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Technical note

Weight distribution of below-knee amputee and able-bodied children during standing

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Abstract

The purpose of this investigation was to compare weight distributions of a relatively large number of below-knee (BK) amputee and able-bodied children during two different standing positions. Twenty-one BK amputees and 200 able-bodied children volunteered as subjects for this investigation. Each child stood on a pressure plate and three sets of trial data were collected. One set of trial data was collected with both feet together on the pressure plate and two were collected with feet placed 20cm apart. The total force applied by each foot to the pressure plate was normalised by dividing by subject weight to yield foot force to body weight ratios. Data were separated into forefoot and rearfoot areas, force for the forefoot area was then calculated and normalised by dividing by total foot force to yield forefoot to whole-foot force ratios. Ratios for the two foot placement conditions and for non-prosthetic, prosthetic, dominant, and non-dominant feet were compared using paired t-tests ($p<0.05$). Results indicated that: 1) BK amputee children placed more weight on their non-prosthetic limb than their prosthetic limb, yet this was not different from able-bodied children in respect of weight distribution between dominant and non-dominant limbs; 2) approximately 90% of the load on the prosthetic foot was placed on the forefoot; and 3) the load on the non-prosthetic foot was evenly distributed between the forefoot and rearfoot like that of able-bodied children. It was concluded that except for substantially more weight on the forefoot of the prosthetic leg BK amputee children stood in the same way as able-bodied children.

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Introduction

A previous investigation indicated that during standing, weight distribution between the non-prosthetic and prosthetic feet of below-knee (BK) amputee children and between the dominant and non-dominant feet of able-bodied children was not significantly different (Engsberg *et al.*, 1989). The study did, however, indicate significant differences between the forefoot-rearfoot weight distribution. The investigation had two shortcomings. The first was that the relatively small boundaries of the pressure plate (i.e. 19.6cm by 33.6cm) forced the children to stand with their feet together. This foot placement may not have reflected the typical or natural loading patterns of these two groups of children during standing. The second shortcoming was that the sample size of the two groups of children was small and it was questionable whether the results could be generalised. The purpose of this investigation was to compare weight distributions of a relatively large number of BK amputee and able-bodied children during two different standing positions.

Methods

Twenty-one BK amputee children volunteered as subjects for this investigation. Subject and prosthetic characteristics are presented in Table 1. Two hundred able-bodied children (104 boys, 96 girls, range 7–12 years, mean age 9.4 years, mean height = 136.8cm, SD = 12.6, mean mass = 32.3kg, SD = 9.3kg) consented to act as subjects. Table 2 presents a

Table 1. Subject characteristics of BK amputee children.

Subject Number	Age (years)	Gender	Height (cm)	Mass (kg)	Amputation	Terminal Device	Socket Type	Suspension
04	8	m	124	20	left	SACH	PTS	Condylar
05	10	f	117	19	left	SACH	PTB	Condylar
06	11	m	147	43	left	Flex	PTB	Sleeve
14	17	m	168	63	right	Flex	PTB	Sleeve
32	14	m	155	49	right	SACH	PTB	Condylar
33	8	m	130	28	right	SACH	PTB	Condylar
34	12	m	144	37	right	Seattle	PTB	Figure of eight
36	12	m	155	54	left	Flex	PTB	Sleeve
37	5	m	116	22	left	SACH	PTB	Condylar
38	5	m	113	20	left	SACH	PTB	Sleeve
39	13	m	140	37	right	Single axis	PTB	Sleeve
43	11	m	138	29	right	Seattle	PTB	Condylar
46	12	m	178	65	right	Seattle	PTB	Thigh corset
51	17	m	170	66	left	SACH	PTB	Condylar
52	11	m	130	29	right	SACH	PTB	Condylar
53	6	m	112	20	right	Flex	PTS	Condylar
54	12	f	144	32	right	SACH	PTB	Condylar
55	15	f	160	42	left	Seattle	PTB	Condylar
56	13	f	153	49	left	Seattle	PTB	Condylar
59	15	m	171	60	left	SACH	PTB	Condylar
60	7	m	113	19	right	SACH	PTB	Condylar
mean	11		142	38				
SD	(3.6)		(21)	(16)				

pediatric orthopaedic surgeon's evaluation of the condition of the able-bodied children's feet. Each child stood on a pressure plate (EMED by NOVEL GmbH) and three sets of trial data were collected. The first trial data was collected with both feet together on the pressure plate (Engsberg *et al.*, 1989). The remaining two sets of trial data were collected while the children's feet were placed 20cm apart with only one foot at a time on the plate. The pressure plate was mounted flush to a raised platform and the entire platform was covered with a cloth to prevent the child from being acutely aware of which foot was on the pressure plate.

The mean pressure of each cell was calculated from the 31 samples per trial. The amount of force applied by each foot to the pressure plate was determined for the trials and normalised by dividing by subject weight. For the able-bodied children the foot with the greater amount of force was declared as the dominant foot (Engsberg *et al.*, 1989). Pressure output was separated into forefoot and rearfoot areas. The force for each area was then calculated and normalised by dividing by total force from that foot (Engsberg *et al.*, 1989). The resulting ratios (i.e., foot force to body weight ratios and forefoot to whole-foot force ratios) for the two standing conditions and for non-prosthetic, prosthetic, dominant, and non-dominant feet were compared using paired t-tests ($p<0.05$).

Results and discussion

Figure 1 shows the pressure plate results for the ratios of foot-force to whole body weight for the BK amputee and the able-bodied children for the two foot positions. For the BK amputee children the results indicated that significantly more weight was placed on the non-prosthetic foot than the prosthetic foot. However the same trend existed for the dominant and non-dominant feet of the able-bodied children. It should be noted that no significant differences

Table 2. Foot evaluation of 200 children by pediatric orthopaedic surgeon.

Foot type	Pronation and Cavus						Pes Planus		
	Pronated		Cavus		Normal	Total	Pes Planus	Normal	Total
	Mild	Moderate	Mild	Moderate					
Number of Subjects	87	24	3	1	85	200	43	157	200

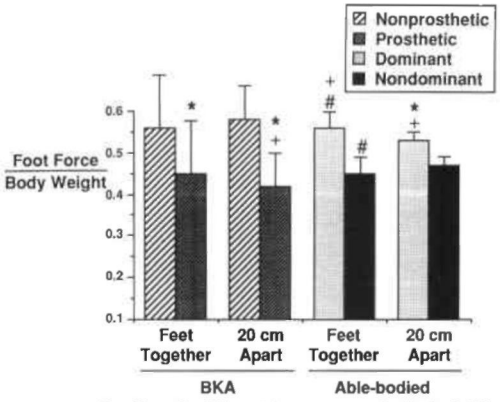

Fig. 1. Foot force to body weight ratio for the feet of BK amputee and able-bodied children.

existed between the able-bodied girls and boys and between ages, and all data were grouped together. Futher, by definition of the dominant foot, the results indicated more weight was placed on the dominant foot than the non-dominant foot. However, it was not by definition that the differences were significant. The results comparing the non-prosthetic feet to the dominant feet and the prosthetic feet to the non-dominant feet were not significant for the "feet together" position, but they were for the wider foot placement. Finally, the "feet together" position was significantly different from the "20cm apart" position for the able-bodied children. The results of the present investigation are in agreement with those previously reported for a smaller cohort of subjects (Engsberg *et al.*, 1989).

Figure 2 presents the ratio of forefoot force to whole-foot force for the two different foot placements. A forefoot force to whole-foot force value of 0.5 would describe a case in which weight was evenly distributed between forefoot and rearfoot areas. This was the case for the non-prosthetic leg of the BK amputee children and the legs of the able-bodied children. A value greater than 0.5 would indicate more force as applied to the forefoot than the rearfoot. Such was the case for the prosthetic foot where approximately 90% of the force on the foot was applied to the forefoot and only 10% was applied to the rearfoot. No significant difference existed between the foot placements. The forefoot to whole-foot ratio for the prosthetic foot and the dominant and

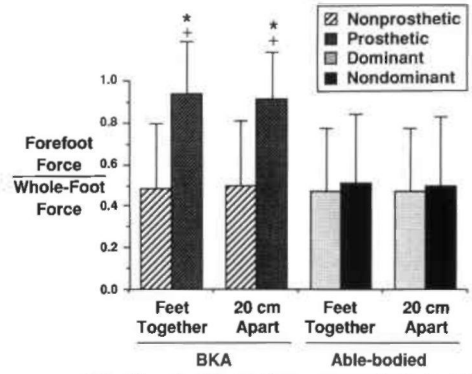

Fig. 2. Forefoot force to whole-foot force ratio for the feet of BK amputee and able-bodied children.

non-dominant feet of the able-bodied children agree with those previously presented. However, the forefoot to whole-foot force for the non-prosthetic leg do not agree. In the previous investigation about 33% of the force was on the forefoot and 67% on the rearfoot. In the present investigation the force was about evenly distributed and the same as that of the able-bodied children.

Conclusion

BK amputee children have significantly greater loading on their non-prosthetic leg compared to their prosthetic leg. Yet this is not different from that of able-bodied children in respect of dominant and non-dominant legs. Thus, except for substantially more weight on the forefoot of the prosthetic leg, BK amputee children stand the same as able-bodied children. In addition, the same results are obtained for the BK amputee children whether they stand with their feet together or with their feet 20cm apart.

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REFERENCE

ENGSBERG JR, ALLINGER TL, HARDER JA (1989). Standing pressure distribution for able-bodied and below-knee amputee children. *Prosthet Orthot Int* **13**, 152–155.