

A comparison of the SACH and single axis foot in the gait of unilateral below-knee amputees

N. E. DOANE and L. E. HOLT

Faculty of Health Professions, Dalhousie University, Halifax, Nova Scotia

Abstract

The gait patterns of unilateral below-knee amputees wearing prostheses with either a SACH foot or a single axis foot were compared. A temporary below-knee prosthesis was fabricated for each subject using plaster of Paris and Plastazote for the socket, a pylon and an artificial foot. Eight subjects were filmed at two separate sessions, one in which the SACH foot was worn on their prosthesis and one with the single axis foot on their prosthesis.

Measurements of the normal leg with a SACH foot on the prosthetic limb were compared to measurements of the normal leg with a single axis foot on the prosthesis. Measurements of the prosthetic leg with both devices were also compared. A one tailed *t* test ($p < .05$) was used to determine statistical significance of the results obtained in six measurements of lower limb joint angles and on the percentage of the time of gait cycle for stance and swing phase of the prosthetic leg.

Discussion centres on the interpretation of the results from both statistical and clinical points of view. Major differences (excepting the ankle at foot-flat) between the prosthetic devices were not found.

Introduction

The two artificial feet used in this study were the single axis foot and the SACH (solid ankle cushion heel) foot. These devices seem to be the most commonly used at present. Throughout the 1970's the SACH foot was the artificial foot of choice in North America when fitting the majority of below-knee amputees (Fishman, et

al. 1975). However, the single axis foot, which was first used during World War 1, appeared to be capable of more closely simulating human gait, due to the dorsiflexion and plantarflexion movement of the device.

The choice of prosthetic foot is important to the amputee and to the amputee clinic team prescribing the prosthesis. According to Statistics Canada, there were 1,198 below-knee amputations performed in Canada in 1974. Patients in the 55 to 67 age group are usually amputated for peripheral vascular disease which accounts for 80 per cent of the total number of amputations (Hunter and Waddell, 1976).

Breakey (1976) observed the effect of lost ankle movement on the gait of below-knee amputees by comparing the gait of five normal subjects to the gait of five unilateral below-knee amputees. These amputees were wearing a patellar tendon bearing prosthesis with a SACH foot. Breakey (1976) suggested that the lost ankle movement affects the knee movement and foot timing. He stated that knee flexion was decreased to 7 degrees from a normal value of 17 degrees during the stance phase, decreased to 30 degrees from a normal value of 37 to 43 degrees during toe-off and decreased to 57 degrees from a normal value of 61 to 68 degrees during the swing phase of gait.

Stance phase occurred for 57% of the time of the gait cycle for the involved limb and 63% for the uninvolved limb in Breakey's amputee subjects.

Robinson et al. (1977) tested 19 unilateral below-knee amputees, mean age 43, wearing a SACH foot on their patellar tendon bearing prosthesis. They observed a mean stride length of 1.32 metres, a mean step length from uninvolved to involved limb of 0.68 metres, and a mean step length from involved to uninvolved

All correspondence to be addressed to Ms. Nancy E. Doane, Russellville Medical Plaza, 719 Highway 43, By Pass N.E., Suite B, Russellville, Alabama, AL 35653, USA.

of 0.63 metres. An increased amount of time spent on the uninvolved limb compared to the involved limb contributes to an increase in stance phase. The mean walking velocity of these subjects was 1.07 m/s.

Subjects

Eight males were selected according to the following criteria: unilateral below-knee amputees wearing a patellar tendon bearing prosthesis with cuff suspension. These subjects were between the ages of 55 and 67, in good general health and had no skin problems with their stump.

Methodology

Each amputee was fitted with a temporary prosthesis to accommodate the interchange of prosthetic feet. The temporary prosthesis consisted of a plaster socket lined with Plastazote, cuff suspension, a pylon and prosthetic foot. The socket was fabricated and aligned on the pylon and foot following the same principles as a permanent patellar tendon bearing prosthesis.

The selection of the first prosthetic foot to be measured was made according to the availability of the prosthetic feet. The subjects were tested two days after fitting of a prosthetic foot if the foot was the same design as the one on their permanent prosthesis. A time lapse of one week was allowed if the prosthetic foot was not the same design as the one worn on their permanent prosthesis. The first prosthetic foot was changed after the filming was completed. The second foot was aligned on the prosthesis and the subject given a date for the second filming.

Data collection

A distance of approximately six metres (on level ground) was used as a walking zone allowing the subjects to complete three gait cycles. The subjects were filmed simultaneously from lateral and frontal perspectives. The anterior view (Bolex camera, 64FPS) was used to check knee angle measurements (varus, valgus), lateral deviation of the trunk and shoulder elevation. The subjects were filmed twice with the normal (non-amputated leg) closest to the side camera (Locam camera, 86FPS) and twice with the prosthetic leg closest to the camera.

A one foot measurement board was filmed in the centre of the walkway and used to convert digitized co-ordinates. The processed film was projected on to a digitizing tablet by a stop action projector. The nineteen body parts necessary for the computer to calculate the centre of mass were digitized and recorded on paper tape for each subject at heel-strike and every fifth frame following until the gait cycle for the leg was completed. The nineteen body parts in sequence, were the head, sternum, crotch, right shoulder, elbow, wrist and hand, left shoulder, elbow, wrist and hand, right hip, knee, ankle and foot and left hip, knee, ankle and foot. The paper tape was fed into a computer terminal and data points stored on a magnetic disc. Key punch cards were used to obtain the program output from the computer which included the path of the centre of mass for each subject.

The measurements obtained in this study to compare the gait of the amputee subjects were as follows:

1. The vertical displacement and velocity of the centre of mass of each subject on each trial were obtained from the computer printout.
2. The lower limb joint angles were measured by projecting the lateral view films on to a wall using a stop action projector. The selected angles of the hip, knee and ankle were measured using a goniometer. The joint angles for heel-strike were measured as the heel came in contact with the floor following swing phase. Foot-flat was measured as soon as the entire foot came in contact with the floor. As the hip moved directly over the foot, angle measurements for mid-stance were taken. The angle measurements for heel-off, as the heel left the ground and toe-off, as the toe left the ground completed the stance phase measurements.
During swing phase the angle measurements were taken as the knee passed directly under the hip for acceleration, as the foot passed directly under the hip for mid-swing and as the knee ceased to extend for deceleration.
3. The percentage of time of gait cycle of stance phase, swing phase and double support phase and the time of the gait cycle were calculated using the number of frames and the frame rate of the film.

Table 1. Statistically significant variables

Variables	p value	Mean SACH	Standard deviation	Mean SA	Standard deviation
Hip angle, toe-off normal leg	·041	-3·0°	7·1	-7·0°	5·3
Knee angle, acceleration normal leg	·020	55·6°	5·0	59·0°	5·1
Hip angle, foot-flat prosthetic leg	·035	13·1°	6·8	17·1°	9·6
Ankle angle, foot-flat prosthetic leg	·001	-5·4°	2·1	-11·9°	3·0
Ankle angle, heel-off prosthetic leg	·034	4·4°	4·1	0·9°	3·3
Hip angle, acceleration prosthetic leg	·009	11·0°	1·2	13·9°	2·3
Percentage of time of gait cycle stance phase prosthetic leg	·040	61·8%	1·7	60·5%	0·9
Percentage of time of gait cycle swing phase prosthetic leg	-·040	38·2%	1·7	39·5%	0·9

4. Step length and stride length were obtained using the digitizing tablet and the projected film.

Results

The measurements obtained when the subjects were wearing a single axis foot on their prosthesis were compared to those obtained when they were wearing a SACH foot on their prosthesis. A paired *t*-test was used to determine whether the two means were significantly different. A probability level of 0·5 was selected for a 1-tailed *t* test. The degrees of freedom for all comparisons was seven. Statistical significance was obtained in six comparisons of lower limb joint angles and the percentage of the time of gait cycle for stance and swing phase of the prosthetic leg (Table 1). The mean velocity of the body's centre of mass for both the SACH foot and the single axis foot measurements was 1·22 m/s. The difference in velocity comparing the subjects SACH foot gait and single axis gait was no greater than 0·2 m/s. (Table 2).

Discussion

Although statistical significance was obtained in six comparisons, only one variable was felt to have any clinical significance. The determination of clinical significance was based on research by Murray (1967) on 30 subjects which identified one standard deviation of ankle angle measurements to be approximately 7°, knee

angle to be 5° and hip angle to be 11° at an average walking speed of 1·39 m/s. In this study the ankle angle at foot-flat of the prosthetic leg measurements showed a difference of 6·5° between the single axis foot and the SACH foot measurements. The design of the single axis foot permits a greater range of plantarflexion and dorsiflexion around a transverse ankle axis with the range limited by posterior and anterior rubber bumpers. The SACH foot permits a limited range of plantarflexion through the compression of the posterior rubber heel insert. The remaining statistically significant lower limb joint angles were not considered clinically significant since a measurement difference of 4° or less was obtained.

The percentage of time of gait cycle for stance and swing phase of the prosthetic leg fell within the reported normal ranges of 60 and 40 per cent

Table 2. Velocity of centre of mass

Subject	Velocity m.s	
	SACH foot	Single axis foot
1	1·17	1·16
2	1·31	1·33
3	1·41	1·26
4	1·06	1·25
5	1·15	1·34
6	1·39	1·18
7	1·23	1·27
8	1·04	0·99
\bar{x}	1·22	1·22
S.D.	0·13	0·11

(Drillis, 1958) and 62 and 38 per cent (Peizer et al. 1969) for stance and swing phases. Although the difference obtained was statistically significant, once again it was not felt to be of clinical significance.

Conclusion

In this study, interchanging the prosthetic foot on a prosthesis did not appear to have a significant effect on the gait patterns of unilateral below-knee amputees. The ankle of the prosthetic foot during the foot flat phase of gait showed a significant statistical and clinical difference.

Acknowledgements

The authors are grateful to the Nova Scotia Branch, War Amputations of Canada for their support and in providing funds for this study.

REFERENCES AND SELECTED BIBLIOGRAPHY

- BREAKEY, J. (1976). Gait of unilateral below-knee amputees. *Orthot. Prosthet.*, **30**(3), 17-23.
- DRILLIS, R. (1958). Objective recording and biomechanics of pathological gait. *Ann. N. Y. Acad. Sc.*, **74**, 86-109.
- EBERHART, H., INMAN, V., BRESLER, B. (1968). The principal elements in human locomotion. In: Klopsteg, P. E., Wilson, P. D. (eds) *Human limbs and their substitutes*. Hafner, New York, 437-471.
- FISHMAN, D., BERGER, N., WATKINS, D. (1975). A survey of prosthetics practice, 1973-4. *Orthot. Prosthet.*, **29**(3), 15-20.
- FOORT, J. (1965). The patellar-tendon bearing prostheses for below-knee amputees, A review of technique and criteria. *Artif. Limbs*, **9**(1), 4-13.
- HUNTER, G., WADDELL, J. (1976). Management of the patient requiring leg amputation for peripheral vascular disease. *Can. Med. Assoc. J.*, **115**, 634-638.
- INMAN, V. (1966). Human Locomotion. *Can. Med. Assoc. J.*, **94**, 1047-1054.
- MURRAY, M., DROUGHT, A., KORY, R. (1964). Walking patterns of normal men. *J. Bone Joint Surg.*, **46A**, 335-360.
- MURRAY, M. (1967). Gait as a total pattern of movement. *Am. J. Phys. Med.*, **46**, 290-333.
- PEIZER, E., WRIGHT, D., MASON, C. (1969). Human Locomotion. *Bull. Prosthet. Res.*, **10-12**, 48-105.
- ROBINSON, J., SMIDT, G., ARORA, J. (1977). Accelerographic, temporal and distance gait factors in below-knee amputees. *Phys. Ther.*, **57**, 898-904.