The use of a new biofeedback insole weight-bearing measuring device in determining weight-bearing deficits following Anterior Cruciate Ligament Reconstruction

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Background: There are no short-term studies quantifying weight-bearing deficits following Anterior Cruciate Ligament Reconstruction (ACLR), nor whether differences exist between various surgical procedures and replacement graft choices in the acute- phase (0-3 weeks) post surgery.

Hypothesis: Weight-bearing is affected during gait in the acute-phase (0-3 weeks) following ACLR. There exist different weight-bearing deficits between various surgical procedures and replacement graft choices in the acute-phase (0-3 weeks) following ACLR.

Study Design: Case series; Level of evidence, 4.

Methods: A new, innovative computerized air-insole auditory biofeedback system was utilized to measure weight-bearing and gait characteristics in the acute post-surgical stage (0-3 weeks) of 16 patients who had undergone ACLR. The entire group was sub-grouped into those patients who underwent a hamstrings graft reconstruction, those who underwent an allograft reconstruction, and finally those who had a hamstring graft reconstruction combined with a medial meniscus suture.

Results: The average entire-foot, hind-foot and fore-foot percentage body-weight/weight-bearing (PBW/WB) values of the operated group were all statistically significantly lower than the normal group ($p<0.01$), with the hind-foot values exhibiting the most pronounced difference. The cycle time (secs) as well as the cadence time (steps/min) were also both statistically significantly lower than the normal group ($p<0.01$). Although the allograft group scored far better on all PBW/WB values, the smaller number of subjects tested did not allow for valid statistical analysis.

Conclusions: Clinicians involved in post-ACLR rehabilitation should place more emphasis on encouraging hind- foot weight-bearing as early on as possible following ACLR. Initial results may suggest the choice of the allograft over the other graft types vis-à-vis post-surgical pain and functional weight-bearing ability in the short-term.

Key Terms: anterior cruciate ligament · weight-bearing deficits · reconstruction surgery · acute – phase

Weight-bearing deficits following Anterior Cruciate Ligament reconstruction

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INTRODUCTION

The primary goal of Anterior Cruciate Ligament Reconstruction (ACLR) should be to improve knee stability, thereby ensuring a fast, safe return to normal functional and sporting activity. This aim should be goal-based and not time–based[3]. ACLR results in changes in lower extremity joint kinetics as well as in the normal gait pattern[14]. These changes include abnormal lower leg movement patterns, a stiffening strategy of the knee and reduced knee range of movement. [6, 21, 22, 2, 3, 13, 14].
Asymmetric gait patterns persist up to 1 year after surgical reconstruction and are more pronounced during stair ascent and descent than in level walking[7]. These results indicate that clinicians should include specific interventions targeted at improving knee function during stair use in order to restore normal function after ACLR[4]. It may take up to a year to achieve more normalized gait biomechanics in these patients[25, 8]. Early normal gait restoration has shown not only to be safe, but important[1] to rapidly regain normal muscle function[5] and to significantly lower post surgical complications, such as knee stiffness [23, 24]. As a result, it is accepted that early full weight-bearing should be a primary rehabilitative goal from almost immediately post ACL surgery[20, 23, 18]. In order to enhance weight-bearing deficits following ACLR, it is firstly required to ascertain the magnitude of these deficits.

AIMS

1. **To determine to what extent weight-bearing is affected during gait in the acute-phase (0- 3 wks) following ACLR.**
2. **To determine whether there exist different weight-bearing deficits and distribution patterns between different replacement graft choices in the acute-phase (0- 3 weeks) following ACLR.**

LITERATURE REVIEW

The author searched the following computerized databases: MEDLINE (1966-December 2008), CINAHL (1982 - December 2007), EMBASE (1982 – December 2008), the Cochrane Musculoskeletal Injuries Group's specialized register, and the PEDro database to December 2008. Subject-specific search was based on the combinations of "ACL reconstruction" and "weight-bearing deficits". Many abstracts were retrieved relating to ACLR, but only one[3] related specifically to changes in weight-bearing following ACLR. They found differences from the norm on an average of 1.5 months after ACL injury and up to 3 months following surgical reconstruction. Their measurements were done on a static force platform and did not reflect weight-bearing changes in functional walking. There were however no studies quantifying different weight-bearing deficits in the short-term (0-3weeks) following ACLR Two authors, [19, 16] both reported that seven years after ACL reconstruction, the subjective and objective outcomes were similar after using the central-third bone-patellar-bone autograft and triple/quadruple semitendonosus autograft. Good outcomes in both the bone-patellar tendon-bone and quadruple-strand semitendinosus/gracilis groups were found two years following surgery[17]. It was concluded that six-year outcomes were very satisfactory irrespective of graft source[12]. There were however no studies quantifying differences that exist between the various surgical procedures and replacement graft choices in the acute- phase (0- 3 weeks).

METHODOLOGY

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

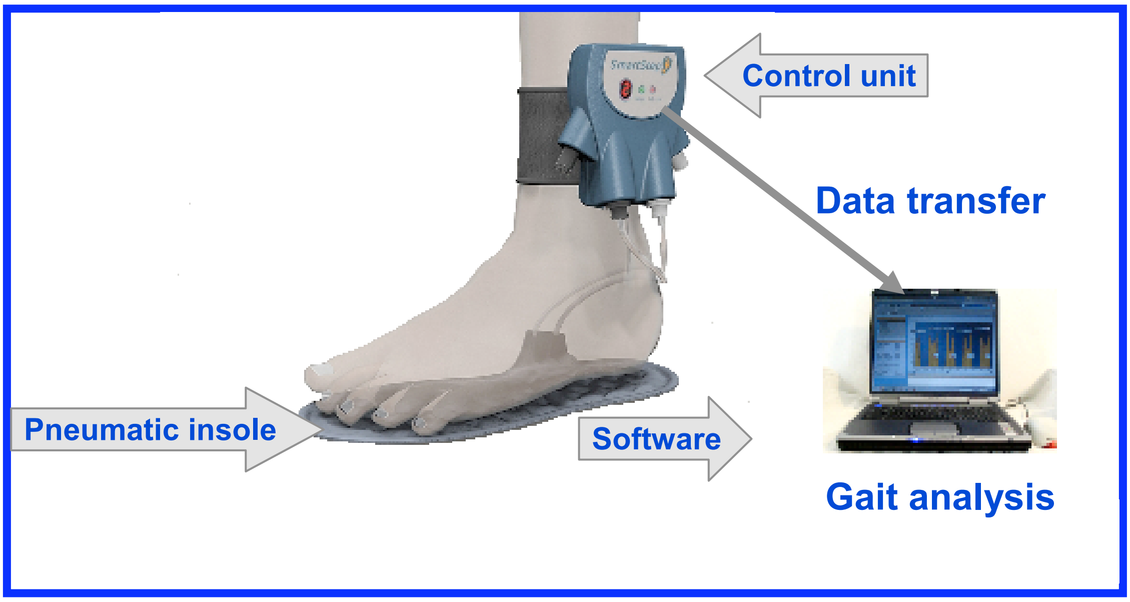


Fig 1. The computerized air-insole auditory biofeedback system (SmartStep™)

The SmartStep™ pneumatic insole measured key gait parameters during ambulation in the sagittal plane. The data was received and analyzed by the miniature portable microprocessor, which was worn around the ankle. The data was then transmitted to a computer running the SmartStep™ software. This software also maintained patient medical records and functioned as an assessment of gait analysis, including weight-bearing distribution (Fig. 2), stance/swing phase and cadence values. In a previously published randomized control study, the SmartStep™ has proved to be an effective, accurate gait training and evaluation tool that enhances weight-bearing on the affected limb and improves patient's weight-bearing performance[10].

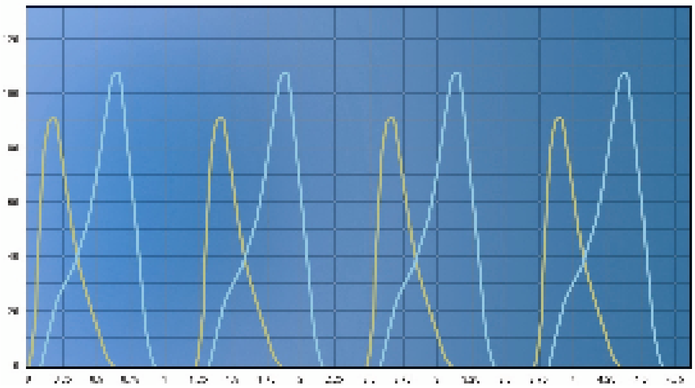


Fig. 2. Typical normal SmartStep™ gait analysis reading

In this study, the weight-bearing values and gait characteristics in the acute post-surgical stage (0-3 weeks) of 16 subjects who had undergone ACLR were analyzed (Tab. 1). The study was conducted in the Lerner Sports Center, Hebrew University of Jerusalem. The subjects were tested by the author on their first appearance at the author's clinic. There were no ethical considerations in this study and all participants were required to sign a consent form prior to participation in the study. The physical testing conditions were identical for all subjects tested. They were instructed to walk at their normal pace over a 16 meter distance while the portable microprocessor recorded the data collected. The entire study group was sub-grouped into those patients who underwent only a hamstrings graft reconstruction (n=9), those who underwent an allograft reconstruction (n=2), and finally those who had a hamstring graft reconstruction combined with a medial meniscus suture (n=5).

In order to obtain a set of comparative normal percentage bodyweight/weight-bearing (PBW/WB) values, the author and colleagues have conducted a similar study using the Smartstep™ system. 80 tests were carried out on normal subjects. Exclusion criteria included a previous history of lower limb surgery, pain in any part of the lower limb during activities of daily living and a leg length discrepancy of more than one centimeter. The normative values and group characteristics are found in Tab. 2.

	Stats	Age	Weight	Days tested post-surgery	Entire Foot WB%	Hind Foot WB%	Fore Foot WB%	Stance %	Swing%	Cycle	Cadence
Allograft	Average	26.00	73.00	5.50	81.00	46.50	80.50	58.50	41.50	0:01:55	75.56
	Stdev	1.41	24.04	4.95	7.07	6.36	7.78	0.71	0.71	0:00:34	17.47
Quad Ham	Average	32.13	76.63	6.63	68.00	32.63	58.88	58.12	41.88	0:01:53	85.91
	Stdev	12.49	13.39	4.90	29.13	27.67	33.52	6.66	6.66	0:00:27	31.70
Quad Ham MM	Average	36.60	71.4	7.6	50.40	16.30	38.80	71.4	28.60	0:02:09	60.63
	Stdev	12.28	16.24	7.73	34.95	19.92	32.34	19.28	19.28	0:00:32	25.48
Total Group	Average	32.80	74.4	6.8	63.87	29.03	55.07	62.6	37.40	0:01:58	76.10
	Stdev	11.55	14.58	5.60	29.89	24.66	32.56	13.04	13.04	0:00:28	29.16

Table 1: Entire study group PBW/WB values (n=16)

Age (Yrs)	Weight (Kg)	Entire foot WB %	Hind foot WB %	Fore Foot WB %	Stance phase %	Swing Phase %	Cycle time (secs)	Cadence (steps/min)	Dominant leg
34 SD=13.63	72.95 SD=15.80	115.35 SD=14.43	**82.33** **SD=12.89**	**110.92** **SD =15.65**	62.38 SD=2.10	37.62 SD=2.10	01:15 SD=00:08	105.20 SD= 15.78	R = 34 L = 6

Table 2: Normal group average PBW/WB values (n=80)

STATISTICAL METHODS

In order to compare the parameters measured in the study group (Table 1) to the group of healthy subjects tested (Table 2), the 1-sample t-test was applied. Due to the small sample size (of the allograft group in particular), the non-parametric Kruskal-Wallis test was employed in order to compare the three different surgical procedures. The tests were two-tailed and the p value of statistical significance was 5% or less.

RESULTS

The baseline characteristics of the subjects indicated that all subgroups were well balanced regarding their demographic and clinical variables, and there were no statistical differences in the age or weight between the three groups tested ($p<0.05$). There were marked statistical differences in most of the results for the average PBW/WB values between the operated groups (Table. 1) and the normal group (Table .2). The average entire-foot, hind-foot and fore-foot PBW/WB values of the operated group (Tab.1) were all statistically significantly lower than the normal group ($p<0.05$). The most marked difference being that the hind-foot PBW/WB value was 29.03% in the operated group versus 82.33% in the normal group. This was clearly evident from the typical weight-bearing pattern graph result in the operated group (Fig. 3), where the heel strike (first yellow curve) was reduced as opposed to the forefoot. This differed from the typically normal pattern (Fig. 2), where the heel- strike curve was closer to the fore-foot curve, expressing less of a PBW/WB difference. Neither the

stance nor the swing-phase percentage values of the entire group were statistically different compared to the norm. In the combined hamstrings graft/medial meniscus repair group, there was a large percentage difference in the percentage time spent in both the stance and swing phases as compared to the norm($p<0.05$). The stance phase was 71.4% as opposed to 62.38% in the normal group and the swing phase was 28.6% as opposed to 37.62%. Due to the small sample size however, there was no statistical difference detected.

When analyzing the differences between all the groups (Graph 1), the values of the allograft group most closely resembled those of the norm (even though they were tested sooner post-surgery), whereas the combined hamstrings graft/medial meniscus repair group had the poorest values. Once again, due to the small sample size however, there was no statistical difference detected.

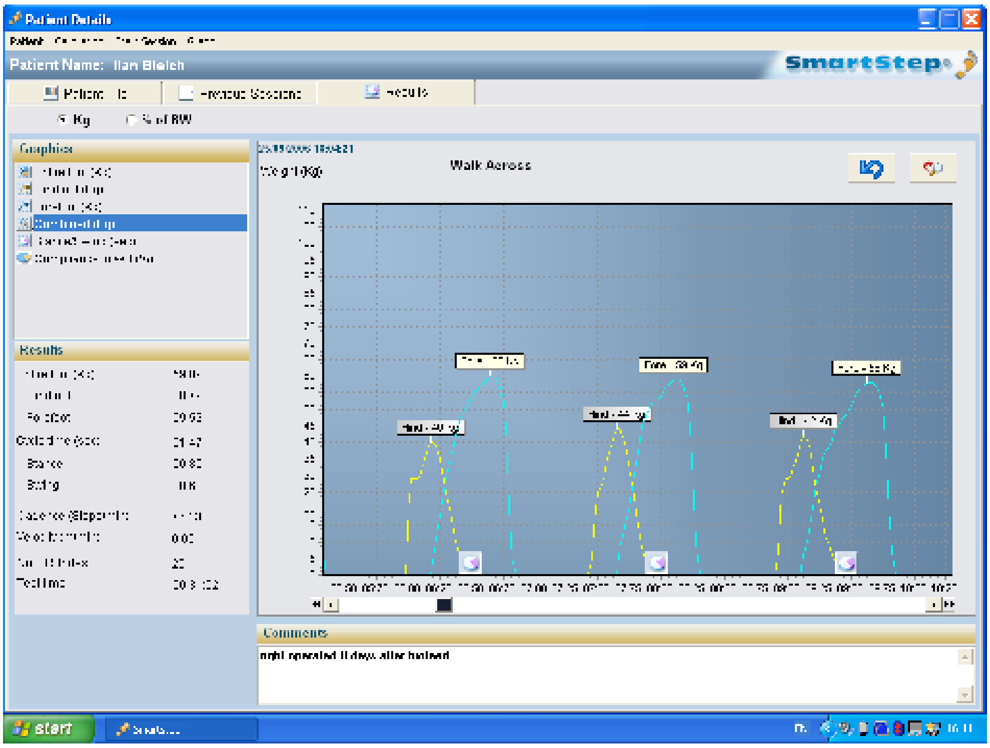
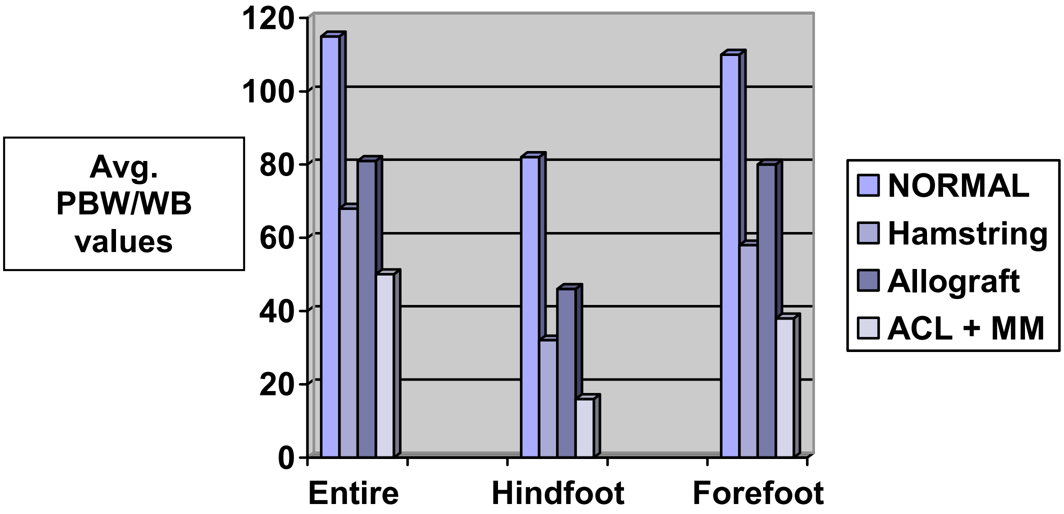


Fig. 3. The typical weight-bearing pattern common to all operated groups



Graph 1. Comparison of surgical techniques

The reduced entire-foot, hind-foot and fore-foot PBW/WB values in all the groups were probably due to the typical flexed-knee gait pattern and reluctance to fully weight-bear following most knee surgical procedures. The local knee discomfort caused changes in the normal heel-toe weight-bearing pattern and resulted in a more fore-foot-type weight-bearing pattern. In the acute post-surgical period, there existed more discomfort in the combined hamstrings graft/medial meniscus repair group. This may have explained the increase in the percentage time in the stance phase, with the corresponding decrease in the swing phase. This perhaps concurred with the slower cadence noted on the affected limb. This trend was however not noted in the other surgical groups, probably because after a few days post-surgery, their pain level had decreased to a great extent. When the results of all four groups were reviewed, it was apparent that the allograft group scored the best on all PBW/WB values, most likely as a result of no hamstring tendon interference and local surgical incision. This resulted in less post-surgical pain and functional limitation. There were only two patients in this group and so no definite conclusions were drawn.

CONCLUSIONS

This is the first research study that has attempted to accurately evaluate and compare the PBW/WB values following three different types of ACLR. Although the study was not large enough to perform meaningful subgroup analyses, trends may be elucidated. As a result of the data gathered, clinicians involved in post-ACLR rehabilitation should place more emphasis on encouraging hind-foot weight-bearing as early on as possible following ACLR. This is integrally connected with the ipsi-lateral knee and hip dynamics. Even though the allograft group only consisted of two subjects, their results were far superior to the others. These initial results may indicate the choice of the allograft over the other graft types, both in terms of post-surgical pain and functional weight-bearing ability in the short-term. The long-term differences have yet to be investigated. The SmartStep™ system provided an accurate assessment in its application as a weight-bearing measuring tool. Its' biofeedback utility has been successfully utilized to encourage weight-bearing[11.] The accurate quantitative assessment of gait analysis and weight-bearing distribution could possibly be added to the existing battery of tests prior to athletes returning to sport activities following sports injury and surgical procedures [6]. This is an on-going study, and the results gained so far would have more statistical strength and significance if the study numbers were increased.

FOOTNOTES :

No potential conflict of interest declared.

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