NORMAL PERCENTAGE BODY-WEIGHT/WEIGHT-BEARING VALUES AND GAIT CHARACTERISTICS IN ACTIVITIES OF DAILY LIVING: AN ORIGINAL RESEARCH STUDY ©

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INTRODUCTION

The achievement of normal and bilaterally symmetrical weight-bearing ability is an important goal in planning and executing rehabilitation protocols following trauma and neurological conditions that affect the lower limb [1,2,3]. Due to current technical limitations, accurate and objective percentage body weight/weight-bearing (PBW/WB) values and gait characteristics in basic functional activities of daily living (FADL) have eluded research investigation. The restoration of unilateral weight-bearing asymmetries has up to the present time relied principally on visual assessment and instructive cues, patient self-observation and training in front of a full-length mirror and standing on a bathroom scale in order to feel the desired weight bearing to be loaded during gait [5,8,9] . These are frequently inaccurate and represent unscientific rehabilitation outcome measures. Current technology includes amongst others the balance plate system (Neurocom™) and the force plate platform (AMTI™)[10]. These produce only static weight-bearing values and therefore cannot provide measurements for basic FADL such as walking, stair climbing and jogging.

AIM

To determine normal PBW/WB values and weight-bearing distribution in five common FADL – walking, ascending stairs, descending stairs, treadmill jogging at a constant preset speed and jogging on a hard surface.

LITERATURE REVIEW

The authors searched the following computerized databases: MEDLINE (1966-May 2009), CINAHL (1982 - May 2009) and EMBASE (1982– May 2009) and the PEDro database. A subject-specific search was based on the combinations of "percentage body-weight values" and "weight-bearing ". Other than in standing [4], no literature was available related to PBW values and weight-bearing distribution of basic functional activities of daily living (FADL).

METHODOLOGY

For the purposes of the study, the authors used a new, innovative computerized air-insole auditory biofeedback system (Smartstep™) to measure weight-bearing in the hind and fore-foot during locomotion and to analyze gait pattern changes (Fig. 1).**

Fig 1. The computerized air-insole auditory biofeedback system (SmartStep™)

The Smartstep™ pneumatic insole measures key gait parameters during ambulation.The data is received and analyzed by the miniature portable microprocessor, which is worn around the ankle. This is then transmitted to a computer running the Smartstep™ software, which also maintains patient medical records and functions as an assessment of gait analysis including weight-bearing distribution (Fig. 2), stance/swing phase (Fig.3) and cadence values. The unit further contains a biofeedback training application for rehabilitation. The product has FDA 510(k) clearance granted and CE & ISO approvals in Q2 2005. Numerous reliability and accuracy tests have been carried out comparing the SmartStep™ to the AMTI force platform, with a statistically significant predictor of force plate measurements ($R2=0,9067$, $p=0,004$). When comparing the Smartstep™ with a gait mattress utilizing measurements of regression analysis instance, the time interval results for the stance/ swing/cycle phases were highly significant between the two systems ($R2=0,996/0.995/0,997$ respectively). In a randomized control study, the Smartstep™ has proved to be an effective, accurate gait training and evaluation tool that encourages body weight on the affected limb and improves patient's performance [6,7].

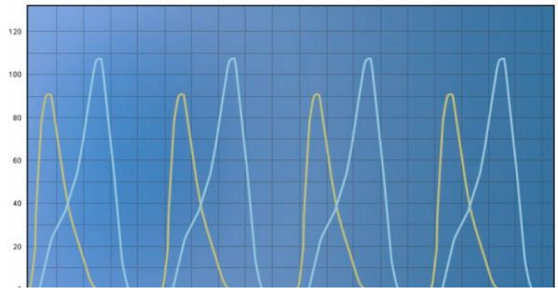

Fig.2: Typical SmartStep™normal gait analysis reading In walking.

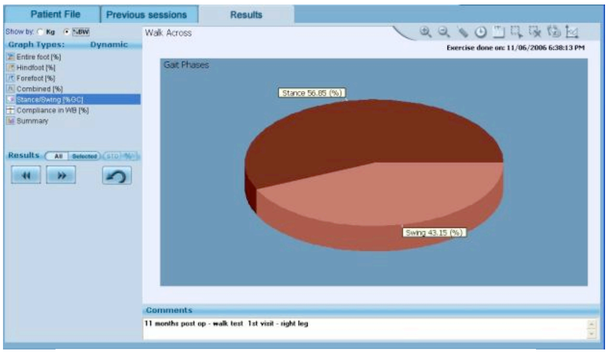

Fig.3. Typical SmartStep™ stance/swing phase comparison

40 normal subjects (Tab.1) were admitted into the study which was conducted in the Lerner Sports Center, Hebrew University of Jerusalem. All subjects were randomly recruited from within the Center. Exclusion criteria included current pain, previous surgery or a history of osteoarthritis or any other related joint disease in the hip, knee or ankle region. The test was explained to each subject, and all were required to sign the Helsinki consent form prior to participation. There were no further ethical considerations in this study. The physical testing conditions were identical for all subjects tested. Prior to each test, one Smartstep™ portable microprocessor control unit was fitted around each lower leg and the relevant data was recorded. The subjects were instructed to carry out five activities:

1. Walk at their normal, comfortable pace over a 16 meter distance.
2. Ascend one flight of 10 stairs (H = 16cm) at their normal, comfortable pace.
3. Descend one flight of 10 stairs (H = 16cm) at their normal, comfortable pace.
4. Jog at a preset speed of 8.5 km/hr over a ten second period on a treadmill (Technogym™ "run excite 700").
5. Jog on a hard surface at their normal, comfortable pace for a ten second period.

Due to the current technological limitations of the Smartstep™ system, weight-bearing results cannot be detected for more than about 130kg. As a result, only individuals whose weight did not exceed 65-70 kg, were tested in the jogging tests. As the values gained are not the actual weight, but rather the PBW/WB values, the normal PBW/WB results for a heavier population should be very similar.

Ave. Age (yrs)	Ave. weight (kg)	Gender	Dominant leg
34 (19-72) SD=13.63	72.95(53-115) SD=15.80	M= 27 F= 13	R= 34 L = 6

Table 1. Study group characteristics (n=40)

RESULTS

As there was no statistical difference between left and right legs for any of the results (p<0.05), it was thus decided to pool the results for both legs. There was no statistical difference between the genders in any of the results obtained. The final results (n=80) are summarized in table 2.

	Walking		Ascending stairs		Descending Stairs		Treadmill Jogging (8.5 km/hr)		Ground Jogging	
		SD		SD		SD		SD		SD
Entire foot (%)	115.35	14.43	107.50	15.59	176.74	26.63	136.46	16.49	215.02	33.8
Heel foot (%)	81.47	13.83	40.89	16.78	88.30	21.39	34.30	15.52	103.89	26.05
Fore foot (%)	111.00	15.45	103.57	17.36	148.73	23.84	110.85	20.61	181.21	37.01
Swing phase (%)	37.62	2.10	36.24	2.15	58.90	6.03	36.47	2.61	64.26	3.85
Stance phase (%)	62.38	2.10	63.76	2.15	41.10	6.03	63.53	2.61	35.74	3.85
Cadence (steps/min)	105.20	15.78	100.59	16.30	157.64	42.94	109.54	19.86	156.59	13.49
Cycle time (mins)	01:15	00:08	01:19	00:12	01:15	00:08	01:18	00:12	0.81	0.05

Table 2. Group PBW/WB values (n=80)

DISCUSSION

In all five FADL tested, the entire foot PBW value was greater than 100%. This is as result of both the push-off force exerted by the fore-foot and the foot-force impact on the ground. This is most pronounced in treadmill jogging, where at the speed tested, the entire foot PBW was 61% more than in walking. In walking, the hind- forefoot PBW ratio was 1:1.3 respectively, in ascending stairs 1:2.5, descending stairs 1: 3.4 and treadmill jogging (8.5 km/hr), 1:1.7 respectively. The percentage time for the swing and stance phases was not significantly different for walking and stairs, but 23% greater in the swing phase during jogging than the former, with a resulting 22% decrease in the stance phase.

CONCLUSIONS

In this original research study, PBW/WB value results for a normal population have now been established in five FADL. Clinicians in all fields of rehabilitation that involve correcting weight-bearing deficits may now benefit in having a table of normative values in these activities. This forms the basis of comparisons when planning and executing rehabilitation protocols involving the improvement of weight-bearing deficits due to lower limb pathology or neurological conditions affecting the lower limbs. One further aim of the current study up will be to subgroup the population tested by age. This will be achieved when sufficient numbers become available. It may be of interest to see whether there is a change in the hind - forefoot PBW ratio as well as swing/stance phase percentage ratios in the different age sub-groups. The values obtained in this study were related to a specific stair height, and treadmill jogging speed conditions. These would tend to change somewhat if these parameters were changed. Normative values for these five FADL may serve as part of the list of discharge criteria in orthopedic rehabilitation, where weight-bearing has been affected as well as return to sporting activities where normal weight-bearing is critical for optimum function.

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