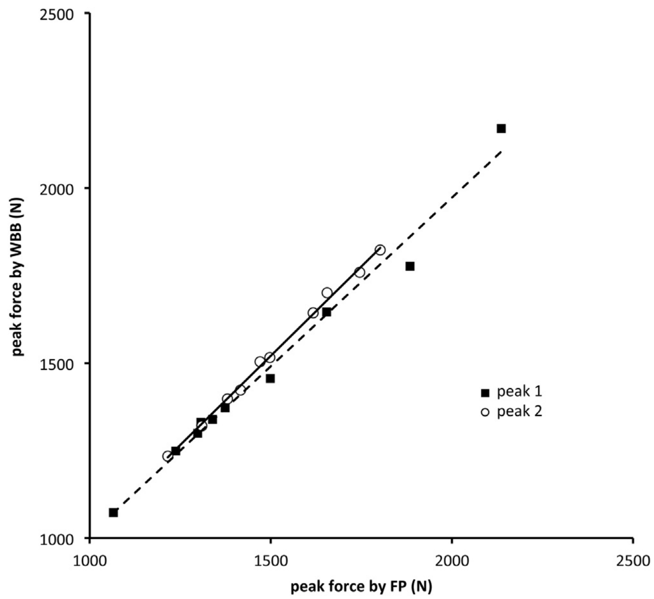

Fig. 3. Correlation between peak values measured by WBB and FP for dynamic testing conditions: squares are the peak value in the landing phase (peak 1 in Fig. 1) and circles are the peak values in the jumping phase (peak 2 in Fig. 1). Solid and dashed lines represent the regression lines in the jumping and landing phase (r = .99, P < .01), respectively.

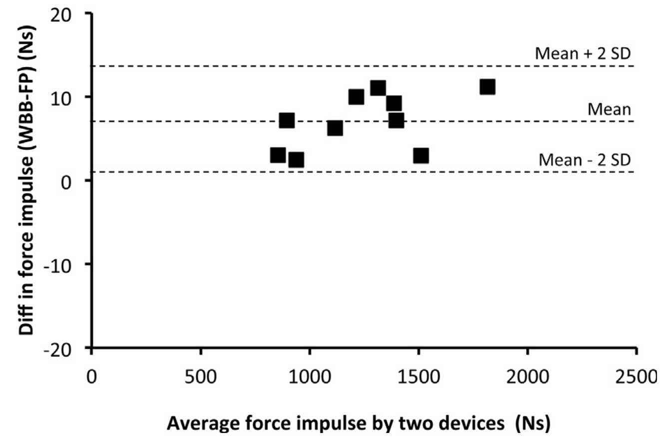

Fig. 5. Bland–Altman plots presenting comparisons of force impulse between FP and WBB for dynamic testing conditions: (a) peak 1 during landing phase and (b) peak 2 during jumping phase.

impulse was 7.0 (3.4) Ns. The mean numbers of the sampling data (SD) of the FP and the WBB during the time interval of the analysis were 1843.5 (442.1) and 181.0 (41.1), respectively. The WBB data were approximately a one-tenth of that of FP on the average.

4. Discussion

Quantifying movements dynamically using a simple method can yield useful information to athletes and coaches during training. In this regard, WBB is expected to be a useful apparatus that is accurate, portable, and inexpensive in comparison with FP. High linear correlation (P < .01, r = .99) in static's test demonstrates the validity of the measurability using WBB. For a static load as high as about 1800 N, WBB can take measurements with precision of less than 2%. Differences of vGRF of both devices exceeded 20 N with weight of more than 130 kg, which was a use restriction of WBB that Nintendo has recommended. This difference was 1.5–1.7% for gross weight. In fact, WBB is the plastic controller of the home-use game console. Therefore as the weight became great, structural deformation of the WBB increased. We infer that a difference occurred in the measured values between the devices. In dynamic inspection, the shock at the time of the landing was regarded as the cause of proportional error recognized to the vGRF peak value of the landing phase, which is regarded as a structural problem described above WBB, and it is inferred that WBB shape was deformed by the shock of the landing. However, the difference between the device measurements is small with the peak value in the jumping phase. Using the training application of WBB, we recommend avoiding movements that include excessive shocks. For example, the peak value of vGRF at the time of the landing of a drop jump from a 70 cm height was 1715 (SD = 403) N on average (n = 23) [8]. Therefore, WBB is expected to be unsuitable for GRF measurements at the landing of the drop jump. However, WBB estimated a peak value of vGRF that was larger (+21.3 N on the average) than that of FP at the jumping phase. For training or clinical applications, careful attention is necessary. This difference is predicted by the static test from the measurement error. The subjects in this study were all of low body weight (59.1 ± 8.6 kg, mean ± SD). The results are, therefore, only applicable for subjects of a similar weight.

Regarding the results of compared force impulses between devices, WBB was estimated as high. However, the difference was less than the difference of the peak value described above. In this regard, integral calculus was thought to be useful to shrink the measurement error. To quantify the ability for jump movement

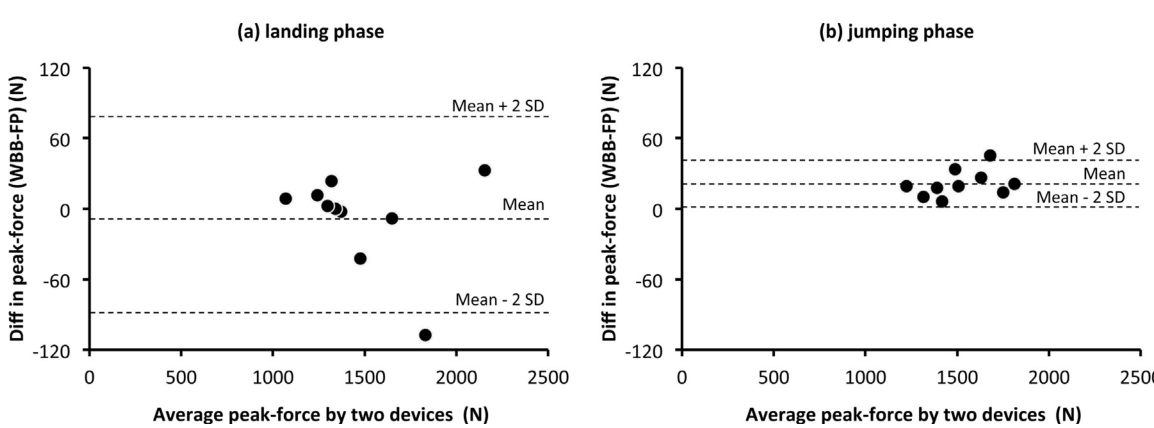

Fig. 4. Bland–Altman plots presenting comparisons of peak values between FP and WBB for dynamic testing conditions: (a) peak 1 during landing phase and (b) peak 2 during jumping phase.

such as vertical jump, it would be useful to measure the force impulse precisely, because the impulse is equaled 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, sports 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.

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