THE USE OF NINTENDO Wii BALANCE BOARDS FOR REAL-TIME INVESTIGATION OF WEIGHT BEARING ASYMMETRY

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This study examined the effect of real-time feedback on dynamic weight bearing asymmetry (WBA). Fourteen elite footballers and 33 age-matched untrained males performed six squats with (VFB) and without visual WBA feedback. The squats were completed on two Nintendo Wii Balance Boards (40 Hz) with customised software. Significant reductions in WBA (p=0.007) with VFB was observed, with correlation analysis revealing that participants with higher levels of WBA generally had the greatest response to visual feedback (R=0.46, p = 0.001). However individual profiles indicated that 21% and 30% of participants in the trained and untrained groups WBA declined further with feedback. This acute response by some participants may reverse with further training, or may be due to differing learning preferences (e.g. auditory, kinaesthetic).

KEY WORDS: injury, rehabilitation, sport, health.

INTRODUCTION: Recent innovative research suggests that computer gaming technology, namely the Nintendo Wii Balance Board (NWBB), may be a valid tool for assessing limb loading and centre of pressure patterns in clinical and sporting settings (Clark *et al.*, 2010). Asymmetrical loading has been associated with musculoskeletal injuries and neurological impairments in both athletic and non-athletic populations (e.g. Chmielewski *et al.*, 2002). Clinically, most estimate higher risk limbs as those with an asymmetry of more than 10 to 20% (Grace, 1985), but there is a limited number of prospective studies on inter-limb asymmetries and injuries to support these guidelines. Identifying and training to eliminate limb asymmetry may however have a significant impact on injury rates in many sports.

The squat is one of the most common exercises for improving lower body strength and power (O'Shea, 1985), and is also an important exercise in the rehabilitation of lower limb injury such as an anterior cruciate ligament (ACL) tear (Escamilla, 2001). Typical WBA observed during squatting in healthy populations (~5-6%) is lower than patients who have undergone recent ACL reconstruction surgery (33-48% at 1.5-4 months post surgery; Neitzel et al., 2002). This WBA can also be accentuated by a person's ability to perceive their asymmetry. Carpes *et al*. (2008) identified that only 12% and 50% of untrained and trained participants respectively were able to perceive their loading asymmetry during a closed kinetic chain lower limb exercise. Consequently, real-time visual feedback of information on WBA using two NWBBs could possibly be employed to provide training interventions to help reduce asymmetry.

The purpose of this study was to examine the effect of real-time visual feedback on dynamic weight bearing asymmetry in highly trained and untrained healthy males. It was hypothesised that visual feedback would improve WBA during squatting exercise, and that highly trained athletes would have less WBA than age-matched, untrained adults.

METHODS: Fourteen elite Australian Rules Football (AFL) players (age = 23.1 + 2.9 yrs, mass = 91.5 + 14.1 kg, height = 189.7 + 6.8 cm) and 33 untrained males (age = 24.3 + 4.8 yrs, mass = 77.6 + 13.1kg, height = 179.3 + 7.6cm) volunteered to participate in this study. The AFL players were currently performing weighted squats as part of their regular conditioning program, whereas the untrained males were physically active but not performing squats as a part of their weekly exercise. All participants provided written informed consent

prior to participation, and were free from lower extremity injury and muscle soreness at the time of testing. This study was approved by the Universities Human Research Ethics Committee.

Each participant completed six squats with and without visual WBA feedback. The order of the tasks was randomised between participants in each group. The squats were unloaded and completed to a self selected depth at a tempo of one squat every six seconds. The loading condition in this study was much lower than a typical load encountered during resistance training in AFL athletes. However this was because Flanagan and Salem (2007) indicated that increased loading had minimal influence on the magnitude of WBA. A low frequency, low volume tone provided an audio cue at three second intervals to guide the squat tempo at the top and bottom of the movement. The participants completed the squats with their feet positioned on each board as shown in Figure 1a. Familiarisation trials without WBA were used to establish a comfortable inter-board width for each participant, and to ensure a comfortable squatting position.
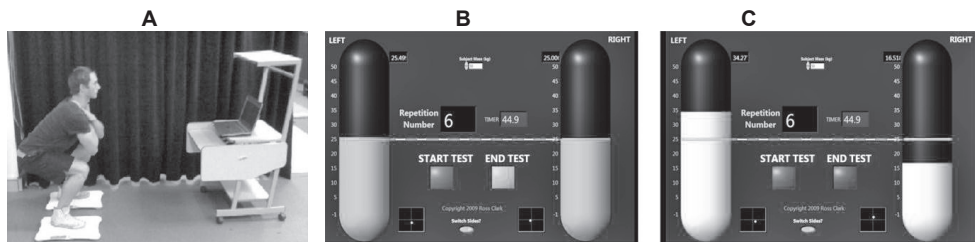

Figure 1: The equipment set-up for the squatting protocol including the Nintendo Wii Balance Boards and a laptop that was connected via a wireless Bluetooth connection (a) to display visual feedback, in real-time, when the participants weight bearing movement was symmetrical (b) and asymmetrical (c).

The symmetry of the weight distribution during the squatting tasks was evaluated using two Nintendo Wii Balance Boards (NWBB; Nintendo, Redmond, Washington) sampling at 40 Hz. Customised software (Labview 8.5, National Instruments, Austin, Texas, U.S.A.) was used to apply a 12 Hz low pass filter to the load data, and to capture and display, in real-time, the left and right weight distribution of the participant. Calibration data provided consistent results between days ($R^2 > 0.99$ for all loads) with minimal measurement error (<0.2 kg for all loads). The software was run and displayed on a laptop computer directly in front of the participant, linked to NWBBs via a Bluetooth connection. The software included an auditory tempo tone to guide the pace of the squatting tasks for both feedback conditions, and a visual display of vertical bars that were green in colour when the squatting movement was symmetrical (Figure 1 b), and turned orange when it was asymmetrical (Figure 1c). WBA was defined as when the load on each limb was greater than $\pm 5\%$ of the participant's body mass.

WBA was calculated using the symmetry index (SI) was calculated to determine asymmetries in force patterns during squatting as follows (Zifchock *et al.*, 2005):

$$SI = \frac{Load_{Right} - Load_{Left}}{0.5 \, (Body \; Mass)} \times 100$$

where the load and body mass was measured in kilograms (kg). Inter-day (one week apart) reliability results from pilot testing of 25 male, untrained participants indicated moderate to excellent reliability (ICC range = 0.79 – 0.97) for the assessment of load (mass) distribution during squatting across a variety of outcome measures that included SI.

The Shapiro-Wilk test revealed that the SI measures were not normally distributed, and therefore non parametric statistics were used. Consequently, medians and inter-quartile ranges were calculated for each group and the groups combined. Wilcoxon signed-rank tests were used to identify any differences in squatting performance in response to visual

feedback. Secondly, Mann-Whitney U tests were used to evaluate if the trained compared to the untrained population demonstrated greater levels of symmetry during squatting in both visual conditions. Finally, an assessment of the relationship between WBA and the response to feedback was determined using Spearman's rank order correlation analysis. This was performed by correlating the combined group data for the SI during the no feedback condition with the percentage improvement in SI between the no feedback and feedback conditions. All statistical analysis was performed at an alpha level of 0.05.

RESULTS: Overall the athlete and non-athletes WBA (SI) was significantly reduced (p=0.007) from 5.9 (2.8 - 9.0) to 3.5 (1.9 – 6.5)% with the real-time visual feedback provided by the NWBB system. Group comparisons between the feedback conditions for the trained AFL players and untrained males are provided in Figure 2. In the untrained group only, there was a significant reduction in SI with visual feedback (p=0.026). No group differences were identified for SI, however lower median WBA was observed in the AFL players. To evaluate whether participants with higher levels of WBA received greater benefit from the visual feedback, a Spearman rank correlation was performed between the no feedback condition and the percentage improvement with feedback. This revealed a moderate relationship between baseline WBA measures and the percentage change in these measures with feedback (SI: R=0.46, p=0.001).
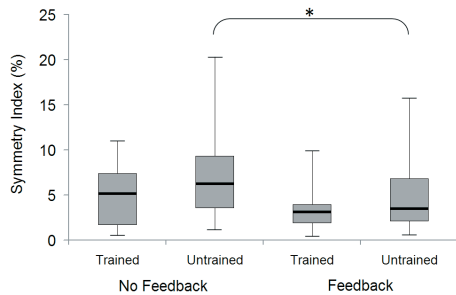

Figure 2: Median results for the symmetry index for the trained and untrained groups for both feedback conditions.
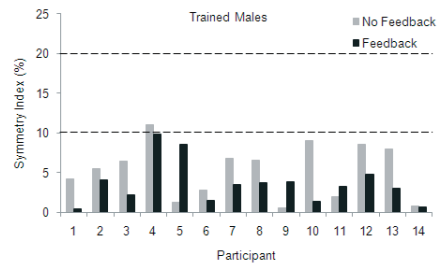

Figure 3: Individual symmetry index results for trained (AFL) players with and without feedback.

Individual responses to the real-time visual feedback are profiled in Figure 3 for the trained group and Figure 4 for the untrained group. Whilst significant improvements in WBA asymmetry were identified in the group data overall and in the untrained group, the individual profiles revealed that some participants (21% and 30% of participants in the trained and untrained groups) WBA during the squatting task did not improve with visual feedback.
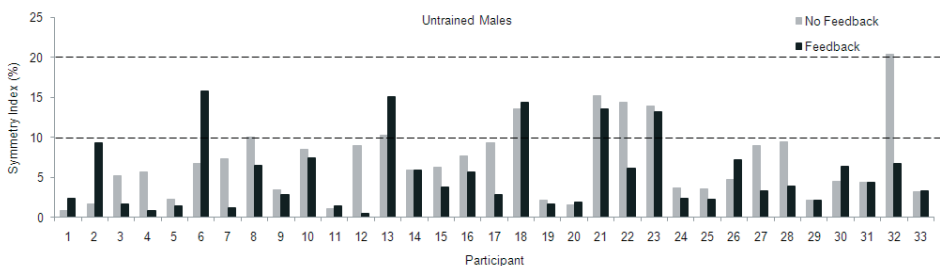

Figure 4: Individual symmetry index results for untrained males with and without feedback.

DISCUSSION: To our knowledge, this is the first study to evaluate WBA during squatting exercise in trained and untrained populations using a NWBB system. The results indicate

that participants with higher levels of WBA will record the greatest improvement when presented with real-time visual feedback. However individual monitoring of participants is required due to a small proportion of participants who did not respond favourably to the intervention. This acute response by some participants may reverse with further training, or may be due to differing learning preferences (e.g. auditory, kinaesthetic). Learning preference profiling of participants (Fleming *et al.*, 2005), known as VARK testing, may indicate whether the individual does have a vision dominant learning preference and may therefore respond to more prolonged visual feedback training.

Overall observations of WBA without intervention in this study of healthy males was similar to the 5-6% previously reported by Neitzel *et al.* (2002) for squatting. WBA in the limb loading (SI) beyond 10% was more frequently observed in the untrained males with only one participant in that group exhibiting 20% WBA. As all of the participants were healthy in this study, this indicates that Grace's (1985) recommendations of a 10-20% asymmetry risk range could be possibly refined to 10% for trained and 20% for untrained populations for unloaded squatting. However this would require further prospective study to confirm whether exceeding these WBA thresholds does led to heightened injury risk.

CONCLUSION: This study observed WBA in elite athletes with extensive strength and conditioning backgrounds and in healthy, untrained populations without squatting experience. These asymmetries were assessed and generally improved using inexpensive, portable and widely available NWBB with customized software. These findings demonstrate that this technology may be utilized in clinical and sporting settings to evaluate and improve WBA; however differing feedback methods (e.g. auditory) may be required for some individuals. Although unloaded squats were examined, each NWBB has the capacity to hold 150 kg. Therefore it would be possible to incorporate the NWBB into an athlete's normal training routine where their exercises such as the squat are loaded.

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