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REVIEW

Current Advances in Training Orthopaedic Patients to Comply with Partial Weight-Bearing Instructions

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Partial weight-bearing instructions are commonly given to orthopaedic patients and are an important part of post-injury and/or post-operative care. However, the ability of patients to comply with these instructions is poorly defined. Training methods for instructing these patients vary widely among institutions. Traditional methods of training include verbal instruction and use of a bathroom scale. Recent technological advances have created biofeedback devices capable of offering feedback to partial weight-bearing patients. Biofeedback devices have shown great promise in training patients to better comply with partial weight-bearing instructions. This review examines the background and significance of partial weight bearing and offers insights into current advances in training methods for partial weight-bearing patients.

INTRODUCTION

Orthopaedic patients are often instructed on how much weight to bear through an injured or postoperative extremity. Common instructions are for touch-down weight bearing, partial weight bearing (often prescribed in number of pounds), or weight bearing as tolerated. While specific weight-bearing instructions are given to a majority of lower extremity orthopedic patients, it is often difficult for patients to comply with given instructions [1,2]. Reasons for patient non-compliance with partial weight-bearing instructions include the difficulty in judging pressure over the lower extremities [3] and the difficulty in adequate training methodologies to ensure patient compliance [1,2,4,5].

There have been a few publications about engineering devices that monitor

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weight bearing [6], but these have generally not gone to the point of clinical application. The current review will, therefore, focus on the clinical application of partial weight-bearing training methodologies by examining the efficacy of currently used training methodologies, identifying clinical factors associated with partial weight-bearing compliance in orthopaedic populations, and highlighting the clinical applications of newly developed, partial weight-bearing devices.

RATIONALE FOR RESTRICTING WEIGHT BEARING

Orthopaedic patients are given weight-bearing restrictions in a clinical balancing act between protecting the injury site or surgical construct and increasing bone growth at the fracture site. This is part of routine orthopaedic clinical practice [7].

Weight bearing is restricted based on the fear that excessive weight seen by an injured or operative site will lead to implant failure, therefore affecting the fracture stability and alignment [8]. Implant failure can occur when high loads are placed on the extremity causing deformation (plastic failure) or breakage (brittle failure) of the implant. However, the greatest risk of implant failure arises from repetitive loading above a tolerance point (fatigue failure) [9]. Therefore, as patients ambulate following surgery, partial weight-bearing instructions are given to limit the risk of fatigue failure of the surgical construct.

Conversely, the rationale for advancing weight bearing is that repetitive loads can stimulate osteoblastic activity in fracture patterns and fixation constructs in load-bearing extremities [10]. Therefore, the difficulty in ambulating an orthopaedic patient with an affected lower extremity is the dual desire to both protect the surgical construct by limiting weight while simultaneously stimulating bone growth by increasing weight bearing. Thus, a common recommendation for an affected extremity is for restricted weight bearing that is gradually liberalized as healing occurs.

Common instructions in partial weight bearing are for touch-down weight bearing, partial weight bearing, or weight bearing as tolerated. No common practice is employed to define these three instructions. However, at our institution, we employ specific poundage definitions of touch-down weight bearing defined as 25 pounds and partial weight bearing defined as 75 pounds [11]. Other researchers have used percentage of patient body weight, with a common distinction of touch-down weight bearing defined as 0 to 20 percent of body weight and partial weight bearing defined as 20 to 50 percent of body weight [12].

DIFFICULTY IN DEFINING THE CLINICAL USE OF PARTIAL WEIGHT BEARING

Two questions remain unanswered in weight-bearing research: 1) what type of weight-bearing limitations yield the best clinical outcomes and 2) how best can patients be trained to comply with weight-bearing instructions.

Researchers and clinicians alike have struggled to define the best weight-bearing strategies to maximize clinical outcomes. To date, there are no large, standardized clinical trials of weight-bearing regimes for specific clinical conditions. This is most likely due to the fact that surgical techniques and implants in orthopaedics are always evolving, which secondarily changes the rehabilitation period following surgery. Therefore, even if large, standardized clinical weight-bearing data were available, they would quickly become outdated as surgical practices and new surgical devices evolve.

Furthermore, weight-bearing restrictions are also partially a reflection of surgeons choosing a conservative approach to weight bearing with respect to construct failure. Even if a construct may not fail under full weight bearing in a patient, most surgeons will hesitate to advance weight based on the remote chance of failure. However, it is important to remember that for the patient, a weight-bearing limitation requires constant vigilance and limits activity, therefore af-

Table 1. Summary of studies evaluating the effectiveness of currently used training methodologies for partial weight-bearing orthopaedic patients.

Authors	Outcome
Tactile Feedback	
Gray et al. [16]	Feedback method 20 to 30 percent off actual weight, suggesting it is a poor method of weight-bearing training.
Scales	
Dabke et al. [4]	Neither six healthy volunteers nor 23 post-op lower limb patients were able to reproduce weight bearing while walking with crutches following training with a bathroom scale.
Malviya et al. [18]	Training with bathroom scales leads to retention of static weight bearing at 0 mins and 60 mins in 12 weight-bearing subjects.
Warren et al. [5]	Bathroom scales had little effect on training patients. What little effect that was present rapidly decreased over ensuing days.
Biofeedback	
Chow et al. [19]	Audio Biofeedback better than conventional bathroom scale for six transtibial amputation patients.
Hershko et al. [12]	Biofeedback training shown to be superior to physiotherapy in 33 post-operative lower extremity orthopaedic patients.
Hustedt et al. [11]	Biofeedback shown to be superior to both bathroom scales and verbal instructions in 20 partial weight-bearing subjects using crutches.
Hustedt et al. [21]	Biofeedback shown to be effective across age groups in 50 weight-bearing subjects aged 20 to 78 years.
Hustedt et al. [34]	Biofeedback training is maintained over a 24-hour period in 10 weight-bearing subjects.
Isakov et al. [32]	Biofeedback shown to be effective in use of partial weight-bearing patients as compared to standard physiotherapy in 42 post-op orthopaedic patients.
Pataky et al. [15]	Biofeedback works in 11 patients after total hip arthroplasty, but patients forget 30 minutes later, as well as at one and two day follow-up.
Vasarhelyi et al. [2]	Neither 23 patients nor 11 healthy volunteers were able to comply with weight-bearing limitation at 3-day follow-up following biofeedback training.

fecting post-operative course and patient satisfaction. Thus, improved understanding of post-operative weight bearing and standardization in outcomes studies could greatly impact both patient and surgeon satisfaction in post-operative partial weight-bearing care.

Some researchers have argued that weight-bearing limitations are not even necessary in certain clinical scenarios as patients will self-limit their weight bearing because of pain in the post-operative period [13,14]. Koval et al. showed such a case of self-limited weight bearing in intertrochanteric and femoral neck fracture patients, as did Aranzulla et al. in tibial fracture patients [13,14]. This, and similar research, has led to more liberal weight-bearing strategies at certain institutions; however, it is still common practice to restrict weight in most clinical scenarios.

Adding to the difficulty of defining partial weight bearing in the clinical setting is the overwhelming data that patients have difficulty in complying with given weight-bearing limitations [1,2,4,5,15]. Researchers have argued that while patients may have a sense of weight in lifting objects, they do not share that same weight sense of weight borne over an extremity [3]. Therefore, adequate training needs to take place prior to expectation that patients will comply with weight-bearing instructions.

Thus, in order to better determine the proper ambulation of patients following lower extremity injury, researchers need to better define weight-bearing classifications and find ways to train patients. As the second issue of training patients is more readily addressable, the remainder of this review will examine ways to train patients to comply with weight-bearing instructions.

PARTIAL WEIGHT-BEARING TRAINING

Training patients to comply with weight-bearing instructions is commonly done by physical therapists. Physical therapists utilize clinical techniques as well as devices such as scales, biofeedback systems, and force plates to train patients to comply with partial weight-bearing instructions. A summary of common procedures and their effectiveness in clinical weight bearing follows. For summaries of studies included in the review, see Table 1.

Tactile Feedback

Physical therapists often use a clinical tactile feedback training method in which the amount of weight on the patient's extremity is estimated by placing the physical therapist's hand or foot underneath the foot of the patient. Gray et al. evaluated this technique and found it to be "subjective guesswork at best" [16]. Hurkmans et al. showed that on average, even well-trained physical therapists were up to 20 to 30 percent off from the target weight when attempting to train patients with the clinical examination technique [17]. All studies suggest that this technique does not work to adequately train patients [1], yet it continues to be one of the most widely used techniques due to its easy application [6].

Scales

The scale technique utilizes scales to offer quantitative feedback to the patient. The patient can load and unload on the scale to a given weight restriction, thereby "learning" what it feels like to place a specific poundage on a lower extremity.

A significant limitation in using this method is that the static activity of standing on the scale does not adequately represent the dynamic activity of walking. Thus, researchers have shown that this technique works when patients are asked to stand only [18,19], yet the technique fails when patients are asked to walk after using bathroom scales [4,5]. Chow et al. suggested that one possible method with the use of scales for weight training is to place a row of eight bathroom scales on the floor between parallel bars [20]. Research at our institution found that the use of a bathroom scale led to significant excess in weight bearing when used as a primary training device [21].

Overall, the difficulty in transferring the static measurement of scales to the dynamic activity in walking has limited the use of scales in partial weight-bearing training.

Biofeedback Devices

To surmount the difficulty of providing dynamic feedback, biofeedback devices have been developed that can give constant feedback to patients as they are walking. Biofeedback devices have been around for many years [22-27], yet the early devices had trouble with accuracy and portability. Bergmann et al. and Engel et al. showed that they were successful in instrumenting walking aids that showed promise in estimating patient weight bearing [28,29]; however, these techniques have not become commercially available.

New technological advances have provided commercially available biofeedback systems that are fully portable. The most notable systems are the Pedar (Novelgmbh, Munich, Germany), F-Scan (Tekscan Inc., Boston, MA, USA), and SmartStep (Andante Medical Devices, Beer Sheva, Israel) weight-monitoring systems (see Table 2). Many studies have been undertaken to com-

Table 2. Commercially available biofeedback devices.

Product	Benefits	Approximate price ($US)
F-Scan (Tekscan Inc., Boston, MA, USA)	Real-time plantar pressures, excellent for orthotic evals	$15,000
Pedar Force Monitoring System (Novelgmbh, Munich, Germany)	Sensitive pressure monitoring system excellent for research	$19,000
SmartStep (Andante Medical Devices, Beer Sheva, Israel)	Real-time patient feedback and simplified operating system tailored for clinical application	$7,000

pare and validate the commercially available biofeedback systems [30-32]. A comparative study between the Pedar and F-Scan system showed the superiority of the Pedar system in both validity and reliability [33]. The SmartStep system also has been shown to be accurate and effective in training patients to comply with partial weight-bearing instructions [11,21,32].

Biofeedback systems have been shown to work better than conventional bathroom scales in training patients to comply with weight-bearing limitations [19]. Hershko et al. showed that in comparison to normal physiotherapy, patients instructed with a biofeedback device complied significantly more with their weight-bearing limitations [12]. Research at our institution found that training with a biofeedback device was superior to training with a bathroom scale or training with verbal instructions [11,21].

However, the excitement of the clinical use of these devices has been dampened by the question of the long-term retention of biofeedback training. Most biofeedback devices are currently expensive and designed for use in a clinical setting. Therefore, patients are given training sessions and then expected to retain the initial training while ambulating in an outpatient setting. Research on the long-term retention of biofeedback training is inconclusive. Pataky et al. and Vasarhelyi et al. found that while patients initially complied with limitations, patients could not retain the training over periods of time greater than 24 hours [2,15]. However, research at our institution suggests that patients can retain weight-bearing instructions over a 24-hour period [34]. Further research will help to better define the use of biofeedback devices.

Overall, biofeedback devices offer significant improvements over bathroom scales and clinical examinations. Areas for future research include the application of biofeedback in long-term compliance of biofeedback training as well as take home biofeedback devices that can be worn by patients throughout ambulation.

Force Plates

Force plates are expensive, highly accurate measuring devices that are the most important measuring devices in biomechanics laboratories. Force plates can accurately measure external forces during walking [35] and have been shown to be more accurate in training patients to comply with partial weight-bearing instructions than bathroom scales or a therapist's hand [16]. However, due to their expense and their immobility, force plates do not have wide application in ambulating patients in the clinical setting.

Yet, force plates are often used to validate other weight-monitoring systems. Two systems that are highly regarded are the AMTI (Advanced Mechanical Technology, Inc., Watertown, MA, USA) and the Kistler (Kistler Instrumente AG Winterthur, Switzerland) force plates [6]. These systems have been shown to have high accuracy and are considered by some to be the gold standard in the field [30,31].

FUTURE APPLICATIONS IN WEIGHT-BEARING RESEARCH

Biofeedback devices have been shown to be superior to both bathroom scales and clinical instructions. Yet, their full potential has yet to be fully elucidated. Future research efforts should focus on the long-term retention of biofeedback training and its application in varying clinical scenarios in orthopaedics. Additionally, as in all areas of orthopaedics, there continues to be a lack of level I evidence showing the clinical benefits of different weight-bearing strategies.

Future research should attempt to both define the best way to use biofeedback devices as well as examine the clinical outcomes of weight-bearing strategies. With carefully designed studies, this area of research has the potential to greatly improve care for a large majority of lower extremity, weight-bearing orthopaedic patients.

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