Short communication

Assessing and training standing balance in older adults: A novel approach using the ‘Nintendo Wii’ Balance Board

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ABSTRACT

Older adults, deemed to be at a high risk of falling, are often unable to participate in dynamic exercises due to physical constraints and/or a fear of falling. Using the Nintendo ‘Wii Balance Board’ (WBB) (Nintendo, Kyoto, Japan), we have developed an interface that allows a user to accurately calculate a participant’s centre of pressure (COP) and incorporate it into a virtual environment to create bespoke diagnostic or training programmes that exploit real-time visual feedback of current COP position. This platform allows researchers to design, control and validate tasks that both train and test balance function. This technology provides a safe, adaptable and low-cost balance training/testing solution for older adults, particularly those at high-risk of falling.

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1. Introduction

Each year 30–60% of older adults fall, and 10–20% of these falls result in either significant injury or mortality [1]. Although considerable efforts have been made to develop means of identifying and rehabilitating factors that predispose individuals to an increased risk of falling, there is still a need to develop new safe ways of engaging older adults in balance based training on a regular basis. The current article proposes a new solution that exploits WBB technology, to provide a safe, low-cost, engaging, balance training solution for older adults, particularly those at risk of falling.

The WBB is predominantly used in combination with its associated gaming console. A recent study, however, has shown that older adults who are willing to play existing games, often finding the level too advanced [3]. Although these existing balance based games were not designed to train balance in older adults, the benefits of WBB technology can still be exploited. A recent study reported how changes in COP derived from the WBB signals post hoc were very similar to those obtained from a typical force plate [2]. These results, along with good test–retest reliability provide a general validation of the WBB as a means of monitoring COP. By designing an interface that retrieves information from the WBB and displays the resulting COP as real-time visual feedback, we wanted to see if functional balance training games can be developed specifically for an older adult population.

2. Materials: description of interface

The WBB contains four transducers that provide information relating to force distribution. The wireless communication protocol normally used to exchange commands and data between the WBB and the games console is well known and thus any computer with appropriate software can be configured to use the data from WBB sensors. Virtools 4.0 (Dassault Systems) provided the monitoring and data processing environment, in addition to rendering the virtual environment and presenting graphical feedback to participants. The flexibility of Virtools allows users to create their own data acquisition modules which can be loaded and used as part of any environment or action script. Data from the WBB can therefore be integrated into an interactive virtual environment and processed synchronously with other sensor input in real-time. To accomplish this, a plug-in module (‘Building Block (BB)) was written and used as part of a Virtools script to acquire the input from the WBB sensors, and scale it to real-weight values. The BB uses multithreaded software architecture. Two tasks run simultaneously, the first runs within the Virtools programme to feed signals into the action script. A second task acquires the data from the WBB using a fast and robust Bluetooth wireless channel, and prepares it for use by Virtools. The tasks are

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synchronised, allowing visual feedback to be generated within 70 ms.

Prior to the development of the balance tasks, it was important to check the validity of the data being acquired in the Virttools programme from the WBB. We achieved this through progressively loading weights on to each sensor of the WBB and recording the resultant values displayed in the virtual reality software (one value for each sensor). A very high correlation ($r^2 > 0.99$; Fig. 1) was found between the mean of three individual readings for each weight and the actual weight placed on the WBB sensor. The Centre of Pressure (COP) ($X$, $Y$) was calculated using the data from the four sensors on the WBB using the following equation:

$$\begin{align*}
X &= \frac{\sum_{i=1}^{4} Wght_i \cdot x_i}{\sum_{i=1}^{4} Wght_i} \\
Y &= \frac{\sum_{i=1}^{4} Wght_i \cdot y_i}{\sum_{i=1}^{4} Wght_i}
\end{align*}$$

where $(x_i, y_i) =$ coordinates of each pressure sensor $(i)$ in the Wii balance board’s reference frame; $Wght_i =$ weight recorded on each sensor $(i)$; and $(X, Y) =$ coordinates of the COP.

The COP was then used to control the position, in real time, of an object in the virtual environment provided by Virttools.

With this interface, our objectives were to create a series of balance tests and games that could be used to both train and examine balance function. The various tasks were designed to incorporate actions that are commonly associated with balance function and predicting fall-risk, namely maintaining a static position (reducing postural sway) [4,5], or reaching limits of stability [6].

Two games were designed, each comprising levels of incrementing difficulty. Our first game involved a participant controlling the medio-lateral position of a basket using their COP in an attempt to catch apples falling from a tree. The second game required both medio-lateral and anterior–posterior control of COP to manipulate the position of a character in an attempt to move towards, and pop rising bubbles. Games were designed to be intuitive and easy to play whilst avoiding the need to make fast destabilising postural responses. In addition, the position of COP and all objects within the virtual environment were time-stamped and automatically saved in a text file for post hoc analysis. Our second objective was to develop a safe environment for individuals to participate. This was achieved by mounting the WBB into a purpose built platform (surface of the WBB being flush with the platform floor).

In order to evaluate the suitability and effectiveness of the new WBB interface we recruited 6 (1 male, 5 female) healthy older adults (mean age (years): 84.1 years ± 5.1; none reported falling in the previous 12 months) who participated in 10 sessions of game play (20 min each) over a four-week period.

Both prior to, and following the block of training sessions six participants’ balance was assessed using tasks developed with the WBB interface, where participants were required to maintain a static standing position, minimising movement of their COP. Tests lasted for 30 s, once with eyes open, and again with eyes closed. Although post-intervention mean sway variability decreased in both medio–lateral and anterior–posterior sway in both eyes open and eyes closed conditions, it only reached significance in the eyes closed anterior–posterior sway ($t(5) = 3.042; p = 0.03$—see Fig. 2).

Following training, when asked whether participants would choose to continue playing the balance games over a longer period (e.g. six months), all responded “definitely yes”. Furthermore, all participants reported having enjoyed the gaming experience and reported an 11% mean improvement in Tinetti’s Falls Efficacy Scale [7] post-training compared to pre-training, reflecting greater confidence in the ability to perform functional tasks.

3. Applications

Clark et al. [2] suggested that the WBB might provide clinicians with a low-cost tool to assess standing balance. Our interface provides the next step; a novel method to design and deliver balance training tasks that require the use of visual feedback to
control COP. Our interface also provides the potential to easily reproduce many of the validated tasks used in diagnosing balance impairments, such as testing limits of stability and functional reach tests [5,6], movement in COP both with and without visual feedback [4] and COP tracking tasks [5]. The interface described could also be used to provide more dynamic tasks, such as squatting exercises and pointing with one foot to locations on the WBB specified in the virtual environment. Furthermore, clear opportunities exist to translate tasks produced using the WBB/Virtu tools interface for use with other software, allowing mass replication and participation.

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**Conflict of interest statement**

All authors confirm there are no known conflicts of interest.

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