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Joint angle parameters in gait: Reference data for normal subjects, 10–79 years of age

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Abstract—In the laboratory, gait analysis is often completed with goniometry. In a previous article (*Journal of Rehabilitation Research and Development, Vol. 30 No. 2*), reference data for basic gait parameters were presented. The aim of this study was to provide such reference data for joint angle parameters. Two hundred and thirty-three healthy subjects (116 men and 117 women) 10–79 years of age, were entered into the study. The measurements were made in a gait laboratory with electrogoniometers with Lamoreaux type of exoskeleton. A series of reference tables for slow, normal and fast speed are presented. Means, standard deviations, coefficients of variation, 95% confidence intervals, and 95% prediction intervals were calculated. We found minor changes with age, no differences between right and left side, significant sex differences, and significant changes with increasing gait speed. The reference data are considered valid in an indoor laboratory situation. If gait analysis is used for evaluation of disabled people, a comparison must be made with data from healthy people. This study provides such normative data for joint angle parameters.

Key words: *gait analysis, goniometry, joint angles, reference data.*

INTRODUCTION

The basic gait parameters are gait speed, step length, and step frequency. In a previous article, reference data of such parameters were presented for men and women, aged 10–79 years (1). Such reference data are important in all gait analysis. However, in the laboratory gait analysis often includes goniometry (i.e., measurement of joint angles); therefore, there is also a need for reference data for such measurements. In this article, we present reference data on hip and knee motion for men and women of different ages.

Electrogoniometry represents a simple and reliable method for measuring joint motion during gait (2–5). The most frequent methods of presenting such data are as figures of total joint excursion during gait (3,6–9), as a plot of joint angle against time (10), or as angle/angle diagrams (11–13).

Goniometer measurements have been reported from studies of men (2–4,6–8), and women (3,9,14). Age effects on joint excursions during gait have also been studied by several authors (6–10,14). However, most of these studies have been done on small numbers of subjects, and cannot be used as reference data. The aim of this study was to present age and sex specific joint angle data obtained during gait analysis.

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METHODS AND MATERIAL

Subjects

Originally, 240 healthy subjects were examined. However, seven subjects were excluded from the original material, three girls and three boys aged 0–9 years, and one subject aged 80 years, because they were too few to represent a separate age-group. The remaining 233 subjects, aged 10–79 years, and consisting of 116 men and 117 women, were divided into 7 age-groups. Age and sex characteristics are shown in **Table 1.**

Gait Analysis

We used a modification of the gait analysis method that was developed at the Biomechanics Laboratory, University of California, Berkeley, California and the Department of Orthopaedic Surgery at the University of Uppsala, Sweden. The gait laboratory has a 10-meter long walkway, including acceleration and deceleration distances. Two photocells with 5.5 m intervals, self-aligning electrogoniometers, a computer, and a plotter constitute the equipment. The measurements were performed between the two photocells. Potentiometers with self-aligning exoskeleton were used (15,16). Heel strike was indicated by means of a manual switch. Basic temporal gait parameters and joint angle data were collected during slow, normal, and fast gait. The subjects had to walk between the photocells 13 times, 10 times without goniometers, and 3 times with goniometers. The mean of the three goniometer measurements was calculated for each joint angle parameter. The subjects were asked to walk at three self-selected gait speeds: slow, normal, and fast.

Table 1.
Age and sex characteristics of the subjects.

Age group years	Number		
	Men	Women	Total
10-19	27	27	54
20-29	15	15	30
30-39	15	15	30
40-49	15	15	30
50-59	15	15	30
60-69	15	15	30
70-79	14	15	29
Total	116	117	233

Statistical Methods

Analysis of variance (ANOVA) and regression analyses were performed using standard methods (17,18). All computations were made with a commercial statistics package for a personal computer (SYSTAT /SYGRAPH for Windows).

RESULTS

Age-related Changes (Tables 2 a-c and 3 a-c)

There were minor changes in joint angle data with age. For many of these data the changes were statistically significant. Regression analysis showed an increase in knee angle at midstance of about 0.5° per decade, and a decrease of the knee swing of 0.5-0.8° per decade. The least changes were seen in hip flexion-extension. The age-related changes were slightly more pronounced at slow gait speed than at fast speed.

Side Differences (Tables 4 a-c)

Two-sided z-test showed no significant changes for most parameters, irrespective of gait speed.

Sex Differences (Tables 5 a-c)

There was a statistically significant difference in almost all parameters, similar at all speeds. In the knee parameters the men had larger excursions than women, but in the hip flexion-extension the values were slightly lower for men.

Gait Speed (Appendix Table 6)

The mean gait speed was 91.7 (SD = 17.9) cm/s at low speed, 119.0 (SD = 17.5) cm/s at normal speed, and 153.5 cm/s (SD = 22.7) at fast speed. All joint angles increased with increasing gait speed. This increase was statistically significant ($p > 0.05$) for all variables. Knee angle at midstance increased from about 15° to 24° in men, and from about 12° to 20° in women. Knee swing increased from about 65° to 68° in men, and from 61° to 68° in women. Hip flexion-extension increased from about 43° to 53° in men, and from 42° to 51° in women. The relation between gait speed and joint angle parame-

Table 2a.
Joint angles. Changes with age. Men (N = 116). Slow gait.

Variable	One-way ANOVA *F*-value df = 7	*p*-value	Regression analysis Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	1.48	N.S.	+0.5	1.81	N.S.
Left knee, midstance	2.35	$p<0.05$	+0.5	1.63	N.S.
Right knee, swing	2.06	N.S.	−0.7	−2.68	$p<0.01$
Left knee, swing	2.16	$p<0.05$	−0.6	−2.01	$p<0.05$
Right hip, flex-ext	1.08	N.S.	+0.1	0.48	N.S.
Left hip, flex-ext	1.49	N.S.	+0.3	0.95	N.S.

Table 2b.
Joint angles. Changes with age. Men (N = 116). Normal gait.

Variable	One-way ANOVA *F*-value df = 7	*p*-value	Regression analysis Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	2.50	$p<0.05$	+0.5	2.00	$p<0.05$
Left knee, midstance	2.34	$p<0.05$	+0.5	1.79	N.S.
Right knee, swing	2.60	$p<0.05$	−0.4	−1.61	N.S.
Left knee, swing	2.50	$p<0.05$	−0.6	−2.17	$p<0.05$
Right hip, flex-ext	0.75	N.S.	+0.2	0.65	N.S.
Left hip, flex-ext	2.15	$p<0.05$	+0.4	1.22	N.S.

Table 2c.
Joint angles. Changes with age. Men (N = 116). Fast gait.

Variable	One-way ANOVA *F*-value df = 7	*p*-value	Regression analysis Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	1.13	N.S.	+0.3	1.35	N.S.
Left knee, midstance	1.49	N.S.	+0.1	0.30	N.S.
Right knee, swing	2.66	$p<0.05$	−0.4	−1.59	N.S.
Left knee, swing	3.45	$p<0.01$	−0.6	−1.88	N.S.
Right hip, flex-ext	0.74	N.S.	0.0	−0.04	N.S.
Left hip, flex-ext	1.78	N.S.	+0.1	0.24	N.S.

N = Number of subjects N.S. = Not significant

Table 3a.
Joint angles. Changes with age. Women (N = 117). Slow gait.

Variable	One-way ANOVA		Regression analysis		
	F-value df = 7	*p*-value	Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	0.85	N.S.	+0.4	1.65	N.S.
Left knee, midstance	1.47	N.S.	+0.3	1.54	N.S.
Right knee, swing	2.29	$p<0.05$	−0.7	−2.52	$p<0.05$
Left knee, swing	3.28	$p<0.01$	−0.9	−3.29	$p<0.01$
Right hip, flex-ext	2.17	$p<0.05$	−0.0	−0.06	N.S.
Left hip, flex-ext	2.90	$p<0.01$	−0.1	−0.23	N.S.

Table 3b.
Joint angles. Changes with age. Women (N = 117). Normal gait.

Variable	One-way ANOVA		Regression analysis		
	F-value df = 7	*p*-value	Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	1.83	N.S.	+0.5	2.21	$p<0.05$
Left knee, midstance	2.47	$p<0.05$	+0.6	2.93	$p<0.01$
Right knee, swing	3.04	$p<0.01$	−0.8	−3.08	$p<0.01$
Left knee, swing	3.44	$p<0.01$	−0.7	−2.65	$p<0.01$
Right hip, flex-ext	1.53	N.S.	+0.3	1.03	N.S.
Left hip, flex-ext	4.04	$p<0.01$	+0.1	0.44	N.S.

Table 3c.
Joint angles. Changes with age. Women (N = 117). Fast gait.

Variable	One-way ANOVA		Regression analysis		
	F-value df = 7	*p*-value	Change degrees per decade	*t*-value	*p*-value
Right knee, midstance	1.62	N.S.	+0.5	2.05	$p<0.05$
Left knee, midstance	2.00	N.S.	+0.5	2.24	$p<0.05$
Right knee, swing	2.19	$p<0.05$	−0.5	−2.15	$p<0.05$
Left knee, swing	2.13	$p<0.05$	−0.5	−1.97	N.S.
Right hip, flex-ext	1.70	N.S.	+0.2	0.67	N.S.
Left hip, flex-ext	3.30	$p<0.01$	−0.2	−0.51	N.S.

N = Number of subjects N.S. = Not significant

Table 4a.
Joint angles. *Z*-Test for side difference. Men (N = 116) and Women (N = 117). Slow gait.

Variable	Sex	*z*-value	*p*-value
Knee, midstance	M	0.31	N.S.
Knee, midstance	F	0.31	N.S.
Knee, swing	M	0.37	N.S.
Knee, swing	F	0.37	N.S.
Hip, flex-ext	M	1.84	N.S.
Hip, flex-ext	F	1.85	N.S.

Table 4b.
Joint angles. *Z*-Test for side difference. Men (N = 116) and Women (N = 117). Normal gait.

Variable	Sex	*z*-value	*p*-value
Knee, midstance	M	0.41	N.S.
Knee, midstance	F	1.07	N.S.
Knee, swing	M	1.02	N.S.
Knee, swing	F	0.55	N.S.
Hip, flex-ext	M	1.60	N.S.
Hip, flex-ext	F	2.28	$p<0.05$

Table 4c.
Joint angles. *Z*-Test for side difference. Men (N = 116) and Women (N = 117). Fast gait.

Variable	Sex	*z*-value	*p*-value
Knee, midstance	M	0.24	N.S.
Knee, midstance	F	1.52	N.S.
Knee, swing	M	0.96	N.S.
Knee, swing	F	0.49	N.S.
Hip, flex-ext	M	1.63	N.S.
Hip, flex-ext	F	2.84	$p<0.01$

M = Males
F = Females
N = Number of subjects
N.S. = Not significant

Table 5a.
Joint angles. Test for sex differences. Men (N = 116) and Women (N = 117). *Z*-test. Slow gait.

Variable	z-value	p-value
Right knee, midstance	7.46	$p<0.001$
Left knee, midstance	5.39	$p<0.001$
Right knee, swing	5.30	$p<0.001$
Left knee, swing	5.72	$p<0.001$
Right hip, flex-ext	1.71	N.S.
Left hip, flex-ext	1.29	N.S.

Table 5b.
Joint angles. Test for sex differences. Men (N = 116) and Women (N = 117). *Z*-test. Normal gait.

Variable	z-value	p-value
Right knee, midstance	5.22	$p<0.001$
Left knee, midstance	6.67	$p<0.001$
Right knee, swing	5.27	$p<0.001$
Left knee, swing	6.46	$p<0.001$
Right hip, flex-ext	2.26	$p<0.05$
Left hip, flex-ext	1.25	N.S.

Table 5c.
Joint angles. Test for sex differences. Men (N = 116) and Women (N = 117). *Z*-test. Fast gait.

Variable	z-value	p-value
Right knee, midstance	5.81	$p<0.001$
Left knee, midstance	7.49	$p<0.001$
Right knee, swing	4.83	$p<0.001$
Left knee, swing	5.50	$p<0.001$
Right hip, flex-ext	2.40	$p<0.05$
Left hip, flex-ext	1.04	N.S.

N = Number of subjects
N.S. = Not significant

ters is also shown in a series of regression diagrams (**Figures 1 a,b, 2 a,b,** and **3 a,b**). There were almost no side differences.

Reference Data (Appendix)

Reference data are shown in the Appendix as joint angles at slow, normal, and fast gait speed for men and women respectively (**Tables 1 a-b, 2 a-b,** and **3 a-b**). Means, standard deviations (SD), coefficients of variation, 95 percent confidence intervals and 95 percent prediction intervals have been calculated. In our opinion, the differences between age-groups are small, and in practice the same reference data can be used for all age-groups (see DISCUSSION). In **Tables 4 a-c** and **5 a-c** joint angle data are presented by age-group for slow, normal, and fast gait speed and in **Table 6**, joint angle data are presented by gait speed for men and women.

DISCUSSION

Goniometry can be used in different ways. We have chosen to present a few joint angle parameters, that can be easily defined during the gait cycle, and

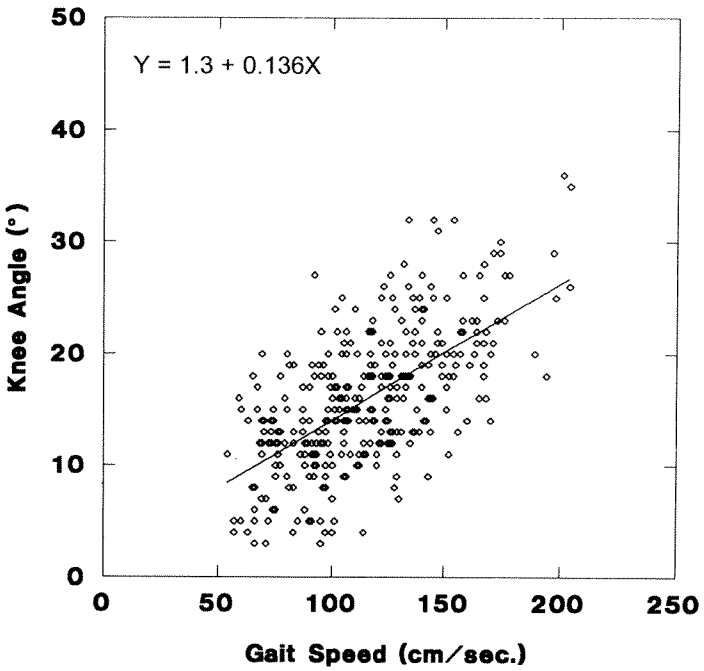

Figure 1b.
Regression diagrams showing the relation between gait speed and right knee angle during stance. The slopes were statistically significant ($p<0.001$).

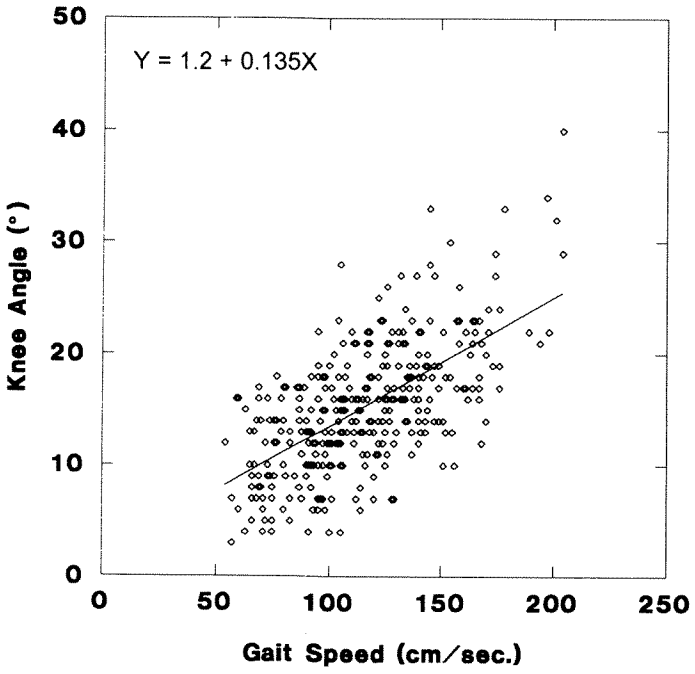

Figure 1a.
Regression diagrams showing the relation between gait speed and left knee angle during stance. The slopes were statistically significant ($p<0.001$). A) left side, B) right side.

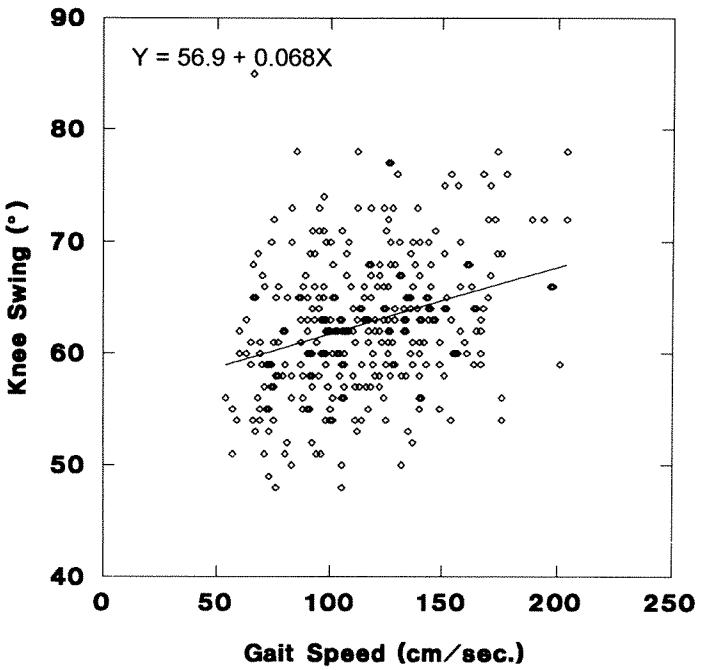

Figure 2a.
Regression diagrams showing the relation between gait speed and left knee swing. The slopes were statistically significant ($p<0.001$).

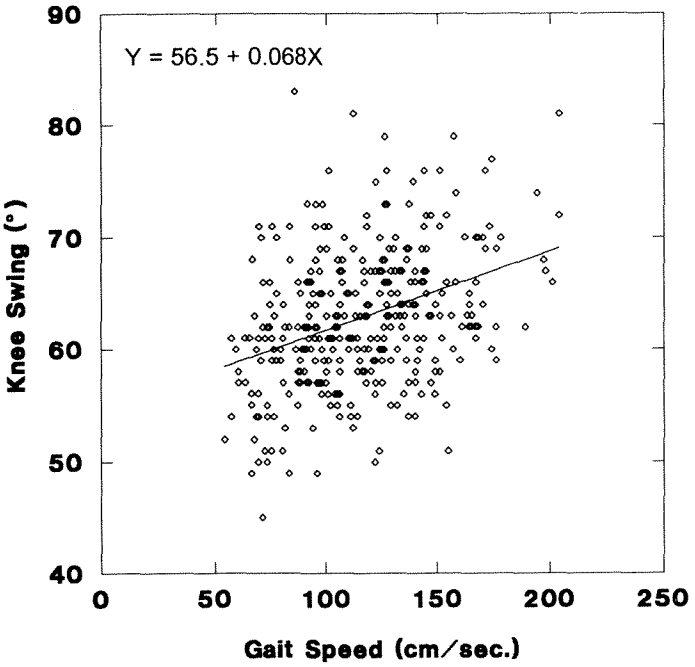

Figure 2b.
Regression diagrams showing the relation between gait speed and right knee swing. The slopes were statistically significant ($p < 0.001$).

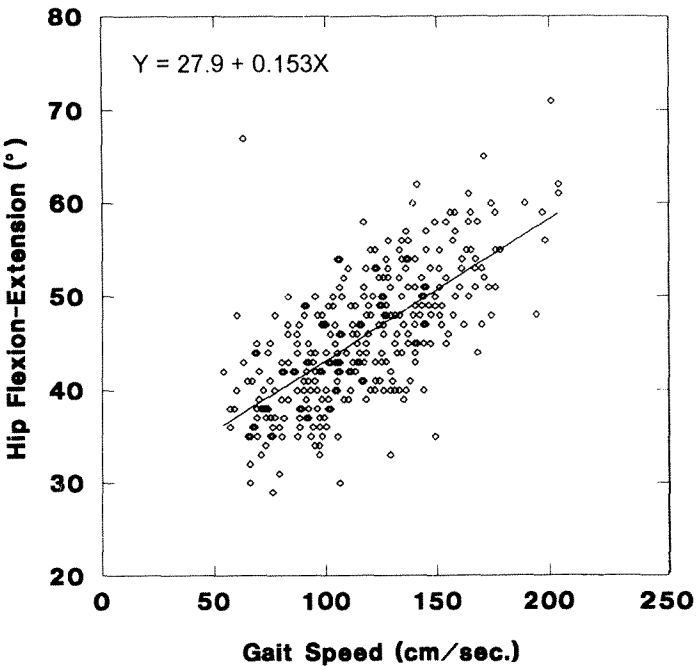

Figure 3b.
Regression diagrams showing the relation between gait speed and right hip flexion-extension. The slopes were statistically significant ($p < 0.001$).

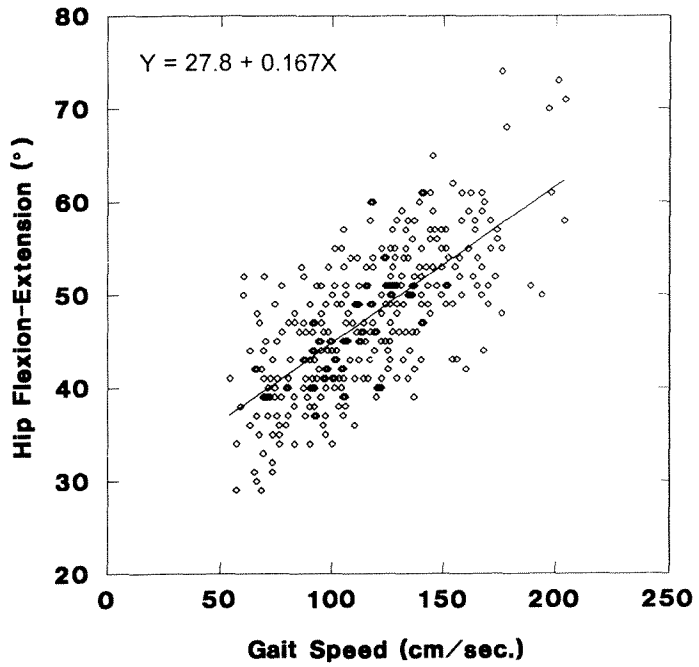

Figure 3a.
Regression diagrams showing the relation between gait speed and left hip flexion-extension. The slopes were statistically significant ($p < 0.001$).

do not need expensive equipment. A variety of methods are available, such as chronocyclography (11) and cinephotography (19). However, these methods are complicated to use. During the last decades electrogoniometers have been in common use, often combined with force measurements on force plates (15). More recently, modern opto-electronic or video-based registration systems have been used (e.g., Selspot, MacReflex). These are computer-based integrated systems for measurement and analysis of human gait (20). The most frequently studied variables are knee and hip angles in the sagittal plane (3,4,10,21,22). Published data do not significantly differ from those in our present study. Angle/angle diagrams have been used to show characteristic gait patterns (11,13,23). Grieve (11) introduced such diagrams for knee-hip angle measurements; he also showed that the cyclical loops were easily recognized. The patterns are constant and they are independent of age and sex (12). They can also show characteristic changes in disease, but it is difficult to quantify these changes of patterns. For this reason, joint angles are often reported at certain phases of the gait cycle. In our present study, we have chosen the hip flexion-

extension, the knee position in midstance, and the maximal knee swing as parameters because they are easy to identify and are automatically calculated by the software associated with our gait analysis system. We have not examined the reliability of goniometry in our study, but it has been reported as good in other studies. Johnston and Smidt (2) examined 33 healthy men in a test-retest study. They found a mean difference of 2°, with a range of 0–4°. Jansen and Ørbaek (5) used a Lamoreux exoskeleton, which was applied 10 times on the same nondisabled person. They found a standard deviation of 5 percent for hip excursion and 10 percent for knee excursion.

In our study, we found significant age-related changes for some joint parameters, but not for others (**Tables 2 a-c** and **3 a-c**). The pattern was not consistent and the changes were less than 1° per decade in all variables. The results reported in the literature are varying. Many authors report no age-related changes in the joint angles during gait. Finley et al. (14), examined one young group of women (mean age 30 years) and one group of elderly women (mean age 74 years). They found that chronologic age *per se* did not affect joint angle data. Similar results were reported by Murray et al. (7), in a study of males aged 20-65 years. They found that the patterns of hip rotation were similar in all age-groups, although small differences occurred in the magnitude of hip flexion. The knee rotation was almost identical in the various age-groups. In later studies, however, Murray et al., found small age-related changes (8). For example, they have shown that older men showed slightly less hip rotation than younger men at both free and fast gait speed of walking. The older men also showed less knee flexion during swing (8). In a group of nondisabled women they found a smaller portion of the range of motion of lower extremity joints with increasing age (8). Since the age-related changes both in our study and other studies are small and inconsistent, we do not regard it as necessary with age-related reference data, but the same reference data for joint angles can be used for all ages. Such reference data are found in **Appendix Tables 1 a-b, 2 a-b**, and **3 a-b**. Values by age-group can be found in **Appendix Tables 4 a-c** and **5 a-c**.

Most studies reported in the literature are concerned with men or women. Kettelkamp et al. (3) examined 16 men and 6 women, aged 21–35 years. They found no significant difference between the sexes in knee-swing, except for knee position in mid-stance. In our present study, we found sex differences in the knee parameters, but an inconsistent pattern in hip flexion-extension. Our findings motivate separate reference data for men and women.

We found no significant side differences. This result agrees with the findings of Kettelkamp et al. (3).

In a previous study, we have found an increasing step length with increasing gait speed (1). Consequently we should also expect an increased range of movement in the joints with increasing gait speed. Winter (10) has reported minor increases of 2-4° of hip and knee angles with increasing cadence. Perry et al. (23) found an increased knee flexion angle during stance phase, and Inman et al. (24) reported increasing stride length and hip flexion-extension with increasing gait speed. They also found a slight increase of the range of movement of the knee. In our present study, we found statistically significant changes of range of movement in all joint angle parameters, more pronounced at lower ages. Thus, our findings agree with the findings in the literature, and they indicate the need for separate reference data at different gait speeds.

CONCLUSION

In the present study, we have presented age- and sex-related reference data for hip and knee angles during gait. We found minor changes with age, no side differences, significant sex differences, and significant changes with increasing gait speed. The tables in the Appendix can be used as normative data for nondisabled subjects.

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APPENDIX

Table 1a.
Joint angles. Slow gait speed. Men (N = 116).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	15.1	6.0	0.40	14.0-16.2	3.4-26.8
Left knee, midstance	15.8	6.3	0.40	14.8-16.7	3.5-28.1
Right knee, swing	65.0	5.4	0.08	64.0-66.0	54.3-75.6
Left knee, swing	66.0	6.3	0.09	64.8-67.1	53.7-78.3
Right hip, flex-ext	42.9	5.4	0.13	41.9-43.9	32.3-53.6
Left hip, flex-ext	44.2	6.8	0.16	43.0-45.4	30.8-57.6

Table 1b.
Joint angles. Slow gait speed. Women (N = 117).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	12.1	5.0	0.41	11.2-13.0	2.4-21.9
Left knee, midstance	11.9	4.6	0.38	11.1-12.8	3.0-20.9
Right knee, swing	60.9	6.2	0.10	59.8-62.1	48.7-73.1
Left knee, swing	61.2	6.3	0.10	60.1-62.4	48.8-73.6
Right hip, flex-ext	41.6	6.2	0.15	40.5-42.7	29.4-53.8
Left hip, flex-ext	43.1	6.2	0.14	42.0-44.2	31.0-55.2

N = Number of subjects
S.D. = Standard deviation
C.V. = Coefficient of variation
C.I. = Confidence interval
P.I. = Prediction interval

Table 2a.
Joint angles. Normal gait speed. Men (N = 116).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	19.3	5.6	0.29	18.3-20.3	8.4-30.2
Left knee, midstance	19.6	5.8	0.29	18.6-20.6	8.3-30.9
Right knee, swing	66.9	5.2	0.08	66.0-67.9	56.7-77.1
Left knee, swing	67.7	6.2	0.09	66.6-68.8	55.6-79.9
Right hip, flex-ext	46.9	5.3	0.11	46.0-47.9	36.6-57.3
Left hip, flex-ext	48.2	6.7	0.15	47.0-49.4	35.1-61.4

Table 2b.
Joint angles. Normal gait speed. Women (N = 117).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	15.7	5.0	0.32	14.8-16.6	5.9-25.5
Left knee, midstance	15.0	4.8	0.31	14.1-15.9	5.6-24.3
Right knee, swing	63.0	6.1	0.10	61.9-64.1	51.1-74.9
Left knee, swing	62.6	5.9	0.09	61.5-63.6	51.1-74.1
Right hip, flex-ext	45.3	5.8	0.13	44.2-46.4	33.9-56.7
Left hip, flex-ext	47.1	6.5	0.14	46.0-48.3	34.4-59.8

N = Number of subjects
S.D. = Standard deviation
C.V. = Coefficient of variation
C.I. = Confidence interval
P.I. = Prediction interval

Table 3a.
Joint angles. Fast gait speed. Men (N = 116).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	24.3	5.1	0.21	23.4-25.3	14.3-34.4
Left knee, midstance	24.5	5.4	0.22	23.4-25.5	13.9-35.0
Right knee, swing	68.2	5.3	0.08	67.3-69.2	57.9-78.6
Left knee, swing	69.0	7.0	0.10	67.7-70.3	55.4-82.6
Right hip, flex-ext	52.0	6.2	0.12	50.9-53.1	39.8-64.2
Left hip, flex-ext	53.6	8.1	0.15	52.1-55.0	37.7-69.4

Table 3b.
Joint angles. Fast gait speed. Women (N = 117).

Variable	Mean Degree	S.D. Degree	C.V.	95% C.I. Degree	95% P.I. Degree
Right knee, midstance	20.3	5.4	0.27	19.3-21.3	9.7-30.9
Left knee, midstance	19.2	5.3	0.28	18.3-20.2	8.8-29.6
Right knee, swing	64.7	5.7	0.09	63.7-65.8	53.5-76.0
Left knee, swing	64.4	5.9	0.09	63.3-65.4	52.8-75.9
Right hip, flex-ext	50.0	6.4	0.12	48.9-51.2	37.4-62.6
Left hip, flex-ext	52.5	7.0	0.13	51.2-53.8	38.7-66.3

N = Number of subjects
S.D. = Standard deviation
C.V. = Coefficient of variation
C.I. = Confidence interval
P.I. = Prediction interval

Table 4a.
Joint angles. Mean values. Different age-groups. Slow gait. Men (N = 116).

Variable	Age-group, years 10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	12.8	15.9	12.2	16.0	13.7	16.4	17.5	16.0
Left knee, midstance	16.2	14.2	10.9	18.1	15.8	17.8	17.9	15.8
Right knee, swing	67.3	67.3	62.9	67.0	65.2	64.3	64.2	62.1
Left knee, swing	69.3	66.3	63.3	68.6	67.5	65.5	65.3	62.5
Right hip, flex-ext	44.5	40.9	42.0	44.0	42.5	42.3	45.3	42.1
Left hip, flex-ext	44.8	44.1	41.3	45.1	44.7	44.7	48.3	43.4

Table 4b.
Joint angles. Mean values. Different age-groups. Normal gait. Men (N = 116).

Variable	Age-group, years 10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	17.5	21.6	16.1	18.5	17.3	20.3	22.0	20.9
Left knee, midstance	18.7	20.5	14.6	20.3	19.9	20.5	21.8	20.4
Right knee, swing	68.4	70.3	63.4	67.7	66.7	66.8	67.0	65.0
Left knee, swing	70.7	69.1	64.5	69.6	69.4	67.6	67.1	63.8
Right hip, flex-ext	48.3	45.9	45.7	47.0	46.8	46.1	49.2	46.8
Left hip, flex-ext	48.0	50.1	44.6	47.8	46.2	47.8	52.8	48.4

Table 4c.
Joint angles. Mean values. Different age-groups. Fast gait. Men (N = 116).

Variable	Age-group, years 10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	23.3	25.7	22.5	23.1	23.2	26.2	26.2	25.2
Left knee, midstance	25.0	26.2	21.5	24.6	24.1	26.9	26.9	24.2
Right knee, swing	71.3	70.5	64.5	68.8	68.0	68.7	68.3	66.1
Left knee, swing	73.3	72.3	63.6	70.9	68.5	69.1	68.8	66.0
Right hip, flex-ext	53.8	52.3	49.7	52.8	52.1	50.5	53.7	51.7
Left hip, flex-ext	53.5	56.6	50.0	54.7	50.5	52.8	57.8	52.5

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Table 5a.
Joint angles. Mean values. Different age-groups. Slow gait. Women (N = 116).

Variable	Age-group, years							
	10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	11.1	12.3	11.1	12.1	10.8	11.6	13.5	14.1
Left knee, midstance	9.9	12.1	12.6	12.1	10.2	11.7	11.8	14.6
Right knee, swing	61.3	64.3	61.4	64.3	58.8	58.4	59.0	60.0
Left knee, swing	64.3	63.8	61.9	64.5	59.5	57.3	58.0	61.1
Right hip, flex-ext	37.4	42.2	45.9	41.6	40.4	40.7	42.8	41.0
Left hip, flex-ext	40.8	46.5	43.9	43.0	41.7	38.7	46.1	43.5

Table 5b.
Joint angles. Mean values. Different age-groups. Normal gait. Women (N = 116).

Variable	Age-group, years							
	10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	14.8	15.7	14.6	15.1	14.1	14.2	18.1	18.5
Left knee, midstance	13.1	15.1	13.9	14.7	13.1	14.4	16.6	18.7
Right knee, swing	66.2	65.4	63.9	65.6	60.5	59.7	60.2	63.2
Left knee, swing	65.5	64.3	63.3	65.8	59.9	58.8	60.2	63.3
Right hip, flex-ext	40.9	45.4	46.4	46.8	45.1	44.2	47.1	45.7
Left hip, flex-ext	43.9	49.9	47.4	48.7	45.3	41.8	51.0	48.3

Table 5c.
Joint angles. Mean values. Different age-groups. Fast gait. Women (N = 116).

Variable	Age-group, years							
	10-14	15-19	20-29	30-39	40-49	50-59	60-69	70-79
Right knee, midstance	17.6	20.2	20.2	20.5	19.3	18.7	23.0	22.4
Left knee, midstance	15.8	19.2	19.4	20.2	17.7	18.2	20.3	22.3
Right knee, swing	68.3	66.4	64.3	66.7	62.1	62.1	63.6	65.0
Left knee, swing	66.3	66.1	65.4	66.5	61.0	61.9	62.9	65.1
Right hip, flex-ext	46.0	49.4	51.7	52.1	49.7	48.6	52.8	49.0
Left hip, flex-ext	51.2	55.4	53.5	53.9	50.1	47.0	56.7	52.1

Table 6.
Joint angles at different gait speeds. Men (N = 116) and women (N = 117).

Variable	Men			Women		
	Slow	Normal	Fast	Slow	Normal	Fast
Right knee, midstance	15.1	19.3	24.3	12.1	15.7	20.3
Left knee, midstance	15.8	19.6	24.5	11.9	15.0	19.2
Right knee, swing	65.0	66.9	68.2	60.9	63.0	64.7
Left knee, swing	66.0	67.7	69.0	61.2	62.6	64.4
Right hip, flex-ext	42.9	46.9	52.0	41.6	45.3	50.0
Left hip, flex-ext	44.2	48.2	53.6	43.1	47.1	52.5