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Chukwuduziem U. Opara
Boston University

Pamela Levangie
Sacred Heart University

David L. Nelson
Western Michigan University

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Effects of Selected Assistive Devices on Normal Distance Gait Characteristics

CHUKWUDUZIEM U. OPARA,
PAMELA K. LEVANGIE,
and DAVID L. NELSON

The purpose of this study was to investigate the effects of selected assistive devices on normal standards of gait. The gait characteristics of stride length, step length, step width, and foot angle were analyzed for 24 right-dominant, healthy men under four conditions: right ankle-foot orthosis (AFO), right hemiplegic arm sling (HAS), both devices (AFO+HAS), and no devices. The dependent variables were measured by a standard method from ink traces left by subjects walking on newsprint. Order of conditions was controlled, and cadence remained consistent across all four conditions for each subject. The AFO and AFO+HAS conditions produced statistically significant changes from normal gait characteristics. The HAS alone did not produce significant changes. Data from the study may be used as a basis for goal setting and as a guideline for the optimal level of function possible for a person wearing these devices. The extent of the patient's orthopedic and neurologic involvement should of course be considered.

Key Words: *Gait, Orthotic devices, Physical therapy.*

A primary objective of most physical therapy services is to maximize the patient's abilities. Physical therapists frequently use assistive devices, modalities, or interventions that effectively raise the patient's functioning levels. These devices, however, may simultaneously prevent the attainment of ideal function. Therefore, goal setting for the patient would be enhanced by a knowledge of the optimal level of function that can be expected under the conditions of the intervention. What level of function can reasonably be expected if the patient wears a specific assistive device? Continuing physical therapy services could be based on achieving a specified optimal level rather than on aiming for the ideal level of function.

In rehabilitating the hemiplegic patient, therapists concentrate on the patient's attainment of optimal ambulation. Goal setting in ambulation should take into account not only the patient's handicap but also the effects of any intervention. Two assistive devices sometimes used with hemiplegic patients are the ankle-foot orthosis (AFO) and the traditional hemiplegic arm sling (HAS). The purpose of this study is to identify the effects of these assistive devices on normal standards for gait. These devices might preclude perfectly normal gait in healthy people, although they partially correct patterns of gait used by patients with hemiplegia.

Researchers and clinicians have not agreed on the exact effects of the HAS in the rehabilitation of stroke patients. This sling has been used predominantly for preventing subluxation of the glenohumeral joint. Among many arguments against the HAS, some studies have shown that the sling interferes with the distribution of body weight and inhibits attaining or maintaining a normal walking pattern because the sling positions the arm in front of the body.[1-3] Delwaide et al monitored electromyographic (EMG) responses in healthy subjects and showed that the position of the upper limb induced lower limb reflexes even though the upper limb muscles had EMG quiescence.[4] Positioning the arm in an arm sling may cause a deviation from normal gait by inducing compensatory patterns. In healthy individuals, arm swinging appears to counteract excessive horizontal trunk rotation. A limitation of arm swing by use of the HAS may result in a lack of the counter effect, which, in turn, affects gait.

The AFO is widely accepted by clinicians and researchers.[5-7] Friedland found that an AFO, such as the double upright, improved the subject's gait considerably and was also cosmetically acceptable.[2] The brace facilitates safe, effective ambulation with minimum energy expenditure, especially for patients with marked weakness around the ankle and foot.[8] Magora et al, however, warned that the standard rigid lower limb brace produces changes in the contralateral lower extremity that may explain the early degenerative osteoarthritic changes, discomfort, and fatigue felt by many patients in the unbraced limb.[9] Smidt and Mommens supported this line of thought when in a study of the influences of some ambulatory aids on gait, they concluded that the use of assistive devices tends to increase the vertical loading on the body structures.[10]

Given the use in rehabilitation of the HAS and the AFO, clinicians need to know the optimal level of ambulatory function that can be expected of patients using one or both of these devices. Any changes produced in normal gait by these assistive devices should be anticipated in a patient's gait. This "modified" gait represents the best that the average

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Mr. Opara is a doctoral student in the Department of Health Sciences, Sargent College of Allied Health Professions, Boston University, Boston, MA 02215 (USA).

Ms. Levangie is Assistant Professor of Physical Therapy, Sargent College of Allied Health Professions.

Dr. Nelson is Associate Professor of Occupational Therapy, Western Michigan University, Kalamazoo, MI 49008.

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patient should be able to achieve; expectations should be further modified by the extent of the handicap.

Distance gait factors have been identified as one class of variables of importance in quantitative gait evaluation.[11] We chose the gait characteristics of stride length, step length, step width, and foot angle for our study. These characteristics are measurable by clinicians without access to sophisticated instrumentation.

METHOD

Subjects

Twenty-four men between the ages of 20 and 55 years were recruited from the university community. We deemed the wide age range acceptable because we compared the subjects with themselves in a Latin Square design using repeated measures. Only those whose reported height, weight, and age fell within the optimal range on a height-weight chart as listed by the Metropolitan Life Insurance Company were accepted for the study. The subjects were allowed ample time to read and sign an approved informed consent form. Right dominance was determined by the choice of hand used to sign the consent form and by kicking accuracy. Subjects wore their own shoes.

Procedure

Each subject's comfortable free-walking speed was established by letting him walk twice back and forth along a 30-ft* walkway. The light of a metronome was synchronized to his steps. This cadence was maintained for all testing conditions. All cadences fell within norms established for men.[11]

Subjects were randomly assigned to four groups of equal size. Subjects from each group experienced all four experimental conditions. Each group, however, experienced the conditions in a different order (in accordance with the Latin Square design). The four conditions were no devices, HAS alone, AFO alone, and AFO and HAS (AFO+HAS) simultaneously.

The HAS (Fig. 1) had a sliding buckle and metal loops for adjustment and a thumb-loop in the wrist-hand support. One-hundred-degree elbow flexion was maintained. The AFO was the double upright, universal short leg brace without stops.

Assistive devices were worn on the right limbs only. Two 8.00- × 0.76-m walkways of newsprint were secured to the floor for each subject. Before starting the test, we affixed two strips of moleskin to the soles of both shoes in the middle of the widest point of the forefoot and at the midpoint of the heel (Fig. 2). The moleskin strips were soaked in water-based ink, and the subject walked the length of the walkway to the beat of the metronome. Each walkway recorded two of a subject's four trials. The particular experimental condition was noted on the walkway. The two trials were differentiated by ink colors and direction of footprints. The subject rested for 10 minutes between trials while the shoe pads were resoaked and the appropriate assistive devices were put on or taken off.

All measurements were based on the mean of the four strides after the first two steps. Stride lengths were measured as the linear distances between two consecutive heel-pad prints of the same foot. Step lengths were measured as the linear distances between one heel-pad print and the subsequent contralateral heel-pad print. Step width was measured as the distance between one heel-pad print and the opposite line of progression. (The line of progression is a line joining two consecutive heel-pad prints of the same foot.) Foot angle was measured as the angle formed by the line of progression and the line joining the midpoints of the heel and the forefoot pad prints of the same foot.[11-15]

Data Analysis

To test for differences between the four experimental conditions experienced in four different orders, we planned a two-way analysis of variance (ANOVA) with one repeated measure for each dependent variable (conditions × orders). If main effects for conditions were found, we planned a Newman-Keuls *post hoc* analysis.

RESULTS

Table 1 gives a descriptive summary of results. These scores are consistent with values of normal gait as obtained by other investigators.[11,15,16] Pearson product-moment correlations indicated insignificant correlations between cadence and the dependent variables; therefore, cadence was not a confounding variable.

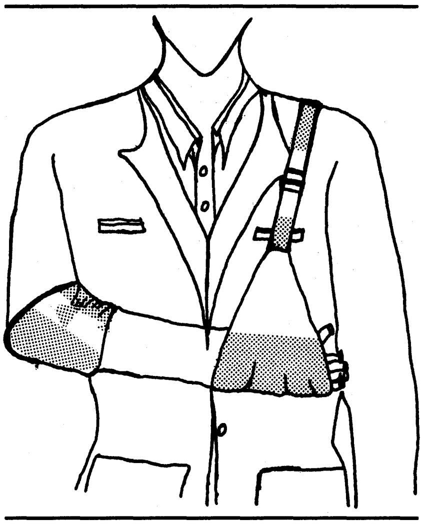

Fig. 1. Right upper limb in HAS.

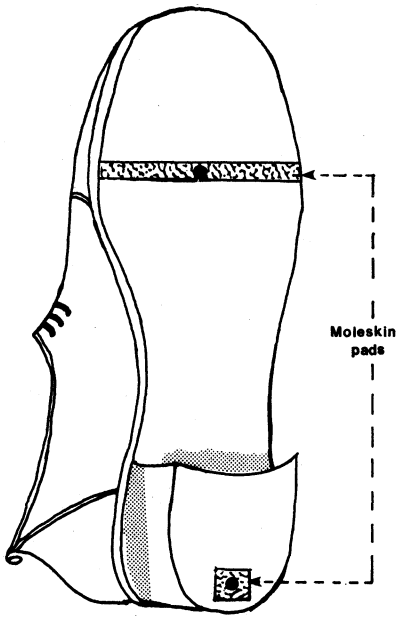

Fig. 2. Moleskin strips on sole of shoe.

The main research questions posed by this study are answered in Tables 2 to 5. In this type of analysis, the main effect for conditions of gait tests whether the different types of assistive devices made a significant difference. Note that the main effect for conditions is significant in all analyses. In other words, the type of assistive device caused significant differences for right stride length, left stride length, right step length, left step length, step width, right foot angle, and left foot angle.

Order showed no significant main effects. Small but significant interactions existed between the order of presenta-

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* 1 ft = 3048 m.

TABLE 1
Summary of Means and Standard Deviations of Gait Characteristics (N = 24)

Gait Characteristics		No Devices		HAS		AFO		AFO + HAS	
		$\bar{X}$	*s*	$\bar{X}$	*s*	$\bar{X}$	*s*	$\bar{X}$	*s*
Stride (cm)	left	153.9	(11.3)	153.2	(11.8)	149.6	(13.1)	149.8	(11.8)
	right	153.9	(11.7)	153.2	(11.4)	149.9	(13.3)	149.4	(11.7)
Step (cm)	left	77.5	(6.8)	77.1	(6.8)	75.1	(7.3)	74.9	(7.2)
	right	76.6	(5.3)	76.2	(5.4)	74.6	(6.4)	74.8	(5.2)
Width (cm)		8.9	(4.0)	8.6	(4.0)	7.9	(3.3)	7.4	(3.3)
Angle (°s)	left	7.9	(4.0)	7.7	(3.8)	10.2	(3.2)	11.3	(3.8)
	right	8.1	(4.0)	7.8	(3.9)	10.2	(3.2)	11.5	(3.5)

TABLE 2
Two-way Analyses of Variance for Right and Left Stride Length

Gait Characteristic	Source	*df*	SS	MS	*F*
Right stride length	orders	3	215	71.7	0.13
	error (between)	20	10843	542.2	
	conditions	3	367	122.3	4.25[a]
	orders × conditions	9	556	61.8	2.15[a]
	error (within)	60	1725	28.8	
Left stride length	orders	3	225	75	0.14
	error (between)	20	10870	543.5	
	conditions	3	360	120	4.24[a]
	orders × conditions	9	546	60.7	2.14[a]
	error (within)	60	1700	28.3	

[a] Significant at $p < .05$.

TABLE 3
Two-way Analyses of Variance for Right and Left Step Length

Gait Characteristic	Source	*df*	SS	MS	*F*
Right step length	orders	3	46.5	15.5	0.14
	error (between)	20	2285.7	114.3	
	conditions	3	72.4	24.1	3.64[a]
	orders × conditions	9	137.8	15.3	2.31[a]
	error (within)	60	397.9	6.6	
Left step length	orders	3	109.8	36.6	0.20
	error (between)	20	3587.4	179.4	
	conditions	3	127.8	42.6	3.94[a]
	orders × conditions	9	172.4	19.2	1.77
	error (within)	60	648.62	10.8	

[a] Significant at $p < .05$.

tion and conditions for stride, step lengths, and step width. This significance means that performance in one condition varied somewhat depending on the conditions following or preceding it.

Newman-Keuls *post hoc* analyses identified the specific conditions that were different from each other. They showed that wearing both the HAS and the AFO at the same time caused significant decreases ($p < .05$) in left and right stride length and in left step length. This combination of assistive devices also caused an increase in step width and both foot angles in comparison with the values obtained when no devices were worn ($p < .05$). The most significant changes were noted in foot angles ($p < .01$). The *post hoc* analyses also showed that wearing the AFO alone caused similar changes in comparison with wearing no devices: a significant decrease in left stride and right step lengths and an increase in step width and both foot angles.

Wearing the HAS alone did not cause any statistically significant changes from normal gait values in the characteristics measured. A trend was noted, however, toward a small deviation in the direction of a decrease from normal values for stride and step lengths and an increase for step width and foot angles.

DISCUSSION

Statistical significance does not necessarily imply clinical significance of great magnitude. The means presented in Table 1 indicate that the four conditions did not differ profoundly from each other. This study found statistically significant but not profound differences between gait in the AFO and AFO+HAS conditions and gait in the condition in which no devices were used. Although the AFO and the AFO+HAS conditions were essentially similar, the shift in significance from the left step for the AFO+HAS to the right step for the AFO alone was unaccountable. The HAS did not contribute to the significance of change, although some changes in values were noted with its use. The changes in gait characteristics were apparently induced predominantly by the AFO. We point out, however, that the results cannot automatically be generalized to all other types of short leg assistive devices.

This study was designed to identify the changes made by the AFO and HAS in selected gait characteristics. From the data gathered, a researcher might also look at the reason these changes occurred. In our study, cadence was held constant, but velocity was not. With a constant cadence, a decrease in step length yields a decreased velocity. Other investigators have shown that an interaction exists between velocity and the gait characteristics of step length, step width, and foot angle.[10,12,13] As velocity increases from the subject's customary gait, step length increases while step width and foot angle decrease. Decreases in velocity from customary gait might be expected in step width and foot angle. From this study alone, we cannot determine whether the AFO caused a change in velocity, which then affected the gait characteristics, or whether the initial effect of the AFO was on the gait characteristics themselves.

The observed changes may also be attributable to changes other than in velocity. The "push" of the braced limb may have had a restriction. Simkin et al identified this restriction as an important factor in forward motion.[17] Similarly, the AFO may have limited the description of the two intersecting arcs of foot and ankle motion. Other investigators have shown these arcs to be important components of the foot-knee mechanism—a major determinant of normal gait.[7,11,14,18] Possibly, wearing the AFO on one side required a mutual compensatory effort by both lower limbs. This explanation of the role of compensation lends support to the theory that early osteoarthritic changes in the unbraced limb may be linked to bracing.[9] Such compensation may have led to changes in distance gait characteristics. Changes in foot angle may be an attempt by the body to maintain comfortable balance while walking. Other possible ways of accounting for these changes might be a consideration of the ranges of joint motion, the muscles involved, the loading factors, and energy expenditure. Ultimately accounting for the causes of change was not within the scope of the study.

CONCLUSION

Our study found that the commonly recommended AFO has significant effects on the normal distance gait characteristics of right-dominant male subjects. These effects were most pronounced when the AFO was used in conjunction with the HAS. The HAS alone had little, if any, effect on distance gait characteristics. The AFO significantly reduced stride and step lengths and caused significant widening of the step width and foot angles in healthy subjects. The study provided documentation of the optimal level of function that can be achieved in terms of distance gait characteristics when the universal double-upright short leg brace is used in conjunction with the traditional hemiplegic arm sling. Consequently, the data may serve as a basis for goal setting when these devices are used in the clinic, considering, of course, the extent of the patient's orthopedic and neurologic deficit. In future studies, further information may be obtained by controlling the velocity of walking and by performing the test on non-right-dominant subjects and subjects of different age groups.

The study was not intended to discredit the use of assistive devices for patients, and the results cannot be generalized to all other assistive devices. Rather, it indicated that the aim of rehabilitation efforts should be to achieve an appropriate optimal functioning level.

TABLE 4
Two-way Analyses of Variance for Step Width

Gait Characteristic	Source	*df*	SS	MS	*F*
Step width	orders	3	96.8	32.3	0.71
	error (between)	20	903.3	45.2	
	conditions	3	31.9	10.7	3.86[a]
	orders × conditions	9	64.9	7.2	2.62[a]
	error (within)	60	165.5	2.8	

[a] Significant at $p < .05$.

TABLE 5
Two-way Analyses of Variance for Right and Left Foot Angle

Gait Characteristic	Source	*df*	SS	MS	*F*
Right foot angle	orders	3	153.8	51.3	1.14
	error (between)	20	900.1	45.0	
	conditions	3	218.3	72.8	24.57[a]
	orders × conditions	9	36.9	4.1	1.38
	error (within)	60	177.7	2.9	
Left foot angle	orders	3	162.2	54	1.20
	error (between)	20	901.2	45	
	conditions	3	222	74	26.73[a]
	orders × conditions	9	42.2	4	1.69
	error (within)	60	166.1	2	

[a] Significant at $p < .01$.

REFERENCES

1. Hurd MM, Farrell KH, Wayloni GW: Shoulder sling for hemiplegia: Friend or foe? Arch Phys Med Rehabil 55:519–522, 1974
2. Friedland F: Physical therapy. In Licht S (ed): Stroke and Its Rehabilitation. Baltimore, MD. Williams & Wilkins, 1975
3. Licht S: Stroke rehabilitation program. In Licht S (ed): Stroke and Its Rehabilitation. Baltimore, MD, Williams & Wilkins, 1975
4. Delwaide PJ, Fijiel C, Richele C: Effects of postural changes of the upper limb on reflex transmission in the lower limb: Cervicolumbar reflex interactions in man. J Neurol Neurosurg Psychiatry 40:616–621, 1977
5. Perry J: The mechanics of walking in hemiplegia. Clin Orthop 63:23–31, 1969
6. Perry J: Lower extremity bracing. Clin Orthop 63:32–38, 1969
7. Saunders JB, Inman VT, Ebenhart HD: The major determinants in normal and pathological gait. J Bone Joint Surg [Am] 35:543–548, 1953
8. Lehman JF: Lower limb orthotics. In Licht S (ed): Orthotics, Etcetera. New Haven, CT, Elizabeth Licht, Publisher, 1966
9. Magora A, Robin GC, Rozin R, et al: Investigations of gait 5: Effect of a below knee brace on the contralateral unbraced leg. Electromyogr Clin Neurophysiol 13:355–361, 1973
10. Smidt GL, Mommens MA: System of reporting and comparing influence of ambulatory aids on gait. Phys Ther 60:551–558, 1980
11. Murray MP, Drought BA, Kory RC: Walking patterns of normal men. J Bone Joint Surg [Am] 46:335–360, 1964
12. Norkin CC, Levangie PK: Joint Structure and Function: A Comprehensive Analysis. Philadelphia, PA, F A Davis Co, 1982
13. Andriachi TP, Ogle JA, Galente JO: Walking speed as a basis for normal and abnormal gait measurements. J Biomech 10:261–268, 1977
14. Ogg HL: Measuring and evaluating the gait patterns of children. J Amer Phys Ther Assoc 43:717–720, 1963
15. Boenig DD: Evaluation of a clinical method of gait analysis. Phys Ther 57:795–798, 1977
16. Perry J: Mechanics of walking: A clinical interpretation. Phys Ther 47:778–801, 1967
17. Simkin A, Magora A, Saltiel J, et al: Relationship between muscle action and mechanical stress in below knee braces. Electromyogr Clin Neurophysiol 13:495–503, 1973
18. Morton DJ, Fuller DD: Human Locomotion and Body Form: A Study of Gravity and Man. Baltimore, MD, Williams & Wilkins, 1952

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