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Comparison of gait using a Multiflex foot versus a Quantum foot in knee disarticulation amputees.

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Abstract

The subjective responses and gait patterns of unilateral knee disarticulation amputees wearing prostheses fitted first with the Multiflex foot and then with the Quantum foot were studied. Nine amputees were included in the trial.

A questionnaire asked the amputees about their preference for one of the feet.

Gait analysis was performed measuring temporal parameters and goniometry of hips, knees and ankles in the sagittal and frontal planes.

There was a slight preference for the Quantum foot. Preference seemed not to be related to physical characteristics of the amputees nor to gait parameters.

There were no differences in gait as far as the temporal factors were concerned.

The main differences in the range of motion of the joints were in the frontal plane: the eversion-inversion movement of the ankle and the adduction-abduction movement of the hip. During walking at comfortable speed with the Multiflex foot the ankle and hip range of motion averaged 2.1 and 3.1 degrees respectively, less than during walking with the Quantum foot.

Introduction

If a prosthesis is to be prescribed after an amputation, the choice of a prosthetic foot is an important one, both for the amputee and for the clinical team. Several studies have reported on differences in gait patterns in trans-tibial (Barth *et al.*, 1992, Culham *et al.*, 1986; Mizuno *et al.*, 1992; Wirta *et al.*, 1991) and trans-femoral (Goh *et al.*, 1984; James and Stein, 1986) amputees resulting from the use of different feet. However, it has so far been difficult to make a choice for the individual patient from the many available artificial feet. The same problem occurs in knee disarticulation amputees. The gait characteristics of the knee disarticulation amputee are difficult to compare with those of trans-tibial amputees because of the absence of a knee joint; neither are they comparable with trans-femoral amputees, because of the end weight-bearing principle of the socket. Hence, studies of trans-tibial or trans-femoral amputees cannot be generalized to knee disarticulation amputees.

This study investigated the gait patterns of unilateral knee disarticulation amputees wearing prostheses fitted with either the Multiflex or Quantum foot. The Multiflex foot is one of the most common prosthetic feet in the Netherlands. The Quantum foot was used because it is one of the modern "energy-storing" feet and because it differs from the Multiflex foot in biomechanical properties such as hysteresis and stiffness (Jaarsveld *et al.*, 1990).

Method

Subjects

Nine subjects who met the following criteria were recruited for the study: unilateral knee disarticulation amputation fitted with an end

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Table 1. Subject characteristics of knee disarticulation amputees.

patient	gender	age (y)	cause of amputation	year of amputation	prosthesis knee-joint (Otto Bock)	initial foot	preferred foot
1	F	67	osteomylitis	1968	3R21	Multiflex	Quantum
2	M	70	vascular	1991	3R21	Multiflex	no. pref.
3	M	24	trauma	1988	3R45	Multiflex	Multiflex
4	M	24	bone-cancer	1968	3R45	Multiflex	Quantum
5	M	45	vascular	1986	3R21	Multiflex	no pref.
6	F	20	trauma	1987	3R45	Seattle	Quantum
7	M	33	trauma	1988	3R45	Multiflex	Quantum
8	F	48	vascular	1991	3R21	dyn. SACH	Multiflex
9	M	39	trauma	1989	3R45	Multiflex	Quantum

bearing socket, relatively pain-free stump with no skin abrasions, and residency in the north of the Netherlands. All gave informed consent.

Details about the patients' age, cause of amputation and year of amputation are given in Table 1.

All patients were wearing a 4-bar linked knee-joint by Otto Bock with a mechanical (3R21) or hydraulic (3R45) swing phase control.

Seven amputees were using a prosthesis with a Multiflex foot, while two patients were provided with a Multiflex foot for the purpose of this study. They walked on the Multiflex foot for at least 3 weeks before the study started.

After the first evaluation the amputees were fitted with the Quantum foot. The prosthesis was aligned by an experienced prosthetist. Prosthetic component design and alignment of the amputee's prosthesis were all directed towards obtaining optimal gait.

Data collection

Gait analysis was performed on a 10 m walkway and on a treadmill. After getting used to the situation, the patients walked on the walkway at comfortable, fast and slow speed.

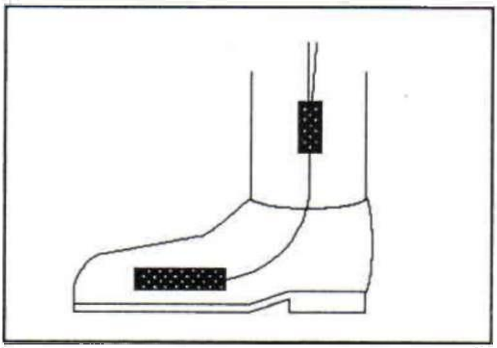

Fig. 1. Position of the goniometers on foot and ankle.

The amputees first walked without equipment, to measure walking speed. Subsequently, swing and stance phase recording and goniometry of the hip, knee and ankles were performed. Electrogoniometers (Penny & Giles) were used for a range of motion measurements. The positions of the ankle goniometers are shown in Figure 1. The position of the ankle goniometers was drawn on a piece of paper at the first measurement, to get nearly the same position the second time. A good test-retest reproducibility with a standard deviation of ± 2 degrees between two measurements was found in normal subjects. In order to standardise walking velocity, walking was performed on a treadmill as well. Three speeds were used on the treadmill : 2 and 2.5 km/h and the comfortable speed minus 0.5 km/h. The comfortable speed used was the speed measured on the walkway on the first day (with the Multiflex foot). The comfortable speed was reduced by 0.5 km/h because many amputees feel unsafe on the treadmill when walking too fast. Gait analysis was performed during walking with both prosthetic feet. At least three weeks were allowed to elapse between the changing of the foot and the evaluation. After the amputees had been evaluated using both feet, they were asked to fill in a questionnaire. The amputees were asked about differences in performance during walking with the two prosthetic feet and about their reasons for preferring one of the feet.

Statistical analysis

Because of the limited number of subjects participating in this study, analysis of the data was performed by means of descriptive statistics and the Wilcoxon Signed-Ranks Test. Tests were performed at the 5% level of significance (two-sided if applicable).

Table 2. Comparison of temporal parameters of gait (values of mean and standard deviations).

comfortable speed				
prosthetic foot	speed m/sec	swing phase msec		step time msec
	mean (sd)	prosth. side mean (sd)	sound side mean (sd)	mean (sd)
Multiflex	1.12 (0.23)	553 (35)	458 (33)	1257 (90)
Quantum	1.11 (0.22)	559 (36)	449 (33)	1267 (97)
fast speed				
prosthetic foot	speed m/sec	swing phase msec		step time msec
	mean (sd)	prosth. side mean (sd)	sound side mean (sd)	mean (sd)
Multiflex	1.37 (0.32)	510 (53)	411 (39)	1110 (90)
Quantum	1.37 (0.31)	532 (70)	422 (43)	1139 (113)

Results

Five amputees preferred the Quantum foot, while two preferred the Multiflex foot and two amputees had no preference. No clear explanation of the preferences could be found, neither in characteristics of the amputees, nor in differences in gait parameters. The reasons for preference which the amputees gave on the questionnaire were not consistent either.

The results of the gait analysis are summarised in Tables 2 and 3 and Figure 2.

Temporal parameters of gait analysis.

No difference in walking speed was found between the Multiflex and the Quantum foot. As expected, the swing phase of the prosthetic side was longer than that of the sound side. The Quantum foot led to a longer swing phase on the prosthetic side in 5 amputees, compared to the Multiflex foot. Step time with the Quantum foot was longer in 6 amputees. Group means did not differ significantly.

Goniometry

Measurement of the ankle eversion — inversion angle during walking at comfortable speed was incorrect in one patient, due to technical problems, so these data were excluded.

The inversion-eversion range of motion of

Table 3. Joint range of motion of the prosthetic and sound sides (values of mean and standard deviation).

comfortable speed								
	joint range of motion							
	ankle		knee		hip			
	inversion/ eversion	plantarfl/ dorsiflexion	flexion/extension		abduction/adduction		flexion/extension	
prosthetic foot	prosth. side mean (sd)	prosth. side mean (sd)	prosth. side mean (sd)	sound side mean (sd)	prosth side mean (sd)	sound side mean (sd)	prosth. side mean (sd)	sound side mean (sd)
Multiflex	6.1 (1.6)	24.2 (4.7)	52.4 (24.8)	58.4 (2.7)	8.6 (2.9)	11.6 (3.3)	43.1 (7.7)	36.2 (4.6)
Quantum	8.2 (3.1)	22.6 (5.6)	58.1 (19.0)	57.9 (9.2)	11.7 (2.7)	11.2 (2.5)	42.1 (7.3)	37.4 (6.5)
fast speed								
	joint range of motion							
	ankle		knee		hip			
	inversion/ eversion	plantarfl/ dorsiflexion	flexion/extension		abduction/adduction		flexion/extension	
prosthetic foot	prosth. side mean (sd)	prosth. side mean (sd)	prosth. side mean (sd)	sound side mean (sd)	prosth side mean (sd)	sound side mean (sd)	prosth. side mean (sd)	sound side mean (sd)
Multiflex	6.8 (2.2)	26.6 (4.9)	60.4 (23.8)	59.7 (2.8)	11.2 (3.4)	12.6 (3.7)	46.9 (8.9)	41.5 (5.6)
Quantum	8.9 (3.2)	25.4 (7.1)	64.6 (17.9)	56.7 (8.9)	13.5 (3.0)	12.1 (2.5)	48.1 (10.2)	43.1 (7.5)

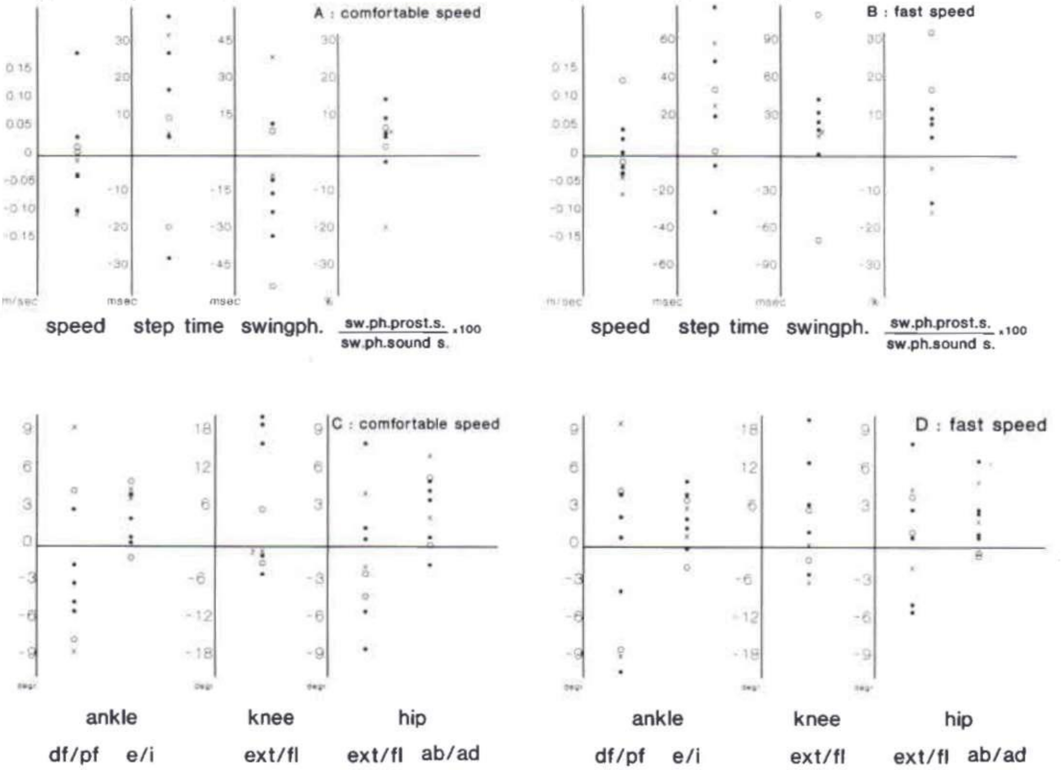

Fig. 2. Differences in temporal parameters and in the joint ranges of motion on the prosthetic side between Multiflex and Quantum foot.
Each dot represents, for each amputee, respectively, the temporal parameter and the joint motion while walking with the Multiflex foot minus the temporal parameter or joint motion while walking with the Quantum foot.
A-B: temporal parameters, C-D: goniometry.
● preference for Quantum ○ preference for Multiflex × no preference

the foot of the other amputees was significantly influenced by the choice of prosthetic foot, both during walking at comfortable speed and at fast speed. During walking at comfortable speed the inversion-eversion angle was 2.1° larger in the Quantum foot than in the Multiflex foot.

The plantar-dorsiflexion range of motion was the same for both feet. Neither was the knee-joint range of motion influenced by the choice of foot, irrespective of whether a hydraulic unit was present or not.

The hip flexion — extension range of motion was not altered by the choice of foot. However, the abduction — adduction range of motion was significantly changed for the Quantum foot in comparison to the Multiflex foot, both during walking at comfortable speed and at fast speed. During walking with the Quantum foot the range of motion was about 3.1° larger than during walking with the Multiflex foot at comfortable speed. Data for the treadmill confirmed the goniometry findings. For the sake of brevity, these data are not discussed here.

Discussion

This study investigated the subjective responses and gait patterns of unilateral knee disarticulation amputees wearing prostheses using first the Multiflex foot and then the Quantum foot in the prosthesis.

There was a slight preference for the Quantum foot. The preference seemed not to be related to physical characteristics of the amputees nor to gait parameters. Perhaps this preference was induced by the fact that, in general, patients do not like to disappoint the doctor. Anticipating this problem, the authors tried to explain to the amputees that they were not trying to prove that one foot was better than the other, but were trying to find an explanation for the fact that some patients preferred the Multiflex foot while others preferred the Quantum foot. One of the two amputees who had not previously used the Multiflex foot, now preferred the Mutliflex foot, while the other preferred the Quantum foot. There were no differences in gait as far as regards the temporal factors.

As expected, the swing phase of the prosthesis was longer than that of the sound leg: the difference was about 23% during walking at comfortable speed. Only one patient showed a nearly symmetrical gait.

The only earlier study comparing Multiflex and Quantum feet — as well as other types — was that by Mizuno *et al.* (1992) using trans-tibial amputees, but they studied other parameters. Most studies (Culham *et al.*, 1986; Doane and Holt, 1983; Goh *et al.*, 1984; MacFarlane, 1991; Wagner *et al.*, 1987) of different feet found no differences in walking speed. Only Nielson *et al.* (1989) found that trans-tibial amputees walked faster when fitted with the Flex-foot than with the SACH foot. Some studies of trans-tibial amputees (Culham *et al.*, 1986; MacFarlane *et al.*, 1991; Van Leeuwen *et al.*, 1990) found differences in symmetry in the stance phase between the prosthetic and sound sides while walking with different feet. Other studies failed to find such differences (Doane and Holt, 1983; Goh *et al.*, 1984).

The main differences in the range of motion of the joints were in the frontal plane: the eversion-inversion movement of the ankle and the adduction-abduction movement of the hip. During walking at comfortable speed using the Multiflex foot, the ankle and hip joint ranges of motion were an average of respectively 2.1° and 3.1° smaller than with the Quantum foot.

It may be assumed that the difference in the ankle joint range of motion in the frontal plane was primary, while the difference in hip joint range of motion was secondary. Differences in ankle joint range of motion between different feet have been found by many authors (Barth *et al.*, 1992; Doane and Holt, 1983; James and Stein, 1986; Wagner, 1987) in studies of trans-tibial amputees. To what extent this increased transverse motion is reflected in the subjective preference, remains unclear.

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