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Technical note

Standing pressure distribution for normal and below-knee amputee children

J. R. ENGSBERG, T. L. ALLINGER and J. A. HARDER*

Human Performance Laboratory, Faculty of Physical Education, University of Calgary
**Alberta Children's Hospital, Calgary*

Abstract

Below-knee (BK) amputee children have a different morphology from normal children and amputees may thus have atypical limb loading during standing. The purpose of this investigation was to examine differences in standing ground-shoe pressure distribution between BK and normal children. A pressure plate was used to measure the ground-shoe weight distribution of three BK children and ten normal children during standing. Results indicated that the weight distribution between prosthetic and non-prosthetic limbs of BK children was not significantly different from the feet of normal children. The anterior-posterior weight distribution for the prosthetic and non-prosthetic feet was significantly different from that of the normal children. Further quantification of weight distribution and analysis of more subjects is necessary to determine the benefits, detriments, or irrelevance of these results.

Introduction

Significant periods of time are spent standing during day-to-day activity. This is neither a fatiguing task nor a potentially injurious task for children with two intact functional lower limbs. However, unilateral lower limb amputees have been forced to adapt to a new artificial morphology that may produce bone and joint abnormalities as an adult (Borgmann 1960; Burke et al. 1987; Hungerford & Cockin 1975; Radin et al. 1986; Radin et al. 1987).

The purpose of this investigation was to examine differences in standing ground-shoe pressure distribution between BK and normal children.

All correspondence to be addressed to Dr. J. R. Engsberg, Human Performance Laboratory, Faculty of Physical Education, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada T2N 1N4.

Methods

Three unilateral BK amputee children and ten normal children volunteered as subjects for this study. These children ranged in age from 7 to 9 years. Each BK had a SACH foot as part of his/her prosthesis.

An EMED pressure system (cell areas 0.5 cm^2) was used to sample the ground-shoe pressure distribution at 20Hz for 1.55 sec, yielding 31 samples for each trial. The EMED pressure plate had a relative error of six percent. Three trials were carried out per subject. Each subject wore his/her own shoes and was told to "stand normally" within the boundaries of the pressure plate (19.6 cm by 33.6 cm).

The mean pressure of each cell was calculated from the 31 samples per trial. This mean pressure distribution trial was divided into areas for the right and left foot, and for a given foot, heel and forefoot areas. From the mean pressures, the total weight in each of the four areas was calculated. These weights for the BKs and normals were compared using one-way analysis of variance ($p<0.05$).

Results and discussion

Pressure plots

A typical pressure distribution plot for a normal subject is displayed in Figure 1. The vertical scale represents the amount of pressure recorded in a given cell. Pressures for this subject appear to be distributed evenly over both feet and between forefoot and heel areas. Figure 2 shows the mean pressure distribution plot for one BK subject trial. The pressures under the non-prosthetic heel were higher than

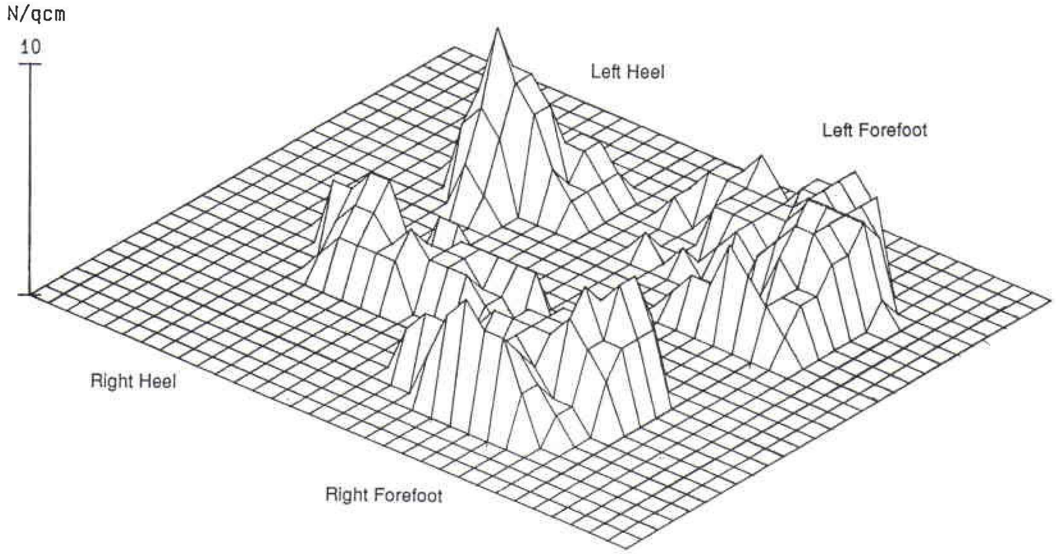

Fig. 1. Typical ground-shoe pressure plot for a normal child standing.

under the forefoot. Data for the prosthetic foot indicate all of the pressure was applied by the forefoot with no pressure being applied by any other part of the foot.

Weight distribution between feet

Ratios of the right and left foot area forces divided by the whole body weight (foot-body weight ratio) are presented in Figure 3. A foot-body weight ratio value greater than 50 percent for a given foot would indicate more weight was placed on that foot than on its counterpart.

Significantly more weight was placed on one foot for each normal and each BK subject.

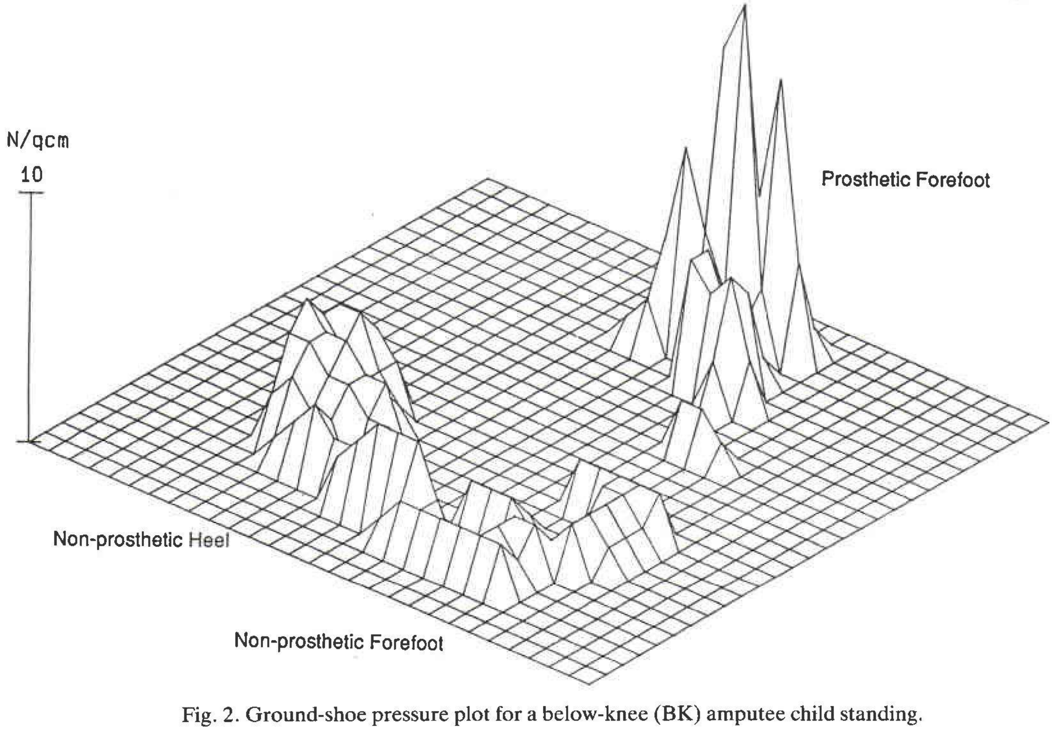

Fig. 2. Ground-shoe pressure plot for a below-knee (BK) amputee child standing.

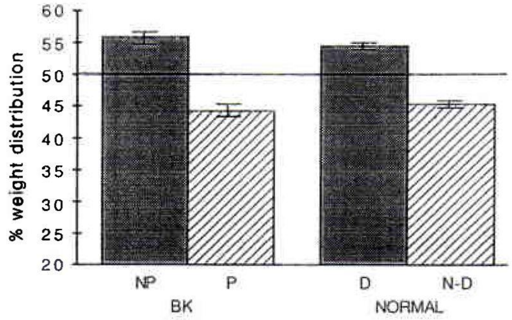

Fig. 3. Foot-body weight ratio for standing, placed on the dominant (D) and non-dominant (ND) foot for three BK (9 trials) and 10 normal (30 trials) children. The BK non-prosthetic (NP) foot is dominant and the prosthetic (P) foot is non-dominant. "I" bars are ± one standard error.

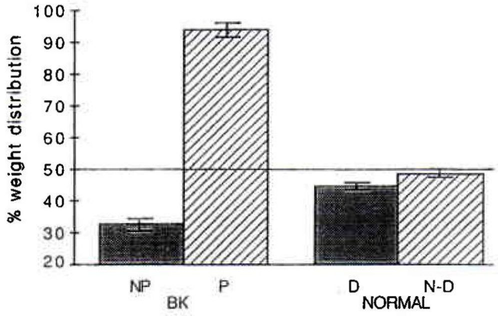

Fig. 4. Forefoot-whole foot weight ratio for standing, placed on the dominant (D) and non-dominant (ND) foot for three BK (9 trials) and 10 normal (30 trials) children. The BK non-prosthetic (NP) foot is dominant and the prosthetic (P) foot is non-dominant. "I" bars are ± one standard error.

Thus, based on the asymmetrical weight distribution between the feet of each subject (mean of three trials), a dominant and a non-dominant foot was declared (i.e., the foot with the larger values was classified as dominant). This grouping was found to be more descriptive than other possibilities. For example, if the normal children's right and left feet were combined in one group, there was a significant difference between the normals and both the prosthetic and non-prosthetic foot-body weight ratios of the BKs.

A comparison of the foot-body weight ratio between the BKs non-prosthetic limb (dominant leg) [55.8±4.9] and the normals dominant limb [54.6±0.95] produced no significant differences. There also was no significant difference between the BKs prosthetic (non-dominant) limb [44.2±4.9] and the normals non-dominant limb [45.4±0.95]. Therefore, the BKs weight distribution between feet was similar to the normal children.

The results of the present investigation differ slightly from the objectives listed in a prosthetic manual (New York University Medical Center, 1980) which proposes that the foot-body weight ratio should be 50 percent on each limb. Considering that no method of quantification of these loads is currently being utilized by the Calgary area prosthetists, their method of aligning the foot, with respect to the weight distribution between feet, appears reasonable.

Anterior-posterior weight distribution

Forefoot force divided by the whole foot force for a given foot, or a forefoot-whole foot ratio (similar to anterior-posterior weight distribution) is illustrated in Figure 4. A forefoot-whole foot ratio value of 50 percent would describe a case in which weight was evenly distributed between heel and forefoot areas, and a value greater than 50 percent would indicate that more weight was placed on the forefoot than on the heel.

Results for the normal subjects indicated they stood with significantly more weight on the heel area than on the forefoot area. There was no significant difference between the dominant and non-dominant foot for these subjects.

BK subjects placed significantly more weight on the non-prosthetic heel than normals placed on either of their feet. This result may be due to the high loads on the prosthetic forefoot of the BKs and could be analogous to results presented by Kirby et al. (1987). They stated that a normal person placing one foot forward (shifting that foot's centre of pressure (COP) forward) caused the COP on the other foot to shift posteriorly.

Results for the BKs are different from that stated in the prosthetics manual (1980). The present study found a forefoot-whole foot ratio in percentage of 33.0±3.6 (mean ±1 Std. Error) on the non-prosthetic foot and 94.2±3.7 on the prosthetic limb. The manual stated that 66.7 percent of the weight on the prosthesis should be on the forefoot. The pressure plate utilized in this investigation could be an aid to the prosthetists during prosthetic alignment to quantify the patients weight distribution during standing.

Interpretation

The differing results between normals and BKs, between the non-prosthetic and prosthetic feet of BKs, and between the forefoot and heel of the BKs raises two important issues. The first is that the asymmetrical loading patterns of the BK during standing may be a logical result of the morphological differences between the prosthetic and non-prosthetic limb. The differing morphology also produces intrafoot loading which is different from normal children. The second issue is that these asymmetrical loading patterns may be placing abnormally high loads on the joints of the lower extremities of these BK children. In either case, it is currently not known whether this type of loading is a detriment, a benefit, or of no concern in maintaining the skeletal integrity of the BK.

It may be desirable to develop a typical profile for BK children during standing to determine whether the results obtained in this investigation are characteristic of BK children in general. It may also be desirable to determine the reaction forces at the joints of the prosthetic and non-prosthetic limbs to gain insight into the relevance of the loading differences.

Conclusion

The results of this preliminary investigation warranted the following conclusions. The standing ground-shoe weight distribution for BK children between prosthetic and non-prosthetic limbs was not significantly different from the feet of normal children. The anterior-posterior weight distribution for the prosthetic and non-prosthetic feet was significantly different from that of the normal children. Further quantification of weight distribution and analysis of more subjects is necessary to determine the benefits, detriments or irrelevance of these results.

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