Original research

Does a more dynamic method of partial weight bearing instruction translate to more accurate reproduction of partial weight bearing protocols during gait?

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Abstract

Background: Partial weight bearing protocols are commonly incorporated into rehabilitation to enhance recovery. Patients are often prescribed protocols that refer to a percentage of their body weight, such as 20% weight bearing, that should be placed through the healing limb during activities such as walking (gait). In order to achieve these partial weight bearing protocols patients are usually provided with walking aids such as crutches. Accurate reproducibility of and compliance these protocols could be considered essential to the rehabilitation process, however poor reproducibility of partial weight bearing protocols during crutch assisted gait using a current method of instruction has been shown. **Aims:** The aim of this study was to determine whether a more dynamic method of partial weight bearing protocol instruction, was more accurately reproduced. **Methods:** In total, 16 participants were randomly allocated to one of two groups and were taught 20% partial weight bearing using two different methods of. A participant's ability to reproduce their target load using crutch assisted gait was assessed using a force plate. **Findings:** The mean error for the static method of instruction was significantly greater than the more dynamic method. **Conclusion:** As seen previously, the static method of instruction of partial weight bearing protocols, using bathroom scales, does not seem to translate accurately to dynamic motion; however, the more dynamic method assessed in this study appears to result in more accurate reproducibility.

Keywords

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

Introduction

Progressive partial weight bearing protocols are a common component of lower limb rehabilitation (Hershko et al, 2008). There is usually a gradual progression from touch-toe weight bearing (<20% body weight) up to full weight-bearing (Hustedt et al, 2012). Adherence to these prescribed protocols can affect the effectiveness of the healing and rehabilitation processes, as overloading tissues 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). Inadequate load bearing can be equally detrimental as appropriate weight bearing encourages the healing process, for example the stimulation of bone tissue regeneration at fracture and fixation sites (Meadows et al, 1990). If both under and overload of healing tissues can

have a detrimental effect on lower limb rehabilitation, effective instruction of, and subsequent adherence to, these partial weight bearing protocols is essential.

The teaching and accurate assessment of partial weight bearing protocols in a clinic setting is typically assessed statically using bathroom scales ([Hambly et al, 2006](#)); however, studies investigating both injured and uninjured participants have arrived at the conclusion that partial weight bearing protocol reproducibility is poor ([Hustedt et al, 2012](#); [Graham et al, 2016](#)), particularly when measured dynamically using force platforms. Dynamic measures have better ecological validity, as they suggest what is actually happening during gait, and can indicate poor compliance at 50% and 20% partial weight bearing protocols ([Graham et al, 2016](#)). The static method of partial weight bearing protocol instruction using bathroom scales does not seem to translate accurately to dynamic motion during gait, and could affect adherence to medical instructions given in a clinical setting ([Malviya et al, 2005](#); [Hustedt et al, 2012](#); [Graham et al, 2016](#)).

Several studies have shown poor compliance with low target loads such as 20% body weight (Gray et al, 1998; [Dabke et al, 2004](#); [Ebert et al, 2008](#); [Ruiz et al, 2014](#); [Graham et al, 2016](#)), with the mean peak vertical ground reaction force (vGRF) error for the 20% body weight target being almost double the intended load ([Graham et al, 2016](#)). Crutch-assisted gait has the features of a complex motor task, with lower partial weight bearing protocols requiring the most variation from movement patterns and muscle activation from pre-injury or pre-surgery gait (Clark et al, 2004). If partial weight bearing protocol accuracy is related to motor task novelty, this would explain why 20% body weight would be less accurately reproduced than 50% body weight or 80% body weight, as 20% is the most different from 'normal' gait. It could also be suggested that an instructional method that more closely represents the motor task of crutch assisted gait would enhance learning of the task and, therefore, compliance with partial weight bearing protocols.

[Ebert et al \(2008\)](#) state that a 5% weight bearing variation from target load is appropriate given the large variation in weight-bearing replication accuracy. Therefore, an instruction method needs to be developed for lower partial weight bearing protocols that will achieve patient adherence within this acceptable limit. However, consideration also needs to be given to the cost implications of this, as there are often limited resources in clinical environments. Equipment such as force platforms and wearable devices that are used to measure forces affecting a person during gait in a laboratory environment are usually both expensive and high tech. They need specific training for staff on the physical use and implementation of the equipment and associated computer software as well as understanding and interpretation of the data generated by these devices. It is unlikely in clinical environments struggling for funding that high tech adjuncts such as these can be justified in terms of equipment or staff training budgets. It would, therefore, be prudent to consider the progression and development of the current bathroom scales method as a feasible and affordable alternative to enhance instruction and adherence in lower limb rehabilitation.

The purpose of this study was to determine whether a more dynamic method of partial weight bearing protocol instruction using bathroom scales – that more closely represented the motor task of crutch assisted gait – would result in a more accurate reproducibility than the previously established bathroom scales method. The clinically important load error of 5% variation from the given target load suggested by [Ebert et al \(2008\)](#) was also taken into consideration in order to give a clear clinical context to the results.

It was hypothesised that participants would be able to more accurately reproduce their PWBP after a more dynamic method of PWB instruction than those taught using the traditional bathroom scales method of instruction. This was because the more dynamic method of weight bearing instruction was intended to more closely match the motor functions involved in crutch assisted PWB gait.

Method

Participants

In total, 16 active uninjured participants (10 males and 6 females) consented to participate in the study (mean $\pm$ SD: age 20 ± 2 ; height 1.67 ± 0.09 m; mass 69.3 ± 4.2 kg). Participants were volunteers from a student population. Participants were randomly allocated to one of two groups via random selection of their participant number. An independent assistant selected participants 'out of a hat' with the first 8 participants being allocated to Group 1 (the traditional method of PWB instruction) and the remaining 8 being allocated to more dynamic method of PWB instruction. Both groups were taught a 20% partial weight bearing protocol; however, the method of instruction varied between the groups. As healthy participants were used, the partial weight bearing protocol was attributed to their dominant limb.

Procedures

Participants attended one 30-minute data collection session. Their mass was recorded and used to calculate their individual target load for the 20% partial weight bearing protocol. Participants were also given elbow crutches set at the correct height for them and were taught standard partial weight bearing three-point gait technique. They were given 10 minutes to practice the crutch assisted gait using the length of the room, with verbal feedback from the researcher to correct technique if required.

Participants were then taught the 20% partial weight bearing protocol using one of two possible methods depending on their group allocation. Group 1 were taught using the traditional more static method of instruction and Group 2 were taught using a modified more dynamic version, that was designed to more closely replicate the action of gait.

Group 1 instruction

Those allocated to Group 1 were taught using the bathroom scales method described by [Ebert et al \(2008\)](#). All participants were bare-footed and instructed to stand with all of their weight on one (nondominant, 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 1](#)). Two subsequent practice attempts were allowed while the participant looked straight ahead and only received verbal feedback from the researcher to reach the required load.

Figure 1. Static method of PWBP instruction

Group 2 instruction

Participants allocated to Group 2 were taught a modified version of the bathroom scales method, which was designed to more closely replicate the 3 point gait method of crutch assisted PWB which usually used for PWBPs of 20%PWB during initial stages of rehabilitation. This test used one set of bathroom scales set within a walkway, so that they were level with the walking surface ([Figure 2](#)). Participants were instructed to stand with all of their weight on their nondominant (non-crutch assisted) leg in front of the scales. They then placed the crutches either side of the scales and stepped forward onto the scales, placing weight through their dominant (crutch-assisted) leg until the researcher informed them that the target load was achieved ([Figure 2](#)). They were then instructed to take the rest of their weight through the crutches and step through with their nondominant (non-crutch assisted) leg onto the walk way at the far side of the scales.

Figure 2. Dynamic method of PWB instruction

Following the instruction of the partial weight bearing protocol, participants were then given 10 minutes to practice their 20% partial weight bearing protocol 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-minute practice period, partial weight bearing protocol accuracy was tested dynamically using crutch-assisted gait over a Kistler force plate. The Kistler 9286BA portable force plate was sampled at 2000 Hz (Kistler Instrument Corporation, Novi, MI, USA). Participants were asked to walk over the force platform performing their 20% PWB protocol 3 times. Participants were instructed to ensure that crutches were placed on either side of the force platform and that the limb being used for the PWB was the one that made contact with it.

Data analysis

The peak vertical ground reaction force values were extracted for each of the three trials and expressed in newtons and the mean of the three trials was calculated. The load data were then converted to percentage body weight and the percentage load error from the target load was calculated. The partial weight bearing protocol error percentage was calculated using data from all of the participants, and subsequently compared to the 5% acceptable deviation outlined by Ebert et al (2008). A mean of the partial weight bearing protocol error percentage was also calculated for each of the groups. A *t*-test was performed to determine whether there was a statistically significant difference in the partial weight bearing protocol percentage error between the two methods of partial, with the target load as a fixed factor, and partial weight bearing protocol instruction method as a random factor.

Results

Statistical analysis demonstrated that there was a significant difference in the partial weight bearing protocol % error between the two groups ($p < 0.05$). When comparing the means of the groups, the error for the static method of instruction by group 1 was significantly greater than the more dynamic method of instruction used by group 2 (*Figure 3*).

The mean error for Group 1, using the static method of instruction was 15.47% (95% CI: 10.36%, 20.59%), which was almost double that of the Group 2, using the more dynamic method of instruction, at 8.24% (95% CI: 3.89%, 12.60%) (*Figure 4*). Also when considering individual

participants, none of the participants in group 1 fell within the 5% error tolerance described by [Ebert et al \(2008\)](#), whereas two of the eight participants in group 2 successfully achieved an error $\leq 5\%$ ([Table 1](#)). The peak vertical ground reaction force data showed the highest % partial weight bearing protocol error to be 25.45% for group 1 compared to 17.04% for group 2. The smallest error for group 1 was 7.06% compared to 2.37% for group 2. The results show that 20% partial weight bearing was more accurately reproduced than the dynamic method of partial weight bearing instruction.

Figure 3. Percentage weight bearing error stem and leaf plot

Figure 4. Graph representing the mean percentage partial weight bearing protocol error for the two methods of partial weight bearing instruction

Table 1. Table showing the load errors for all of the participants across the two groups

Group	Participant Number	Error from Target load (N)	% PWBP Error	Within 5% tolerance?	Group Mean
Group 1 (Static Method of PWB instruction)	1	9	11.25	No	15.47 (95% CI: 10.36%, 20.59%)
	3	12.6	16.36	No	
	4	14	25.45	No	
	5	9.2	12.43	No	
	8	16	22.86	No	
	10	12.4	15.90	No	
	13	6	7.06	No	
	15	10	12.50	No	
Group 2 (Dynamic Method of PWB instruction)	2	5.6	7.78	No	8.24 (95% CI: 3.89%, 12.60%)
	6	10	15.38	No	
	7	13.8	17.04	No	
	9	1.8	2.37	Yes	
	11	2.6	4.19	Yes	
	12	4.8	6.32	No	
	14	3.8	6.23	No	
	16	5	6.67	No	

Discussion

Several studies have shown poor compliance with partial weight bearing protocols with low target loads of around 20% body weight (Gray et al, 1998; Ebert et al, 2008; Ruiz et al, 2014; Graham et al, 2016). The errors reported in this study also suggest crutch-assisted gait, of weight-bearing limited to 20% body weight, is difficult to achieve. The mean percentage of partial weight bearing protocol error for both groups was greater than the 5% weight bearing variation from the target load that Ebert et al (2008) considered appropriate. Therefore, regardless of the instruction

method this is still difficult to achieve. Further research relating to the acceptable error to be tolerated for PWBPs could help better inform patient rehabilitation instructions. It is documented that both under and overloading of healing tissues can be detrimental to the healing process of tissues as part of the rehabilitation process. However if studies such as these suggest patient compliance is likely to be poor at reproducing PWBPs it is likely that the patient population is regularly under or overloading their tissues when compared to the prescribed PWBP. The acceptable amount of error that should be tolerated from PWBPs to allow for effective rehabilitation should be investigated further.

However, the measures reported here support the research hypothesis that the more dynamic method of instruction for partial weight bearing protocol using bathroom scales produces more accurately reproduced PWBPs. This would suggest that this more dynamic method of PWB instruction would lead to better adherence with PWBPs prescribed as part of the rehabilitation process.

[Wulf and Shea \(2002\)](#) describe a motor task as complex. By complex, these authors mean that if the task has several degrees of freedom, is ecologically valid, and cannot be achieved in a single session. Crutch-assisted PWB gait dose have the prescribed features of a complex motor task, as there are many degrees of freedom, and the results reported here suggest that the skill of accurate PWB gait cannot easily be mastered in a single session.

Although the instruction used here was only brief, it is comparable to patient training in a clinical setting [Hambly et al \(2006\)](#). To be effective, more time is required, or a more effective method of instruction needs to be developed. As the time available for training in the clinical setting is unlikely to increase, it is essential to develop more effective methods of partial weight bearing instruction that improve accurate adherence to partial weight bearing protocols and enhance rehabilitation. Of the instruction methods used here, the one that most closely replicated the required motor task was the most effective at achieving more repeatable partial weight bearing protocols. Although more effective, the majority of the participants exceeded the 5% acceptable deviation from their target load. Therefore, further development in this area would be beneficial to enhance the rehabilitation process.

Further improvement may be possible with enhanced feedback during the instruction of partial weight bearing protocols. Audio feedback was shown to improve accuracy of PWB performance (Hershko et al, 2008) and multimodal feedback has been shown to be more effective than single mode feedback in rehabilitation ([Seitz et al, 2014](#)), and in motor learning more generally ([Sigrist et al, 2013](#)).

Limitations

A clear limitation of the study is that the sample consisted of healthy uninjured participants, as partial weight bearing protocols are usually prescribed to patients following surgery or musculoskeletal injury. One school of thought would suggest that pain would be a limiter to weight bearing and protocols would be more easily reproduced by an injured population. Therefore, the role of pain as a limiter to weight bearing in an injured population cannot be considered in this study. The accuracy with which a patient population can reproduce these PWBP as part of their rehabilitation is a potential areas for further study. It could be argued that healthy participants would have a greater level of motor control and proprioception and thus errors reported using healthy participants could represent the best-case scenario. The magnitude of partial weight bearing protocol errors at 20% body weight in the present study are comparable to those reported in previous studies of injured and

patient populations (Hershko et al, 2008). It should 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 musculoskeletal structure (Crowninshield and Brand, 1981). However, as partial weight bearing protocols are commonly prescribed in clinical settings to enhance recovery, this is still an appropriate outcome measure in this instance.

Conclusions

As seen previously, the static method of instruction of partial weight bearing protocols, using bathroom scales, does not seem to translate accurately to dynamic motion, whereas the more dynamic method assessed in this study appears to result in more accurate reproducibility. Although this method seems to enhance adherence, the results for both static and dynamic measures still exceed the 5% variation that has been suggested which could potentially hinder tissue repair. Further investigation and development is required. Practitioners should be aware of the potential errors in reproducing these partial weight bearing protocols and the potential effect this could have on rehabilitation. These results suggest that practitioners should be cautious when using bathroom scales to teach partial weight bearing protocols. Practitioners should consider the most effective way to do this as the more dynamic method described here which more closely replicates the motor task of crutch assisted gait, appears to be more effective.

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None

Conflicts of Interest

None

Declaration

All procedures were approved by the ethics committee and performed in compliance with institutional guidelines.

Key Points

1. Rehabilitation practitioners should be cautious when using static methods of partial weight bearing instruction for lower limb injuries.
2. A more dynamic method of instruction that more closely replicates the motor pattern of crutch assisted gait would appear to result in more accurately reproduction of PWBPs.
3. Further investigation and development is still required into the most effective method of PWB instruction for lower limb rehabilitation.

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