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ORIGINAL RESEARCH ARTICLE

Weight Bearing on the Affected Lower Limb in Residents of a Geriatric Rehabilitation Hospital

ABSTRACT

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Objectives: The purpose of the study was to determine whether and to what extent the treatment goal of enhancement of weight bearing on an affected lower limb is achieved in the gait rehabilitation of patients with poststroke hemiparesis, postprosthetic fitting due to unilateral transtibial amputation, or postunilateral hip or knee arthroplasty.

Design: Nonrandomized prepost study. Subjects were 26 residents of a geriatric rehabilitation hospital in the initial stage of gait rehabilitation after poststroke hemiparesis ($n = 9$), unilateral total hip or knee joint replacement ($n = 11$), or unilateral transtibial amputation with a fitted prosthesis ($n = 6$). Weight bearing on the hindfoot and forefoot of the affected limb was measured by using the SmartStep system version 2.2.0, at least once a week, both before and immediately after a gait-training session. Measurements were performed with the patients using their assistive devices.

Results: In the patients with hemiparesis, there was no significant difference found between the initial pretraining maximal weight bearing on the afflicted limb (39% and 50% of body weight on the hindfoot and forefoot, respectively) and that at discharge (47% and 50% of body weight, respectively). In patients after hip or knee arthroplasty and in those who underwent prosthetic fitting, there was a substantial increase found in the loading of the forefoot, but not of the hindfoot, from the initial evaluation to the time of discharge (from 43% to 54% of body weight, $P = 0.05$, in the arthroplasty group, and from 49.6% to 69.5%, $P = 0.09$, in the prosthetic group).

Conclusions: For elderly individuals belonging to the studied diagnostic groups, the goal of enhancing normal weight bearing on the afflicted limb during the time course of 2–3 wks might be unrealistic.

Key Words: Gait, Rehabilitation, Stroke, Amputation, Arthroplasty

Weight bearing is a frequently used term in physical therapy to characterize the extent to which a lower limb can bear body weight during standing and during the stance phase of walking. Weight bearing in human subjects is dynamic and entails ongoing changes in force and its distribution over the foot.[1–6] In healthy individuals, weight bearing on either lower limb during regular standing and walking is similar. Yet, in pathologic conditions affecting one limb, the ability to load the affected lower limb in the same way as the unaffected one is frequently compromised, making stance and gait asymmetrical.

Conditions such as hemiparesis, unilateral hip or knee joint replacement, or unilateral amputation reduce the ability to load the limb during stance and gait. Therefore, the enhancement of weight-bearing capacity on the affected lower limb is one of the major rehabilitation targets of physical therapy.[7–10] There is a dual purpose for the intentional loading of the affected limb: to improve the loading function of the afflicted side and to relieve the contralateral limb from overloading.

Unfortunately, quantification of the load bearing on the lower limbs is hampered by a lack of user-friendly and easily accessible measurement devices in the clinic. Recognition of that shortage has led to the development of a number of measurement devices, although their clinical availability remains low.[11] In addition, the correlation between subjective judgments of ground reaction forces and measurements made through force plate is unsatisfactory.[12] As a result, the treating clinician lacks objective and valid information regarding the pattern, timing, and amount of weight loaded on each of the lower limbs during stance and gait.

Recently, a novel measurement assembly, the SmartStep system (Andante Medical Devices Ltd), became commercially available. This system enables the continuous monitoring of the weight that is vertically loaded over one lower limb during stance and gait, both indoors and outdoors. In this preliminary study, we applied the system to systematically gauge the amount and pattern of weight bearing on the affected lower limb in a group of elderly patients residing in a rehabilitation hospital.

The purpose of the study was to determine whether and to what extent weight bearing on the affected lower limb is enhanced during the course of postacute rehabilitation in three groups of patients: (1) patients with poststroke hemiparesis; (2) patients with total replacement of either one hip or knee joint; and (3) patients who have recently been fitted with a prosthesis due to transtibial amputation.

METHODS

Subjects

Subjects were 26 patients of a geriatric rehabilitation hospital after poststroke hemiparesis, unilateral total hip or knee joint replacement due to degenerative joint disorder, or unilateral transtibial amputation ancillary to diabetes mellitus. The participants constituted a convenience sample composed of subjects who met the inclusion criteria and were willing to participate. Subjects were eligible to volunteer for participation if they were in the initial stages of gait rehabilitation. They had to demonstrate a satisfactory cognitive state (Mini-Mental State Examination score of 22 points or more)[13] and be without wounds on either lower limb. The study was approved by the local institutional review board, and all participants signed an informed consent form.

Major relevant demographic characteristics and information on the assistive device used for ambulation are provided in Tables 1 and 2, respectively. It should be noted that the majority of the subjects ambulated with a walker. A one- or four-point cane was used on the sound body side by only three participants on admission to the study and by four participants on discharge.

TABLE 1 Major demographic characteristics of the participants

	Hemiparesis	Hip or Knee Joint Replacement	Lower Limb Prosthesis after Transtibial Amputation
n	9	11 (5 post-THR, 6 post-TKR)	6
Gender	5 men, 4 women	4 men, 7 women	5 men, 1 woman
Age, mean (range), yrs	68.5 (52–85)	64 (60–79)	64.5 (46–82)
Side of afflicted extremity	2-Lt, 7-Rt	3-Lt, 8-Rt	4-Rt, 2-Lt
Time from insult/surgery to first test, mean (range)	34.8 (18–51) days	14.1 (11–18) days	3.1 (2.5–5) months

THR, total hip replacement; TKR, total knee joint replacement; Lt, left; Rt, right.

TABLE 2 Number and distribution of users of assistive devices upon admission and discharge

	Hemiparesis	Hip or Knee Joint Replacement	Post-Transtibial Amputation
Admission			
Walker	5	10	5
Four-point cane	1	1	
One-point cane			1
Supervision, no assistive device	2		
Independent	1		
Discharge			
Walker	3	10	5
Four-point cane	3	1	
One-point cane			
Supervision, no assistive device	2		
Independent	1		1

Instruments

Weight bearing on the affected limb was measured by the SmartStep system version 2.2.0 (Andante Medical Devices Ltd http://www.andante.co.il). The SmartStep is a portable gait analysis and biofeedback system, which has been described in detail in previous publications.[14,15] Briefly, the device consists of a pneumatic insole that is placed in the shoe of the monitored limb and is connected to two pressure sensors which measure and transmit the vertical force under the hindfoot and forefoot at a frequency of 40 Hz. The data are received and analyzed by a control unit, which is worn around the ankle. By applying Bluetooth technology, the data are then transmitted to a computer-running dedicated software. For each step, the software provides the peak vertical force over the entire foot (body weight bearing) and over the heel and the forefoot. Temporal parameters, including the number of strides on which the analysis is based, as well as the velocity, cadence, and timing of the stance and swing phase of each step, are also calculated. Notably, the force exerted on the insole is measured in two areas of the foot, the hindfoot and the forefoot, and can be reported and graphically displayed in absolute values (kg or pounds) or in values normalized to body weight (%). This function of separately gauging the forces underneath the hindfoot and the forefoot is a unique feature of the system that does not exist in comparable measurement systems.

Procedure

The same clinical investigator (a physical therapist) recruited patients in the three diagnostic categories and performed all of the gait measurements using the SmartStep system. Each of the participants received physical therapy for 45 min 5 days a week. Treatments were composed mainly of exercises to improve functional range of motion and muscle strength of the affected lower limb, and stance and gait exercises. Weight transfer over the involved limb was practiced during transfer activities, in stance and gait activities between the parallel bars and during guided walking sessions.

After attaching the SmartStep insole and approving the connection to a dedicated laptop computer via the Bluetooth wireless system, the subjects were tested twice while walking at self-selected speed with their walking aid along a 10-m straight course. Subjects were supervised as they walked, and manual contact was applied rarely and only briefly if needed for safety reasons. Gait measurements were taken both before (pre) and immediately after (post) the walking exercises in the same physical therapy session. The monitoring of each patient's gait was conducted at least once a week, starting from the first gait training session and continuing until discharge from the hospital. Because most subjects were tested while walking with an assistive device, full weight bearing during single stance was not expected. However, it was anticipated that enhancement of weight bearing on the affected limb would be evident after the exercise therapy sessions.

Data Analysis

The raw data of the vertical force applied on the SmartStep insoles during testing were stored in the computer and analyzed offline. Data analysis was composed of three stages: (1) Analysis of the gait data was performed using the dedicated software of the SmartStep system. For that purpose, measurements of the peak force underneath the heel (hindfoot) and the forefoot were extracted from 14 to 20 steps, whereas the steps made during turning were discarded. These data were further normalized to body weight and then averaged. The mean percentage of stance duration was also calculated by the same software. (2) The derived data for each subject were entered into an Excel chart along with demographic and clinical data. (3) Descriptive and inferential statistical analysis was applied using SPSS version 14 software.

Because of the abnormal distribution and the small sample size of each of the three groups, nonparametric statistics were used. Thus, the Wilcoxon's signed-rank test was applied to compare mean peak amplitudes between the "pre" and "post" measurements related to a single intervention, as well as between the "post" measurement of one treatment session and the "pre" measurement of the subsequent treatment session to determine between-sessions change. Overall change from the first "pre" measurement to the last "post" measurement was also subjected to statistical analysis.

RESULTS

Patients with Hemiparesis

Of the nine patients with hemiparesis, only three could walk without an assistive device at both admission to and discharge from the study (Table 2). Most subjects were hospitalized for not more than 3 wks from the initiation of gait exercises, and accordingly there was a progressive reduction in the number of patients tested in successive weeks because of discharge from the hospital. Thus, all nine subjects were tested in two successive sessions; six were tested three times; three were tested four times; and one patient was tested five times.

Analyses of changes in peak vertical force on either the hindfoot or the forefoot within sessions and between sessions yielded nonsignificant results. In other words, weight bearing on either the heel or the forefoot in the hemiparetic group was not found to be significantly enhanced by a single treatment session or during the course of successive sessions. Similarly, no significant change in stance duration on the affected limb was registered during the course of the study. Figure 1 displays the mean peak vertical forces on the forefoot and the heel of the affected lower limb at the first examination (at the beginning of gait training) and the last examination (before discharge). The figure shows that despite the nonsignificant results, the subjects increased their weight bearing on the hindfoot from 39% to 47% of body weight, whereas the forefoot was loaded with approximately 50%, both at the beginning and at the end of testing.

Patients after Hip or Knee Joint Replacement

Of the 11 patients belonging to this group, only one patient walked without an assistive device, whereas the other 10 patients used a walker at both admission to and discharge from the study (Table 2). All 11 patients participated in two different gait measurement sessions, but only two of them were still hospitalized in the third week and took part in a third session. Thus, the great majority of individuals after joint replacement were discharged from rehabilitation within 2 wks from the beginning of gait training, with 10 of 11 using a walker for ambulation. Changes within each session were not found to be statistically significant in this group. However, there was an increase of 12% in body weight that was loaded on the forefoot (from 43% before the first treatment session to 54% after the last treatment session), which was determined to be a significant change ($P = 0.053$). Conversely, the increase in weight bearing on the hindfoot and the change in stance duration on the affected limb were not found to be significant. These descriptive data are provided in Figure 2.

Patients with BK Prosthesis

All six individuals belonging to this group participated in two different gait training sessions, with one session conducted per week. Of the six patients, five used a walker and one ambulated with a four-point cane at both admission to and discharge from the study (Table 2). An increase (ap-

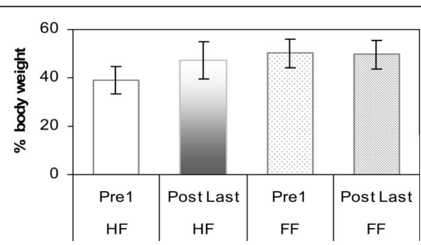

FIGURE 1 *Subjects with hemiparesis: Mean normalized peak vertical force loaded on the HF and on the FF of the affected limb before the first (pre-1) and after the last (post-last) gait training session during the rehabilitation period. HF, hindfoot; FF, forefoot.*

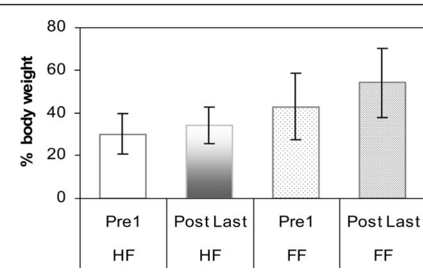

FIGURE 2 *Patients posthip or knee arthroplasty: Mean normalized peak vertical force loaded on the HF and on the FF of the affected limb before the first (pre-1) and after the last (postlast) gait training session during the rehabilitation period. HF, hindfoot; FF, forefoot.*

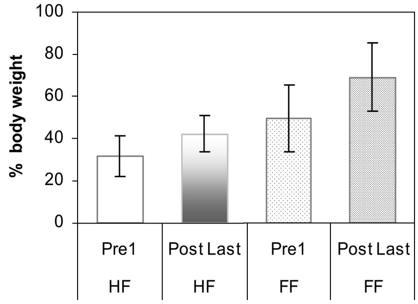

FIGURE 3 *Patients with prosthesis after unilateral transtibial amputation: Mean normalized peak vertical force loaded on the HF and on the FF of the affected limb before the first (pre-1) and after the last (postlast) gait training session during the rehabilitation period. HF, hindfoot; FF, forefoot.*

proaching significance) between the first and the last measurements was noted in the load put on the forefoot ($P = 0.093$) but not on the hindfoot. Figure 3 depicts the data pertaining to changes in the loading on the heel and the forefoot in this group of subjects.

DISCUSSION

These findings indicate that the treatment aim of improving load transfer onto the affected limb was not successfully met. More precisely, in the course of gait rehabilitation, the loading of the hindfoot (heel) on the affected limb was not enhanced in any of the three groups. The noted dysfunction of the hindfoot points to a deficit in the weight acceptance phase of walking, which did not show improvement through gait training during the rehabilitation period in any of the three groups.

Regarding the loading of the forefoot, the fact that 18 of the 26 patients were using a walker at discharge (in the arthroplasty and amputation groups, all patients except one) alludes to a forward weight shift induced by the forward location of the walker.

Nevertheless, the peak forces under the hindfoot and forefoot were substantially lower than normal and upon discharge did not exceed 47% and 69% of body weight, respectively. It should be noted that in the gait of healthy individuals, comparable forces exceed 100% of body weight.

As mentioned, the diminished capacity to load the affected limb in the three monitored groups was compensated by the use of walking aids and, most probably, by overloading of the contralateral limb. It has been demonstrated that walkers (which were used by most of our subjects), as compared with canes, are more effective in increasing stability and facilitate reduction of the ground reaction force of an impaired lower limb.[14]

Because of the lack of comparable studies, these observations cannot be judged against those of others. The emerging question raised by our results is whether the enhancement of normal weight bearing on an affected lower limb during the time period of active rehabilitation is a realistic goal. For the current participants, the majority of whom did not stay in rehabilitation for >2 wks from the start of gait training, the answer seems to be negative.

The recent substantial decrease observed in length of stay for postacute rehabilitation in the Western world,[15–18] may, at least partially, account for the apparent limitations of rehabilitation in achieving significant improvement in weight-bearing capacity. The effort to reduce the length of stay in rehabilitation is reinforced by the establishment of minimal functional, rather than physical, treatment aims.[19] As a result, the positive effects of rehabilitation[20–22] are compromised by the achievement of functional indoor ambulation, which is considered satisfactory for patients' discharge into the community. Given that the length of stay in rehabilitation is determined mainly by the ability to ambulate indoors and that achieving a change in gait pattern and feet loading through rehabilitative treatment in patients belonging to one of the studied groups is a lengthy and slow process,[23–28] it would seem that significant improvement in weight-bearing capacity is not achievable during postacute rehabilitation.

These conclusions call into question the traditional emphasis on weight transfer and loading of the affected limb during postacute rehabilitation for patients in each of the three diagnostic categories under study.

Discussion regarding the proper length of stay in the rehabilitation of elderly individuals goes beyond the context of this study. However, these findings elucidate one potential adverse consequence of short-term functional rehabilitation. Moreover, they raise questions regarding the optimal physical therapy treatment goals for these patients during postacute rehabilitation. Because the enhancement of a normal pattern of weight bearing on the affected limb might not be achieved during postacute rehabilitation, it would seem that community services should assume a more active role in the rehabilitation of weight-bearing capacity in elderly individuals. It must be emphasized that this nonrandomized study is preliminary and has limited generalizability. With the introduction of user-friendly and objective force and motion measurement tools into the clinic, randomized clinical trials in clinical and community environments may soon be applied to further validate the achievement of physical therapy goals during rehabilitation.

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