Link to publisher's version: *http://dx.doi.org/10.12968/ijtr.2016.23.5.215*

Citation: Graham CS, Stephens DM, Dietz KC and Winter SL (2016) Are current methods of partial weight-bearing instruction accurately translating to crutch-assisted gait? International Journal of Therapy & Rehabilitation. 23(5): 215-220.

Title: Are current methods of partial weight bearing instruction accurately translating to crutch assisted gait?

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Sources of grant support: NONE.

The protocol of this study was reviewed and approved by the Research Ethics Committee of the Faculty of Science, University of Kent.

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ABSTRACT

Study Design: Repeated measures, Williams crossover design.

Objectives: The aim of this study was to determine the accuracy with which weight-bearing protocols (20%, 50% or 80% of body weight (BW)) could be reproduced shortly after being taught.

Background: Partial weight bearing protocols (PWBPs) are commonly incorporated into hospital, clinical and field based rehabilitation (Hershko, Tauber & Carmeli, 2008), to enhance recovery, particularly in patients following cartilage surgeries. Overloading can affect healing time and the stability or integrity of the healing structure (Pauser et al., 2012), however underloading can also be detrimental as adequate weight bearing encourages the healing process, for example osteoblastic stimulation (Meadows, Bronk, Chao & Kelly, 1990). Therefore accurate reproducibility of these protocols could be considered essential to the rehabilitation process.

Methods: 30 participants were taught three partial weight bearing protocols (20%, 50% and 80% BW), using bathroom scales. Participants ability to reproduce their target load for each protocol was assessed statically using bathroom scales and dynamically with a force plate using a 3point elbow crutch assisted gait. Participants were assessed 10 minutes after being taught. Errors between actual and target load during these trials was calculated.

Results:

Accuracy assessed with scales was comparatively good for all target loads, however dynamic trials using the force plate showed an inverse relationship between all error measures and target loads (i.e. 20% > 50% > 80% BW; all $p<0.01$). The peak error was double the intended load at 20%BW (95% CI: 11.9%BW, 24.1%BW). At 80%BW the peak error was not significantly different from zero.

Conclusion:

The static method of instruction of PWBPs, using bathroom scales, does not seem to translate accurately to dynamic motion, and therefore affects adherence to medical instruction. Practitioners should be aware of the potential errors in reproducing these loads and the potential effect on rehabilitation. These results would suggest that practitioners should be cautious when using bathroom scales to teach PWBPs and not rely on them to assess reproduction accuracy during gait.

Level of evidence: Controlled laboratory study, randomized cross-over design.

KEY WORDS: rehabilitation, lower limb, crutch-assisted gait, test-retest reliability, partial weight bearing accuracy

INTRODUCTION

Partial weight bearing protocols (PWBPs) are commonly incorporated into hospital, clinical and field based rehabilitation following lower limb fractures, soft tissue injuries and surgery (Hershko, Tauber & Carmeli, 2008)**.** Most rehabilitation plans specify gradual progression from touch-down weight-bearing (<20% body weight [BW]), to partial weight-bearing (PWB) (50% BW), to weight bearing as tolerated (~80% BW), up to full weight-bearing (Hustedt et al., 2012). Even accelerated rehabilitation programs take eight weeks to return patients to full weight bearing (Ebert et al., 2012). Overloading can detrimentally affect healing time, the stability of the healing structure (Hambly et al., 2006), or cause plastic, brittle or fatigue failure of implant or operative sites (Hustedt et al., 2012). Conversely, adequate weight bearing encourages the healing process, for example by osteoblastic stimulation at fracture and fixation sites (Meadows, Bronk, Chao & Kelly, 1990). The teaching and accuracy of reproduction of PWBPs in clinic settings is typically assessed statically using bathroom scales (Hambly et al., 2006), however, studies in both injured and uninjured subjects have led to the conclusion that PWBP reproducibility is poor (Hustedt et al., 2012). Also the teaching and assessment of PWBP adherence using this static method may not be representative of the loads going through the limbs during gait (Hustedt et al., 2012; Malviya et al. 2005)

Previous research has focused on the accuracy of 20% weight-bearing in early rehabilitation (Dabke at al., 2004; Gray, Gray & McClanahan, 1998; Ruiz et al., 2014) . The reproduction accuracy of higher proportions (e.g. 50% and 80%) of body weight is less researched but also important for successful rehabilitation (Ebert et al., 2012), as the healing structure still requires some protection, but also sufficient stimulation (Hambly et al., 2006). While the objective of rehabilitation is to restore normal gait patterns, the patterns of muscle activation during Partial weight bearing (PWB) gait are very different to those during normal gait (Clark et al., 2004) and therefore PWB may be viewed as a novel motor task. It is likely that PWBPs using higher proportions of BW (e.g. 80% BW) will require patterns of movement and muscle activation that are more similar to pre-injury or pre-surgery gait than lower proportions of BW (e.g. 20%) (Clarke et al., 2004). If PWBP accuracy is related to motor task novelty this would suggest that 80% BW would be more accurately reproduced than 50% BW or 20% BW. Ebert et al. (2008) state a 5% weight bearing variation from target load is appropriate given the large variation in weight-bearing replication accuracy. However it is not known whether patients can replicate these prescribed loads, within this clinically acceptable boundary, potentially hindering tissue repair (Ebert et al., 2008). It is also important to determine whether the clinically used static instruction and monitoring methods are translating to PWBP accuracy during dynamic tasks such as gait (Hustedt et al., 2012).

The purpose of this study was therefore to identify the accuracy with which PWBP could be reproduced statically and dynamically, and which target load (20%, 50% or 80%) was most accurately reproduced at ten minutes after instruction. The clinically important load error of 5% variation from the given target load suggested by Ebert et al. (2008) was also considered in order to give a clinical context to the results.

METHOD

Participants

Thirty active uninjured males (mean ± SD: age 26 ± 4; height 1.77 ± 0.08 m; mass 77.1 ± 9.3 kg) consented to participate in the study. Participants were taught 3 PWBPs (20%, 50% and 80% BW) in a random order, and their ability to reproduce these using elbow crutch assisted 3 point gait was assessed. As healthy participants were used, the PWBP was attributed to their dominant limb. The order in which subject were allocated the PWBP was based on a Williams design (Williams, 1948) to allow calculation of, and correction for, first-order carry-over effects.

Procedures

In total the participants attended 3 data collection sessions on 3 separate days (figure 1). Session 1, as described in figure 1, lasted a little longer as participants mass was recorded, and used to calculate their individual target loads for the 3 PWBPs to be taught. They also had elbow crutches set at the correct height for them and were taught standard PWB 3 point gait technique. They were given 10 minutes to practice this using the length of the room, with verbal feedback from the researcher to correct technique if required. As can be seen from figure 1, the procedure following this was then the same for all 3 data collection sessions, with only the specific PWBP being taught differing between these. As part of these sessions participants were taught their PWBP, which they were allowed to practice this for 10 minutes, and they were then assessed on their ability to reproduce this both statically, using bathroom scales, and dynamically, using a force platform.

Participants were taught the PWBPs using the bathroom scales method described by Ebert et al. (2008),and for consistency all participants were bare-footed throughout. The participant stood with all of their weight on one (non-dominant, non-crutch assisted) leg on one set of scales. Then with both verbal feedback (from the researcher) and visual feedback (from the display on the scales) they placed weight through the other (dominant, crutch assisted) leg on an adjacent identical set of scales until the target load was achieved (Figure 2). Two subsequent practice attempts were allowed while the participant looked straight ahead and only received verbal feedback from the researcher. Participants were then given 10 minutes to practice their given PWBP with their elbow crutches using the length of the room. No feedback was given to participants by the researcher during this time.

After this 10 minutes practice period, PWBP accuracy was tested both statically, using the bathroom scales method without any feedback from the researcher, and dynamically, walking over a force platform during crutch assisted gait. Dynamic measures during crutch-assisted walking used a Kistler 9286BA portable force plate (Kistler Instrument Corporation, Novi, MI, USA) sampled at 2,000 Hz and surrounded by a 35 mm high flat wooden walkway (Figure 3). Force plate data were subsequently exported to Matlab 2012a (The Mathworks Inc., Natick, MA, USA) for analysis. Three static and three dynamic trials were performed.

Outcome Measures and Data Analysis

The vertical ground reaction force (vGRF) data were filtered with a zero-lag 4th order low pass Butterworth filter with a 40 Hz cut off. The peak vGRF values were extracted for each footfall.

Measurement of Mass, Target Load and Actual load reproduced in the static data collection were all converted to newtons (N). For the dynamic testing, the vertical ground reaction force (vGRF) data were filtered with a zero-lag 4th order low pass Butterworth filter with a 40 Hz cut off. The peak vGRF values were extracted for each footfall and expressed in newtons (N). The load data for both the static and dynamic trials were then converted to percentage body weight and the percentage load error from target load calculated. From the 3 trials taken statically and dynamically the highest load value was used in the analysis as this would be potentially the most damaging load to healing tissue.

The mean error percentage for each PWBP was calculated using data from all of the participants, and compared to the 5% acceptable deviation outlined by Ebert at al. (2008).

Statistical Analysis

ANOVAs were carried out separately for static and dynamic measures taken across the 3 PWBPs. All outcome measures were expressed as a percentage error from the target load. Target was a fixed factor, and participant was a random factor. First order carry-over and position effects were calculated as described by Williams (1948).

RESULTS

The error during the static trials was not significantly different from zero for any target level (% BW) (Figure 1) and target levels were not significantly different from each other (all $p>0.05$). For the dynamic measures of % BW error there was a significant effect for target. Post-hoc tests showed an inverse relationship between dynamic measures of error and target (i.e. 20% > 50% > 80% BW; $p<0.01$). Peak vGRF error for the 20% BW target was almost double the intended load (95% CI: 11.9%BW, 24.1%BW), and was above target for almost half the foot contact time (95% CI: 37.3%, 56.3%). At 50% BW, peak error was smaller (95% CI: 6.0%BW, 19.3%BW), with the vGRF above the target load for slightly less of foot contact time (95% CI: 27.1%, 45.0%). For 80% BW peak vGRF error and % of foot contact above target were not significantly different from zero(95% CI: -34.7%BW, -25.3%BW). No position or order effects were significant for any of the target loads, indicating no evidence that performance was affected by the training previously conducted (all $p>0.05$). However when considering the mean load error for each of the PWBPs all exceeded the 5% tolerance highlighted by Ebert et al. (2008) both for the static and dynamic measures (Figure 4). However in all cases the error was much greater for the dynamic than the static measures. These results show the that 80% PWBP had a lower error and was therefore easier to reproduce both statically and dynamically than 50% or 20%, with 20% being the least accurate.

DISCUSSION

The different measures of accuracy give a varying picture of how accurately the participants could reproduce each target load: the static measures indicate relatively good compliance at all targets, but the dynamic measures have better ecological validity, as they suggest what is actually happening during gait, and indicate poor compliance at 50% and 20% BW.

The poor agreement between the static and dynamic measures suggests that static tests involving bathroom scales may present a misleading picture of compliance with a particular weight-bearing protocol and may not provide clinicians with an accurate picture of load during PWB crutch assisted gait. All of the load error percentages for both static and dynamic measures across all PWBPs exceeded 5%. This could be considered concerning for the rehabilitation process for which it has been suggested that not adhering to these protocols within a 5% variation could potentially hinder tissue repair.

While the present study is the first to compare performance of three different target loads across a range of body weight proportions, a number of studies have shown poor compliance with lower target loads of around 20% BW (Dabke et al., 2004; Ebert et al., 2008: Grey, Grey & McClanahan, 1998; Ruiz et al., 2014). The errors reported here suggest that the outcome, from crutch-assisted gait, of weight-bearing limited to 20% or 50% BW is difficult to achieve even in healthy uninjured adults. Wulf and Shea (2002) describe a motor task as complex if it has several degrees of freedom, is ecologically valid and cannot be mastered in a single session. Crutch-assisted gait certainly has the features of a complex motor task: there are many degrees of freedom (indeed more than for normal gait), and the results reported here suggest that the skill cannot be mastered in a single session. While the training procedure used here was brief, it is comparable to the patient training given in clinical settings (Hambly et al., 2006), but it is clearly insufficient to achieve a reasonable accuracy in task performance. If adherence to PWBPs is essential to tissue healing and repair, improvements in the way patients are taught and monitored during these protocols would seem to be necessary. Audio feedback has been shown to improve accuracy of PWP performance (Hershko, Tauber & Carmeli, 2008). Further improvements may be possible with multi-modal feedback, which has been shown to be more effective than single mode feedback in rehabilitation (Seitz, Kocher & Uhl, 2014), and in motor learning generally (Sigrist et al., 2013). Finally, it should however be noted that there is a dearth of robust clinical evidence in support of improved outcomes following PWBPs (Hustedt et al., 2012), and some studies have even shown that successful outcomes are possible with patient-limited weight-bearing (Koval et al., 1998).

Limitations

A limitation of the study is that PWBPs are usually undertaken post-surgery or post-injury whereas the participants in the present study were healthy and active in order to achieve the randomization of target loads. It may be argued that healthy participants would achieve greater motor control than injured participants, thus the errors reported here may represent the best case. However, the magnitudes of the dynamic errors at 20% BW in the present study are comparable to those reported in previous studies in injured and patient populations. Comparison is somewhat difficult as many previous studies specified targets as absolute loads, e.g. 60lb (Grey, Grey & McClanahan, 1998), but the errors at 20% reported here are comparable to those for orthopaedic patients (Hershko, Tauber & Carmeli, 2008). It should also be remembered that, regardless of the target load specified, the external ground reaction force measured does not necessarily correspond to the load in any internal musculo-skeletal structure (Crowninsheild et al., 2004). Also the role of pain as a limiter to weight bearing in an injured population cannot be considered in this study.

CONCLUSION

In conclusion, it appears that the static method of PWBP instruction does not seem to translate accurately to dynamic motion during gait in uninjured participants, and could therefore affect adherence to medical instruction in the clinical setting. It is therefore important that clinicians are aware of the issues with reproducibility of these protocols and the potential deleterious effects on lower limb rehabilitation. The findings of this study would suggest that rehabilitation practitioners should be cautious when using bathroom scales to teach PWBPs as this may present them with a misleading picture of load during crutch assisted gait. In fact dynamic measures across all PWBPs exceeded the 5% variation that has been suggested could potentially hinder tissue repair and thus, improvements in the way patients are taught and monitored during these protocols would seem to be necessary.

Key Points:

1. Rehabilitation practitioners should be cautious when using bathroom scales to teach partial weight bearing protocols (PWBPs) for lower limb injuries.

2. Standard partial weight bearing instruction and monitoring using the bathroom scales method may present clinicians with a misleading picture of load during crutch assisted gait.

3. All results for both static and dynamic measures across all PWBPs exceeded the 5% variation that has been suggested could potentially hinder tissue repair.

4. If adherence to PWBPs is essential to tissue healing and repair, improvements in the way patients are taught and monitored during these protocols would seem to be necessary.

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Figures

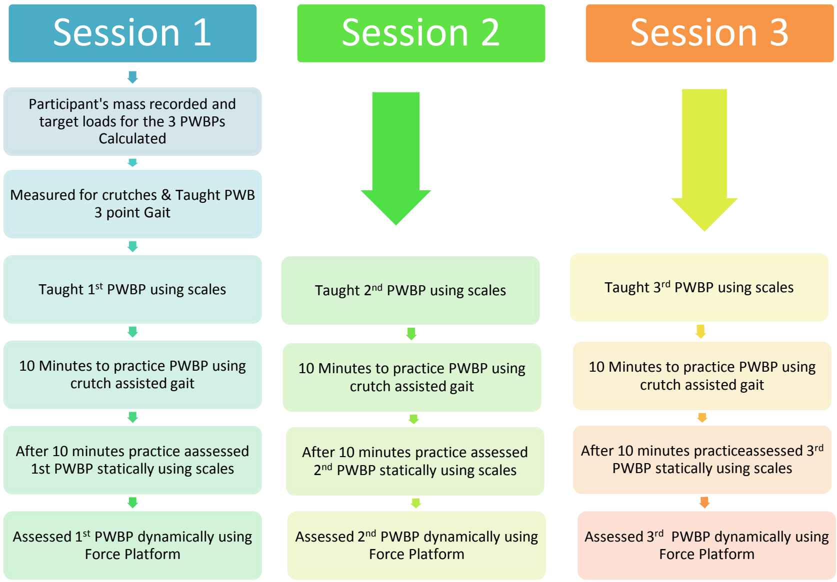

Figure 1: An outline of the data collection session procedures

Figure 2: Bathroom scales method of PWBP instruction

Figure 3: Dynamic assessment of PWBP using force platform.

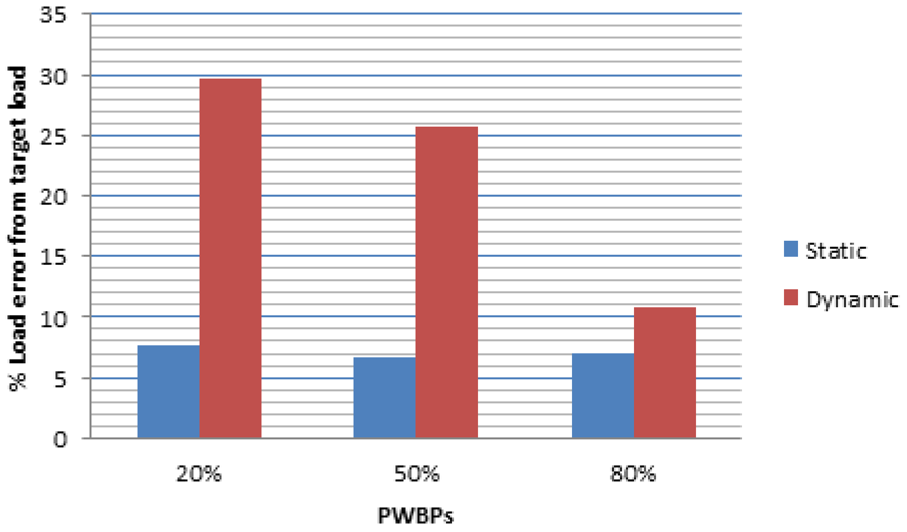

Figure 4. The mean % load error for Dynamic (using Peak vGRF) and Static Measures.