Development of Gait at Slow, Free, and Fast Speeds in 3- and 5-Year-Old Children

RUTH ROSE-JACOBS

The purpose of this study was to describe and statistically analyze 3- and 5-year-old children's gait at slow, free, and fast speeds in terms of stride length, step length (adjusted for leg length), stride width, included angle of feet, and cadence. The study also correlated gait factors and motor development. Gait patterns were recorded with a clinical, footprint method. In general, stride length and cadence were significantly different for age and speed, and step length and stride width were significantly different only for speed. Included angle of feet was not significant for age or speed. Motor ability as measured by the McCarthy Scales of Children's Abilities correlated only with stride length and cadence. It was concluded that gait patterns in 3- and 5-year-old children are not fully mature. Perhaps the interrelationship between gait factors, age, and speed, as well as the relationships among gait factors, present a more realistic analysis of gait in these children than if the variables were considered in isolation. Further research is needed to determine how variability of a child's gait decreases and which gait factors and conditions can be used appropriately to determine gait maturity.

Key Words: *Child development, Gait, Research design.*

The preschool years are a transitional period in the development of gait, and little quantitative research has been conducted in this area. The few quantitative preschool gait studies reported in the literature have examined few subjects, used expensive equipment, and lacked sufficient information regarding the relationships of gait speed, gait development, and general motor development.[1-6] Physical therapists have few quantitative guidelines that can be used to measure gait clinically and objectively during this developmental period.

Although a child may learn a motor skill, such as gait, at an early age, the development of control and elimination of extraneous movements occurs during the preschool years.[7] Only after the child has first attained a considerable level of skill does consistency of the motor activity occur. With maturation and opportunities for experience and motor learning, movements and postural adjustments become more automated to meet the new demands and situations in the child's life.[8,9] Ultimately, the adult or mature level of gait is one of the most consistent human activities in which voluntary control plays a part.[10] Individuals with mature gait patterns are able to ambulate safely and comfortably within a wide variety of gait speeds[11] and maintain highly consistent details of each step at any speed.[11-13] The specific criteria to apply in determining whether gait is mature are highly controversial.[1-3,14,15]

Stride and step length, stride width, included angle of foot placement (the sum of a successive right and left foot angle), cadence, and variability of each of the above gait factors have all been used to measure children's gait. At free speed, stride and step length increase and cadence decreases until gait maturity. How and at what age gait maturity occurs is debated.[1,16-18] The extent to which older children's step length is due to increased height and leg length is also unclear.[2] Scrutton[1] found that in 1- to 4-year-olds, there was a minimal change in stride width, but Burnett[3] found the narrowing of stride width to occur within weeks of attaining independent gait by the infant at 9 to 17 months. In infants, angle of foot placement decreases as the child progresses from supported to independent gait[3,17]; however, little data describe angle of foot placement in the post-inde-

Ms. Rose-Jacobs was a graduate student, Sargent College of Allied Health Professions, Division of Physical Therapy, Boston University, when this study was conducted. She is now Assistant Professor, Department of Physical Therapy, Boston-Bouve College of Human Development Professions, Northeastern University, 360 Huntington Ave, 308 Robinson Hall, Boston, MA 02115 (USA).

This study was supported in part by an Allied Health Professions Traineeship from the Public Health Service Department of Health, Education and Welfare, Washington, D.C.

This article was adapted from a paper presented at the Fifty-seventh Annual Conference of the American Physical Therapy Association, Washington, DC, June 28–July 2, 1981.

This article was submitted May 24, 1982; was with the author for revision 25 weeks; and was accepted for publication February 18, 1983.

pendent stages of gait Before age 3, patterns of foot movement, stance duration, and change of foot force vary with each step.[4] Three-year-olds have a variety of gait patterns ranging in similarity from children younger and older than themselves to adults. Others have found variability in gait in children even 8[19] and 10 years of age.[14]

The speed of ambulation must also be considered.[20] As the child's gait speed increases, the width of gait may become erratic and almost similar to the pattern prior to an infant's independent gait.[3] Gesell's concept of reciprocal interweaving is applicable to this phenomenon; the child attains a new level of developmental maturity in the area of speed but temporarily reverts to a somewhat less mature stride width.[9]

The purpose of this study is to describe and compare 3- and 5-year-old children's gait at slow, free, and fast speeds. Stride length, step length (adjusted for leg length), stride width, included angle of feet, and cadence are compared. This study will also attempt to relate children's level of gait maturity to gross motor development. The following hypotheses are presented: 1) As gait speed increases, the 3-year-old and 5-year-old groups will have longer strides and step lengths, wider stride width, smaller included angle of feet, and higher cadence; 2) as the speed increases, the 5-year-old group will have a longer stride and step length, narrower stride width, smaller included angle of feet, and lower cadence; 3) at each gait speed, the 5-year-old group, when compared with the 3-year-old group, will have a longer stride and step length, narrower stride width, smaller included angle of feet, and lower cadence; 4) at each gait speed, the 5-year-olds, compared with the 3-year-olds, will have less variability of stride length, step length, stride width, and included angle of feet; 5) at each age and at each speed, there will be a correlation between gait factors; and 6) at slow, free, and fast gait speeds, a correlation will exist between a child's scale index equivalent on the motor section of the McCarthy Scales of Children's Abilities[21] and the child's gait factors as measured in this study.

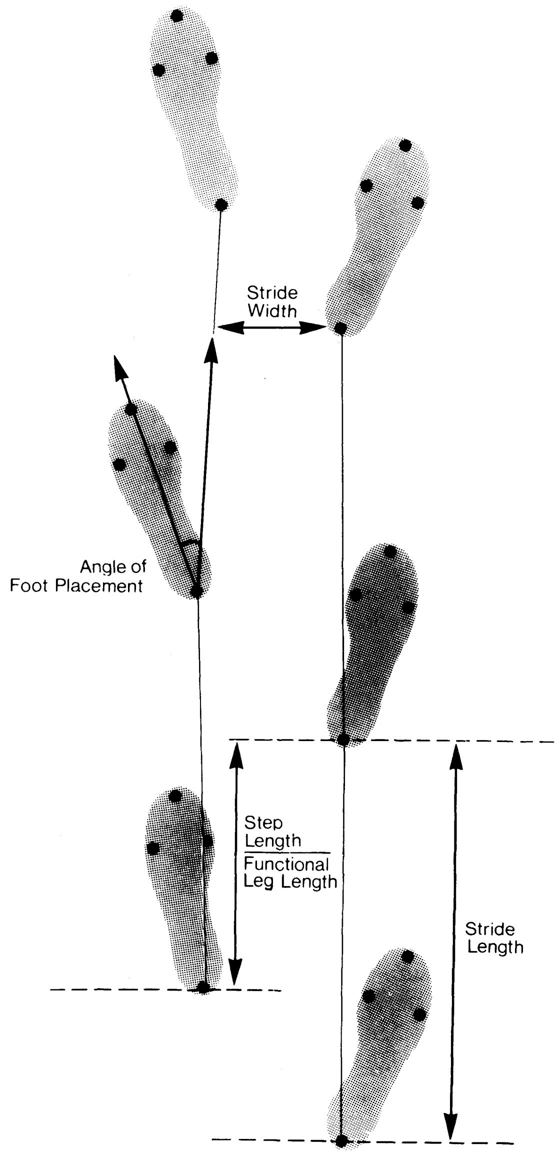

Figure. Measurements from ink footprints on the paper strip.

METHOD

Subjects

Fifteen normal (with no known neurological, orthopedic, or developmental problems) 3-year-old (38–44 months) and 16 normal 5-year-old (58–63 months) children were tested; mean ages were 40.67 (±1.91) and 59.44 (±1.46) months. Seven of the 3-year-olds and six of the 5-year-olds were girls. The sample was not totally random in that children were from middle to upper middle class socioeconomic backgrounds and were selected from four preschools in the greater Boston area. All children of appropriate ages and medical criteria, whose parental consent forms were returned, were included as subjects.

Procedure

Data were obtained by modifying the method used by Ogg.[22] The investigator tested the children at their preschools. Children wore their regular shoes.

Before the test, each child's functional leg length (distance from the palpation of the greater trochanter of the right femur to the point on the floor located just anterior and medial to the medial malleolus on the ipsilateral side) was measured in the standing position and recorded in centimeters. The subject was

TABLE 1

Means and Standard Deviations for Each Gait Factor at Each Age and Speed of Gait

Gait Factor and Age	n	Slow Gait		Free Gait		Fast Gait	
		$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
Stride length (cm)							
3 yr	15	59.85	8.08	70.51	10.85	84.41	13.81
5 yr	16	65.66	8.88	86.23	9.59	100.47	8.95
Step length (cm/cm leg length)							
3 yr	15	0.71	0.14	0.78	0.12	0.93	0.15
5 yr	16	0.64	0.11	0.81	0.09	0.95	0.10
Stride length (cm)							
3 yr	15	8.81	2.15	8.22	2.56	6.84	2.05
5 yr	16	8.63	3.43	8.00	2.41	6.21	2.23
Angle of feet (°)							
3 yr	15	4.31	13.30	5.05	15.38	7.56	14.55
5 yr	16	8.43	14.38	6.35	12.22	7.27	12.31
Cadence (steps/minute)							
3 yr	15	103.00	27.07	143.73	30.17	190.93	38.14
5 yr	16	87.56	19.39	125.63	32.10	155.43	24.14

then seated on a chair at the end of a paper measuring 5 ft by 20 in. Four round, thin, felt pads* 2 cm in diameter were secured to the sole of each shoe at the following landmarks identified by palpation: back center of the heel, bases of the first and fifth toes at the metatarsophalangeal joint and distal end of the second toe. The lateral landmarks were used for orientation purposes; the other landmarks were used at the completion of the study to measure the dependent variables. Markers of each foot were inked with a different color. Each child walked once up and down the 5-ft length of paper to become familiar with the testing procedure. The child was again seated, and markers were re-inked in preparation for the test. The child was then asked to walk normally to the chair at the end of a 26-ft length paper. A stopwatch timed the walk. Speed was controlled by asking the subjects to walk at the speed of the tester who had been trained to walk at 70 cm/sec and 120 cm/sec.[1, 2, 23, 24] Order of slow and fast speeds were randomly presented to subjects. Immediately after the walking, the motor section of the McCarthy Scales of Children's Abilities was administered.[21]

* Dr. Scholl's® Felt Corn Pads, Scholl, Inc, Chicago, IL 60610.

Gait Variables

The gait variables were measured from imprints on the paper in the following manner. The first and last 3 ft of paper were discarded. *Stride length, step length,* and *stride width* were measured on the remaining 20 ft of paper (Figure). Stride length was not adjusted for leg length; however, step length was adjusted by the step factor ratio of step length/functional leg length.[1, 23] This procedure determined whether an older child's longer stride was due solely to a longer leg length. *Included angle of feet* was determined from the angle of foot placement (Figure). The sum of a successive right and left foot angle equaled an included angle. *Cadence* was the number of step imprints per minute. Within-subject variability of gait factors was defined as the variance of each factor for each subject. Motor development level was measured by the raw score and scale index number of the motor section of the McCarthy Scales of Children's Abilities.[21]

Means for all gait factors were analyzed using two-way analysis of variance (speed by age) and specific differences were analyzed by the Newman-Keuls test.

TABLE 2

Analysis of Variance with Repeated Measures: Effects of Age and Gait Speed on the Mean Stride Length

Source of Variance	*df*	MS	*F*	*p*
Speed	2,58	6922.66	88.42	<.001
Age	1,29	3656.81	23.77	<.001
Speed × age	2,58	263.44	3.36	<.05

TABLE 3

Analysis of Variance with Repeated Measures: Effects of Age and Gait Speed on the Mean Step Length

Source of Variance	*df*	MS	*F*	*p*
Speed	2,58	.54	57.13	<.001
Age	1,29	.00	.03	NS
Speed × age	2,58	.03	2.69	NS

TABLE 4

Analysis of Variance with Repeated Measures: Effects of Age and Gait Speed on the Mean Stride Width

Source of Variance	*df*	MS	*F*	*p*
Speed	2,58	39.08	16.65	<.001
Age	1,29	3.02	.21	NS
Speed × age	2,58	.58	.25	NS

TABLE 5

Analysis of Variance with Repeated Measures: Effects of Age and Gait Speed on Cadence

Source of Variance	*df*	MS	*F*	*p*
Speed	2,56	46061.00	113.51	<.001
Age	1,28	13425.00	7.76	<.01
Speed × age	2,56	1107.00	2.73	NS

The *F* distribution was used to determine homogeneity of variance between the two ages for various gait factors. Variance for each group was calculated by summing each child's variance. Finally, the Pearson product-moment correlation was used to analyze the relationships between gait factors at each age and speed and between gait factors and raw motor scores on the McCarthy Scales for each gait speed of the combined ages.

Reliability

Two raters administered and scored the McCarthy Scales of Children's Abilities for two children and scored gait test papers for three children. Interrater reliability was 93 percent and 100 percent, respectively.

RESULTS

Table 1 presents the means and standard deviations of 3- and 5-year-olds for each gait factor at each speed. A preliminary data analysis determined that right and left stride and step lengths were not statistically different at each age group and speed and, therefore, only the right stride and step lengths were considered. Similarly, the set speed of gait of the 3- and 5-year-old groups at slow, free, and fast speeds was not significantly different. The gait speeds, therefore, were combined and mean speeds were as follows: slow, 51.9 cm/sec; free, 83.8 cm/sec; and fast, 128.6 cm/sec. Finally, when the Scale Index Scores of the McCarthy Scales of Children's Abilities were adjusted for age, the scores of the two groups were found to be equivalent.

Stride Length

There were significant differences in mean stride length due to speed of gait, age, and the interaction of speed and age (Table 2). Stride length for combined age groups at a fast speed was significantly longer ($p < .01$) than at slow or free speeds. Mean stride length at free speed was significantly longer ($p < .01$) than at slow speed. At both free and fast speeds, the 5-year-old group had significantly longer strides ($p < .01$) than the 3-year-old group at the same speeds; however, the difference was not significant between the age groups at slow speed.

Within subjects, the 3-year-old group, compared with the 5-year-old group, had significantly greater variance of stride length at slow ($F = 9.48$, $df = 14, 15$, $p < .001$) and free ($F = 3.04$, $df = 14, 15$, $p < .025$) speeds. No significant difference was present at a fast speed.

TABLE 6
Correlations Between Gait Factor at Each Age and Speed

Gait Factors	3-yr-olds Step Length (adjusted)	3-yr-olds Stride Width	3-yr-olds Angle of Feet	3-yr-olds Cadence	5-yr-olds Step Length (adjusted)	5-yr-olds Stride Width	5-yr-olds Angle of Feet	5-yr-olds Cadence
Slow Gait								
Stride length	.15	.27	−.63[a]	−.57[b]	.88[c]	−.64[d]	.55[b]	−.08
Step length (adjusted)		.21	−.09	−.14		−.48[e]	.54[b]	.02
Stride width			−.53[c]	−.23			−.72[c]	−.11
Angle of feet				.08				.24
Free Gait								
Stride length	.82[c]	−.23	−.30	.00	.69[d]	−.24	.34	−.47[e]
Step length (adjusted)		−.33	−.16	.18		−.48	.43[e]	−.35
Stride width			.13	−.49[e]			−.85[c]	.23
Angle of feet				.03				−.08
Fast Gait								
Stride length	.88[c]	−.12	−.05	.08	.74[c]	−.04	−.39	−.48[e]
Step length (adjusted)		−.22	.04	.18		.11	−.24	−.31
Stride width			−.53[b]	−.06			−.64[d]	−.15
Angle of feet				−.13				.06

[a] $p < .01$, [b] $p < .025$, [c] $p < .0005$, [d] $p < .005$, [e] $p < .05$.

Step Length (Adjusted for Leg Length)

Significant differences in mean step length were due only to speed of gait (Tab. 3). Mean step length at fast speed was significantly longer than at slow ($p < .01$) or free ($p < .01$) speeds. Mean step length at free speed was significantly longer ($p < .01$) than at slow. When mean step lengths of 3- and 5-year-olds were compared at each speed, no significant differences were present.

Within subjects, the 3-year-old group, compared with the 5-year-old group, had significantly greater variance of step length at slow ($F = 4.0$, $df = 14, 15$, $p < .01$) and free ($F = 5.54$, $df = 14, 15$, $p < .001$) speeds. At a fast speed, variability of step length of the 3-year-old group equaled the variability of the 5-year-old group.

Stride Width

Significant differences in mean stride width were due only to speed of gait (Tab. 4). Mean stride width was significantly narrower at a fast speed than at a free ($p < .01$) or slow ($p < .01$) speed. There was no significant difference in mean stride width between free and slow speeds. When mean stride width of 3-year-olds and 5-year-olds was compared at each speed, no significant differences were present.

Within subjects, the 5-year-old group, compared with the 3-year-old group, had significantly greater variance of stride width at a slow speed ($F = 6.8$, $df = 14, 15$, $p < .001$). Within-subject variability of the 3-year-old group approximately equaled that of the 5-year-old at free speed, and no significant difference was present at fast speed.

Included Angle of Feet

Included angle of feet was not significantly different even at the .10 level for speed, age, or the interaction of speed and age. When included angle of feet of 3- and 5-year-olds was compared at each speed, no significant differences were present.

Within-subject variability of included angle of feet of the younger group approximately equaled that of the older group at slow and fast speeds. No difference was present at a free speed.

Cadence

Differences in cadence were significant for speed and age but only reached the .10 level for the interaction of speed and age (Tab. 5). There was a significantly higher cadence at fast than at free ($p < .01$) or slow ($p < .01$) speeds. Also, there was a significantly higher cadence at free than at slow speed ($p < .01$).

When the cadence of the 3- and 5-year-old groups was compared at each gait speed, the cadence was not significantly different at slow or free speeds. Only at a fast speed did the older group have a significantly higher cadence than the younger group ($p < .01$).

TABLE 7

Correlations Between Gait Factors (Ages Combined) at Each Gait Speed, and Raw Motor Scores on the McCarthy Scales of Children's Abilities (df = 29)

Gait Factors	Slow	Free	Fast
Stride length	.42[a]	.51[b]	.60[c]
Step length (adjusted)	−.23	.19	.16
Stride width	.07	.01	.07
Angle of feet	−.03	−.13	−.14
Cadence	−.40[d]	−.31[e]	−.40[d]

[a] $p < .01$, [b] $p < .005$, [c] $p < .0005$, [d] $p < .025$, [e] $p < .05$.

Correlations of Gait Factors

Table 6 presents the correlations between gait factors at each age and speed. For the 5-year-old group, significant correlations existed between stride and step length at all speeds. In the 3-year-old group, significant correlations between stride and step length occurred only at free and fast speeds.

Significant correlations were also present between stride or step length and other gait factors. When stride length and width were correlated, only the older group at a slow speed demonstrated a significant inverse relationship. When step length and stride width were correlated, significant inverse relationships were present in the 5-year-old group at both slow and free gait speeds. Five-year-olds at a slow speed had similar positive correlations between stride or step length and included angle of feet, whereas 3-year-olds at the slow speed had an inverse correlation between stride length and included angle of feet and no significant correlation between step length and included angle of feet. At free or fast speeds, the only significant correlation between stride or step length and included angle of feet was a positive correlation between step length and included angle of feet for 5-year-olds at a free speed. At a slow speed, only the 3-year-olds with a longer stride length had a lower cadence. At free and fast speeds, only 5-year-olds with longer stride lengths had lower cadences. At neither age nor at any speed did step length significantly correlate with cadence.

At each age and speed, with the exception of 3-year-olds at a free speed, children with a larger stride width had a significantly narrower included angle of feet. Only 3-year-olds at a free speed had a significant relationship between stride width and cadence; those with a lower cadence had a wider stride. No significant correlations between included angle of feet and cadence were present at either age or any speed.

Table 7 presents correlations between gait factors and raw scores of the motor section of the McCarthy Scales of Children's Abilities. Only stride length and cadence significantly correlated with the raw motor score. The raw motor score increased as stride length increased at each gait speed. As the raw motor score increased, cadence decreased at each gait speed.

DISCUSSION

The results of this study emphasize the complexity of gait and gait development in 3- and 5-year-old children. Perhaps the interrelationships between gait factors, age, and speeds, as well as the relationships among gait factors, present a more realistic analysis of gait in these subjects than if the variables were considered in isolation.

Variability of Gait Factors

Because adults ambulate with a high consistency of gait details within a variety of speeds, one would expect children with a more mature gait to demonstrate less variability of gait factors within a variety of speeds. As expected, at slow and free speeds, the older children had less within-subject variability of stride and step length and, therefore, had fewer extraneous stride or step length movements than the younger children. At slow and free speeds, the older children were perhaps better able to control stride and step length despite the increased need for stability at slower gait speeds. At a fast speed with less need for medial-lateral stability,[2, 15] and presumably less time spent in a unilateral support position, the 3-year-olds probably had less difficulty than at slower gait speeds and, therefore, variability of stride and step length at a fast speed was not statistically different from that of the 5-year-olds.

The 5-year-old group had a greater within-subject variance of stride width at slow speed than the 3-year-old group. These unexpected results help support the theories that the gait of 5-year-olds is not fully matured.[14, 19] Perhaps stride-width consistency is established together with a cluster of other gait and skeletal factors, as will be discussed later, or perhaps Burnett's discussion of Gesell and Amatruda's concept of reciprocal interweaving can be applied.[3] The 5-year-old may have a more consistent stride or step length at a slow speed, but may temporarily revert to a more variable stride width in order to maintain lateral stability, especially at a slow speed.

Within-subject variance of included angle of feet of the two age groups was not significantly different. Variability of included angle of feet, therefore, may be established at an age prior to 3, or perhaps it is incorrect to consider included angle of feet without also considering other factors such as stride length and width.

In general, within-subject variability of gait factors as one means of assessing gait maturation has often been overlooked. Further research is needed to determine how variability of children's gait factors decreases, and which gait factors and conditions can be used appropriately to determine gait maturity. Consistency of gait factors in addition to the factors of increased age and varying speeds may better describe the development of preschool children's gait.

Stride and Step Length

As hypothesized, both stride and step length significantly increased with speed in both groups. Therefore, the mature relationship of increasing stride or step length with speed[12, 13, 23] is established before the age of three. Although it was expected that both stride and step length would increase with age, only stride length, not step length (adjusted for leg length) increased. This result is in agreement with the studies on adults[10] and older[1, 2] children. At free gait speed, an adult male's stride length is systematically related to height.[10] Sutherland[2] and Scrutton[1] found that at a free gait speed, minimal change in children's step length (adjusted for leg length) occurs subsequent to 3 years of age.

As expected, the 5-year-olds, compared with the 3-year-olds, had a significantly longer stride length at free and fast speeds. Either the difficulty both groups may have experienced walking at a slower gait speed, or lack of the medial-lateral and anterior-posterior stability in the supporting limb[2, 15] at a slow gait speed may have caused a similarity of 3- and 5-year-olds' stride lengths at a slow speed. The finding that the stride length of the 5-year-old group was not significantly longer than the 3-year-old group at a slow speed, as well as the lack of consistency of stride width at a slow speed, may indicate absence of a fully mature gait pattern in the 5-year-old group.

Because adult gait is a highly automated and consistent motor activity and step length is a part of stride length, one would expect to find a consistent relationship between stride and step length in both the adult[11] and preschooler gait. At both ages and at all speeds, except for 3-year-olds at a slow speed, the expected significant stride-step length correlation was present. The low stride-step length correlation of the 3-year-old group at a slow speed supports the previous observation that the slower speed was more difficult, especially for the younger children. Previous children's gait studies have not addressed this issue.

Stride Width and Included Angle of Feet

Because Morton and Fuller[25] suggest that the stride width and angle of foot placement together meet the adult's need for medial-lateral and anterior-posterior stability, stride width, and included angle of feet will, therefore, be discussed at the same time. The increased need for the lateral stability at a slower speed may have been the factor that caused the children's wider stride at a slower speed. The responses of the children on some of the tasks in the McCarthy Scales of Children's Abilities indicated that balance was not fully developed. In contrast to the adult,[13, 24] the included angle of feet of the 3- to 5-year-old children did not significantly decrease, a finding that again may be attributed to the need for lateral stability and balance in this group of children. As in the adult, the stride width and the angle of foot placement together help meet the children's gait stability needs.[13, 24] The method by which preschool children combine the two gait factors to accomplish gait stability with modified speed, however, differs from that of adults. Either stride width and included angle of feet are established at an early age, or the development of both factors are indeed more complex than previously thought. The complexity of gait development is demonstrated by the very different relationships in the 3- and 5-year-old groups when stride or step length and included angle of feet were correlated. Only the 3-year-old group at a free speed did not have a significant inverse relationship between stride width and included angle of feet (Tab. 2). The effect of age, speed, and within-subject variability on stride width and included angle of feet demonstrate that an adult pattern of gait with regard to these gait factors has not yet become established in these 3- and 5-year-old children. The varying relationships between stride width or included angle of feet (Tab. 2) and other gait factors at specific ages or speeds, as well as the unexpected direction of the relationship of stride width change due to speed, emphasizes the complex methods by which medial-lateral and anterior-posterior stability requirements are satisfied in a gait pattern that is not fully matured. Further study is required to understand the development of stride width and included angle of feet. Additional variables should be included such as angle of femoral neck, tibial femoral angle,[3] pelvic span as compared with ankle span, rotations of lower extremities and trunk, height of center of gravity, and duration of single stance during gait.

Cadence

Sutherland determined that a mature gait occurred at 3.4 to 4 years of age.[2] The criterion for gait maturity at free speed was a decrease in cadence with a concomitant increase in step length and walking velocity. In the present study, however, it was found that only at a fast gait speed did the 5-year-olds have a significantly lower cadence than the 3-year-olds. The difference in results may be because other studies either used fewer preschool children[5] or statistically analyzed data for a different purpose.[2] Other studies did not statistically analyze cadence for the interaction of both age and gait speed.[1, 4] Because the fast gait speed may be the most automatic of the speeds, the older children may have demonstrated the more mature gait pattern in regard to cadence.

When considering the variety of correlations between cadence and stride length (Tab. 2) of the 3- and 5-year-olds, it is apparent that the method by which the two age groups have attained a cadence at a designated speed has not been fully established. Leg length, the need for anterior-posterior and medial-lateral and single stance mobility, and the development of stride width and angle of feet are all factors that may determine the manner in which cadence is established.

Motor Development and Gait Factors

In this study, the initial assumption was that children with more mature gaits would have a higher motor development level; however, only stride length (unadjusted for leg length) and cadence correlated significantly with the raw motor scores. Because both stride length and cadence are dependent on leg length or height, the correlations may have reflected the longer leg lengths of the older children. A more in-depth motor evaluation needs to be used to determine whether there are more subtle motor developments related to gait factors and gait development. Older children accomplished some of the motor tasks on the McCarthy Scales with greater ease than the younger children although they did not always obtain a higher score on the task. The total possible points earned for these particular tasks, however, were often minimal, or perhaps the scoring system was not sufficiently graded to incorporate subtle developmental accomplishments. The use of a detailed motor test could shed more light on the developmental skills that relate to a more mature gait. The relationships of motor and gait development is an area that warrants further investigation.

Observations and Implications

Slow and fast gait speeds should have been controlled at 70 and 120 cm/sec respectively. The actual average slow speed (51.9 cm/sec) was slower than anticipated. The planned slow speed (70 cm/sec) was, therefore, more similar to the average free speed of 83.8 cm/sec than had originally been anticipated. Because the children were always asked to walk first at a free speed, they may have identified the proposed slow speed as too close to their normal free speed and, therefore, slowed their gait and lagged behind the investigator. The actual fast gait speed of 128.6 cm/sec was very similar to the intended speed, 120 cm/sec.

During the testing procedure for both age groups, the slow gait speed appeared to be the most difficult and the fast gait speed the least difficult. This hierarchy of relative difficulty was based on observations of facial expressions and upper extremity movements. The trend can also be seen in some of the objective gait factor measurements previously discussed.

Conclusions

The results and implications of this study can only be cautiously generalized beyond the group of children studied. Although analysis of variance has as one of its assumptions the presence of a random sample, this study did not have a totally random sample. Furthermore, the sample was relatively small. Also, although this study involved the linear and angular gait measurements that can be measured by the feet, important temporal and angular measurements of more proximal areas involved in gait were not included. Given the above cautions, however, this study has significance and implications for future study.

The gait of two normal 3- and 5-year-old groups has been described and compared at three different gait speeds using a clinical method that can be easily and inexpensively duplicated. The statistical testing of gait data collected for the two groups at three different speeds has emphasized the complexity of gait development between different aged children and in comparison to adults. To obtain more information about the influence of gait speed on gait factors, researchers in future gait studies of preschool children should continue to control speed of gait as they test gait factors. Future gait studies should also involve additional numbers of subjects and statistically test collected data to separate spurious findings attributable only to chance from those of statistical significance. Motor development and gait development should be studied together so that physical therapists working with handicapped preschool children will have a more knowledgeable basis for measuring and treating developmental disabilities.

Acknowledgments. The author wishes to thank Jane Coryell, PhD, and Cynthia Norkin for their advice in the research and writing of this article.

REFERENCES

1. Scrutton DR: Footprint sequences of normal children under five years old. Dev Med Child Neurol 11:44-53, 1969
2. Sutherland D, Olshen RA, Copper L, et al: The development of mature gait. Read at Orthopedic Research Society of the American Academy of Orthopedic Surgeons, Dallas, 1978, 1-19
3. Burnett CN, Johnson EW: Development of gait in childhood Part I and II. Dev Med Child Neurol 13:196-215, 1971
4. Endo B, Kimura T: External force of foot in infant walking. J Faculty of Science, The University of Tokyo, section 5, vol 4, part 2:103-117, March, 1972
5. Grieve DW, Gear RJ: The relationships between length of stride, step frequency, time of swing and speed of walking for children and adults. Ergonomics 5:379-399, 1966
6. Okamoto T, Kumamoto M: Electromyographic study of learning process of walking in infants. Electromyography 12:149-151, 1972
7. Horton ME: Development of movement in young children. Physiotherapy 57:148-158, 1971
8. Stott L: Child Development: An Individual Longitudinal Approach. New York, NY, Holt, Rinehart & Winston General Book, 1967, pp 20-144
9. Gesell A: Reciprocal interweaving in neuromotor development. J Comp Neurol 70:161-180, 1939
10. Murray MP, Drought AB, Kory RC: Walking patterns of normal men. J Bone Joint Surg [Am] 46:335-360, 1964
11. Murray MP: Gait as a total pattern of movement. Am J of Phys Med 46:290-333, 1967
12. Andriacci TP, Ogle JA, Galonte JO: Walking speed as a basis for normal and abnormal gait measurement. J Biomech 10:261-268, 1978
13. Murray MP, Kory RC, Clarkson BH: Comparison of free and fast speed walking patterns of normal men. Am J of Phys Med 45:8-24, 1966
14. Bernstein NA: Coordination and Regulation of Movements. New York, NY, Pergamon Press Inc, 1967, pp 6-95
15. Stratham L, Murray MP: Early walking patterns of normal children. Clin Orthop 79:8-22, 1971
16. McGraw MG: The Neuromuscular Maturation of the Human Infant. New York, NY, Hafner Publishing Co, 1963, pp 74-92
17. Shirley MM: The First Two Years. A Study of Twenty-five Babies I: Postural and Locomotor Development. Minneapolis, MN, University of Minnesota Press, 1931, pp 52-168
18. Popova T: Rudiments of erect forward movement before independent walking in children. In Bernstein NA (ed): Investigations on the Biodynamics of Walking, Running, Jumping. Central Scientific Institute of Physical Culture, Moscow, 1940, chap 4, pp 34-35
19. Tsurumi N: Electromyographic study on the gait of children. Journal of the Japanese Orthopedic Association 43:611-628, 1978
20. Connolly K: Response speed, temporal sequencing and information processing in children. In Connolly K (ed): Mechanisms of Motor Skill Development. London, England, Academic Press Inc, 1970
21. McCarthy D: Manual for McCarthy Scales of Children's Abilities. New York, NY, Psychological Corp, 1972
22. Ogg, HL: Measuring and evaluating the gait patterns of children. Phys Ther 43:717-720, 1963
23. Smidt GL: Hip motion and related factors in walking. Phys Ther 51:9-21, 1971
24. Murray MP, Kory RC: Walking patterns of normal women. Arch Phys Med Rehabil 51:637-650, 1970
25. Morton DJ, Fuller DD: Human Locomotion and Body Form. Baltimore, MD, Williams & Wilkins, 1952