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Basic gait parameters: A comparison of reference data for normal subjects 20 to 29 years of age from Kuwait and Scandinavia

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Abstract—This study obtained measurements of the spatiotemporal gait parameters of healthy young adult Kuwaiti subjects from both genders and compared the data to those collected in a similar study performed in Sweden. Thirty healthy subjects volunteered to participate in the study (which included being asked to walk at their "free," "slow," and "fast" self-selected speeds). We collected the spatiotemporal gait data using an automated system. Descriptive statistics were calculated for each variable measured at each walking condition. The data were then compared to those from the Swedish study. The results indicate several significant differences between Kuwaiti and Swedish subjects in their manner of walking. These results suggest a need to include data from subjects with diverse cultural backgrounds when a database on normal gait is developed or a need to limit the results of the database to a specified ethnic population.

Key words: gait, interindividual differences, speed, step frequency, step length.

INTRODUCTION

Walking, an important activity of daily living, is a mode of bipedal locomotion in which a period of double support, when both feet are in contact with the ground, is followed by a period in which the body is supported by one lower limb while the other is swung forward. Gait is the manner of walking [1]. This recognizes that although the sequence of foot floor contact meets the above definition, we do not all have an identical walking pattern. Perhaps the most commonly reported measurements of gait are the temporospatial parameters. These include walking speed, stride time and length, step time and length, as well as the durations of stance phase and swing phase [2]. These measurements have been referred to as the "basic gait parameters" and the "vital signs of walking" [2–4]. This last statement reflects the fact that these measurements are very useful indicators that a gait pattern may be abnormal and, if so, the extent of that abnormality, without necessarily indicating the cause of the problem. The temporospatial parameters are relatively easy to measure, requiring little more than a stopwatch, making them practical for clinical use [5].

Many investigators have studied the intersubject gait differences in normal samples; some are based on measurements of one or more of the temporospatial parameters. Perhaps the most frequently studied differences are those associated with age [6,7]. However, numerous other normative studies have been undertaken to determine the effects of such variables such as walking speed, height or leg length, footwear, and curb clearance, to mention but a few [8–12].

Abbreviations: ANOVA = analysis of variance, SD = standard deviation.

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When walking is impaired, the clinician's role is to determine the nature and severity of the impairment. This is simply a comparison between the patient and a healthy unimpaired individual of similar age and gender. The most common sources of normative data are those collected on "control" groups that are included in studies on pathological gait patterns for the purpose of comparison. Examples include elderly fallers, people with depression, detoxified alcoholic men, and hemiplegia [13–16]

Because the aim of rehabilitation is to restore function, a normative database of gait parameters is desirable. This is a large task because the database must account for the broad spectrum of what is regarded as normal, including differences not just in gender and age but also among people in different geographical locations and of different cultural backgrounds [17].

Recently, the gait patterns of a large sample of healthy men and women across the lifespan were measured [3,18]. This comprehensive study, done in Sweden, was intended as a database of normative data against which measurements from individuals or groups could be compared. However, the study did not account for ethnicity or cultural differences that may have an influence on gait parameters. In the present study, we collected basic gait data on groups of healthy young adult Kuwaitis of both genders to determine if they duplicated the data published in the Swedish study [3]. This would then allow a decision to be made on whether the Swedish database would be a suitable source of reference, or whether the data were sufficiently different to warrant broadening the database to be more geographically and culturally inclusive.

METHODS

Subjects of this study consisted of a sample of convenience of healthy Kuwaiti men and women between the ages of 20 and 29. The mean age of the men was 25.6, with a standard deviation (SD) of 2.77 years. The women had a mean age of 22.73 with an SD of 1.83 years. The sample consisted of those who responded to a notice seeking volunteers for the study, which was posted by the Department of Physical Therapy at Kuwait University. Fifteen men and fifteen women were selected to match the sample used in the Öberg study for the same age range [3]. Exclusion criteria included (1) a history of cardiovascular or pulmonary dysfunction, (2) a history of neuromuscular dysfunction, and (3) a history of musculoskeletal injuries resulting in symptoms of pain, weakness, loss of range of motion, or loss of coordination within the last year. Both the Swedish and Kuwaiti subjects were primarily university students and staff. The demographic information about the sample is shown in **Table 1**, along with unpublished data from the Swedish study provided by the first author of that paper.

We used the GaitMat II™ gait measurement and analysis system to collect the data. This system consists of a series of mats in which pressure-sensitive switches are embedded. The mats are connected to a computer that determines which switches are closed and for how long. From this information, the position and duration of each footfall are determined. The subjects were asked to wear their regular clothing and comfortable shoes.

The purpose of the study and procedures to be used were explained to them and informed consent was obtained. The subjects' height, weight, and leg length were measured at the beginning of the session. We maintained confidentiality at all times by using code numbers to replace subjects' names.

The subjects were asked to perform three trial walks to become familiar with the procedures. All subjects performed three randomly ordered trials at each self-selected speeds of "free," "slow," and "fast."

RESULTS

In the Öberg study, step frequencies rather than step times were reported. Because the GaitMat II system does not determine step frequency, it had to be calculated. The mean step time was calculated from the right and left step

Table 1.
Mean heights and weights, together with SDs, for subject groups.

Measurement	Women (Kuwait)	Women (Sweden)	Men (Kuwait)	Men (Sweden)
Height (m)	1.64 ± 0.061	1.67 ± 0.042	1.74 ± 0.067*	1.80 ± 0.060
Weight (kg)	64.6 ± 14.41	61.07 ± 6.67	81.57 ± 14.54*	70.73 ± 7.176

*Kuwaiti values were significantly different from values obtained from Scandinavian group of same gender.

times and the reciprocal determined. This procedure provided a measurement of step frequency expressed in units of steps per second, as used in the Öberg study. Similarly, the mean step length was calculated from the left and right step length data from the GaitMat II system to make the comparison to the Öberg study meaningful.

Descriptive statistics (mean, SD) were reported for all the variables. A one-way analysis of variance (ANOVA) was used to determine differences between the men and women in the study sample, with the alpha level set at 0.5. We compared the data from the study to those from the Swedish study using t-tests based on the assumption of equal variance in the two groups [19], with an alpha level of 0.05. These comparisons were made for men versus men and women versus women for each of the three measurements, walking speed, step length, and step frequency, for each self-selected walking speed.

The results for the height and weight are shown in **Table 1**, together with previously unpublished data from the Swedish study, which were provided, by Professor Tommy Öberg, MD, PhD.* No statistically significant differences in height or weight were found between the two groups of women; however, the Kuwaiti men were shorter and heavier than the Scandinavian group. In both the Kuwaiti and Swedish samples, the men were taller and heavier than the women.

The results for the walking speeds, step length, and step frequencies for the three walking speeds are shown in **Tables 2, 3,** and **4**, respectively. Included in these tables are the results from the Swedish study.

*Öberg T. Personal communication, 2003.

Table 2.
Mean walking speeds, expressed in units of meters per second, and SDs for four groups of subjects at each of three self-selected walking speeds.

Group	Slow	Medium	Fast
Men (Sweden)	0.831 ± 0.091	1.227 ± 0.111	1.626 ± 0.201
Men (Kuwait)	0.810 ± 0.168	1.217 ± 0.199	1.809 ± 0.217*
Women (Sweden)	0.837 ± 0.197	1.241 ± 0.171	1.693 ± 0.230
Women (Kuwait)	0.802 ± 0.162	1.082 ± 0.146*	1.575 ± 0.135

*Kuwaiti values were significantly different from values obtained from Scandinavian group of same gender.

Table 3.
Mean step lengths, expressed in units of meters, and SDs for four groups of subjects at each of three self-selected walking speeds.

Group	Slow	Medium	Fast
Men (Sweden)	0.527 ± 0.031	0.616 ± 0.035	0.712 ± 0.057
Men (Kuwait)	0.568 ± 0.061*	0.702 ± 0.073*	0.829 ± 0.074*
Women (Sweden)	0.518 ± 0.072	0.591 ± 0.063	0.667 ± 0.061
Women (Kuwait)	0.534 ± 0.070	0.625 ± 0.060	0.710 ± 0.070

*Kuwaiti values were significantly different from values obtained from Scandinavian group of same gender.

Table 4.
Mean step frequencies, expressed in units of steps per second, and SDs for four groups of subjects at each of three self-selected walking speeds.

Group	Slow	Medium	Fast
Men (Sweden)	1.55 ± 0.29	1.98 ± 0.13	2.34 ± 0.17
Men (Kuwait)	1.42 ± 0.19	1.73 ± 0.15*	2.18 ± 0.27
Women (Sweden)	1.59 ± 0.20	2.08 ± 0.15	2.56 ± 0.25
Women (Kuwait)	1.49 ± 0.17	1.73 ± 0.11*	2.25 ± 0.23*

*Kuwaiti values were significantly different from values obtained from Scandinavian group of same gender.

The ANOVA revealed that no significant differences were found between men and women for walking speed, step length, or step frequency at the self-selected slow walking speed. At the medium and fast speeds, however, male values for both walking speed and step length were significantly different from the female values, although no difference was found in step frequency.

Significant differences between the groups from Sweden and Kuwait were found, and these differences are indicated in **Tables 2** to **4**. At the medium self-selected speed, the Kuwaiti women walked slower than their Swedish counterparts, and at the faster speed, the male Kuwaitis were faster than the Swedish men. In terms of step lengths, no differences were found between the two female groups at any of the speeds, but the male Kuwaitis took significantly longer steps at all three speeds. At the medium speed, the Swedish subjects had higher step frequencies than the Kuwaiti groups, and at the fast speed, the Swedish women used a higher step rate than the Kuwaitis. All other differences were nonsignificant.

DISCUSSION

The data for the Kuwaiti subjects indicate that walking speed differences exist between the men and women for the self-selected medium and fast walking speeds. Height is a significant factor when walking speed is being considered, and since the men were significantly taller than the women, this may explain the differences in walking speed. To test this explanation, we normalized walking speed by dividing speed by height [8]. The relative speed data are shown in **Table 5**. No differences were found in relative speed at the slow and medium self-selected walking speeds, but the men were again significantly faster at the fast self-selected walking speed. Using the same technique for normalizing walking speed with respect to height, a study of healthy young Canadians showed that women walked slower than men at self-selected slow, medium, and fast walking speeds [9]. Although no statistical analysis was undertaken on the Swedish data, the results shown in **Table 2** indicate that differences in walking speed between men and women was less than seen in the present study on Kuwaitis. The Swedish data also showed that at each of the self-selected walking speeds, when measured in absolute values of centimeters per second, the women walked faster than the men. However, one should note that this is only true for the subjects in the 20 to 29 age groups, with few exceptions; in all the other age groups, the mean walking speed was higher for the men than for the women.

Table 5.
Mean relative speeds, expressed in units of statures per second, and SDs for four groups of subjects at each of three self-selected walking speeds.

Walking Speed	Women	Men
Slow	0.49 ± 0.102	0.47 ± 0.100
Medium	0.66 ± 0.093	0.70 ± 0.116
Fast	0.96 ± 0.087	0.82 ± 0.082*

*Value for men was significantly different from value obtained for women.

The Kuwaiti women walked significantly slower than the Swedish women at the self-selected medium speed. Since the Kuwaiti women were shorter, as seen in **Table 1**, this may explain why they walked slower. However, the height difference was not statistically significant, which makes it difficult to ascribe height as the major factor in the differences in walking speed found. At the self-selected fast walking speed, the Kuwaiti men walked faster than the Swedish men. This finding was the only statistically significant difference in walking speed found between these two groups. Since the Swedish group was significantly taller and lighter (**Table 1**), one might have expected to see them have higher walking speeds than the Kuwaiti men.

Although differences were found in walking speed between the male and female groups, when walking at their self-selected medium and fast walking speeds, no significant differences were found in step frequencies. It therefore follows that the increased walking speeds in the men were achieved solely by an increase in step length. This observation that men take longer strides, and therefore steps, than women is not a new finding. Regression equations were determined for the relationship between walking speed and stride time for a group of healthy young Canadians [9]. From these equations, one can determine that at the same walking speed, women will have a shorter stride time and stride length than men.

The two studies differed in the way in which data were collected. In the Swedish study, mean walking speed was obtained by timing each subject walking a distance of 5.5 m. Within this distance, the number of complete steps was counted and timed, allowing the investigators to calculate mean step frequency. The investigators than calculated mean step length by dividing mean walking speed by mean step frequency. The GaitMat II system used in the present study determined the timing and position of each individual footfall with a timing accuracy of ±15 ms and a spatial resolution of 15 mm in both the longitudinal and transverse directions [20] However, these differences in data collection techniques would unlikely affect the findings of this research, and consequently, the differences found between the samples are real.

One potential explanation for differences in gait may be related to footwear. Traditionally in Kuwait, as well as in other parts of the Arabian Peninsula, sandals have been the footwear of choice for both men and women, particularly in the summer. The original hand-made Arabian sandals were rigid and wide to facilitate walking on rough desert and sandy terrain. Today, the vast majority of Kuwaitis wear designs imported from Europe, America, and Asia. The subjects in the study wore differing styles of shoes. Although the published paper did not indicate the type of footwear used by the subjects in the Swedish study, communication with the first author of that paper confirmed that all subjects wore ordinary walking shoes. In neither study did subjects wear high-heeled shoes or open-backed shoes, such as clogs or sandals; therefore, footwear is apparently unlikely to account for differences found between the two studies.

Given the number of studies that have been undertaken on normal gait, it would be reasonable to suggest that a meta-analysis be undertaken. Unfortunately, the variables measured had no consistency. As previously noted, gait speed, step length, and step frequency were the variables compared in this paper, simply because these were the ones selected for the Swedish study. Because gait speed is related to height, one might consider relative speed a better variable to use since it factors out height. As strides include both steps and thereby avoid differences between the right and left steps, one could argue that stride time and stride length are the preferred measures of the temporal and distance gait parameters. We therefore suggest that, to facilitate comparisons, gait studies should include, at a minimum, measurements of walking speed (m/s), relative speed (statures/s), stride time (s), and stride length (m).

From a clinical standpoint, the small but significant differences found in this study are probably unimportant. We are unaware of any studies that definitively demonstrate when changes in the variables measured in this study are of clinical significance. Nonetheless, it is not atypical for studies to show statistical differences between a treatment group and a control group and to infer that the differences were due to the treatment. The results from the current study demonstrate differences in gait variables between two groups of nonimpaired individuals who could represent a control group within their respective ethnic group. This finding suggests that differences between ethnically and geographically disparate populations need to be investigated further so that more encompassing normative gait reference data could be established.

CONCLUSION

This study shows that a number of statistical differences can be found between the data sets collected on the Kuwaiti sample when compared to published normative data for a Swedish sample. The differences found were small and may be too small to be of clinical relevance. However, if a clinical study is undertaken and the outcome data compared to published reference data and if these are found to be statistically different as was found in this study of nonimpaired individuals, then the researcher may come to the wrong conclusion. In this sense, the differences may be important clinically. We suggest that a normal database be developed that takes a more global perspective and allows meaningful comparisons to be made. Such a database of these basic gait parameters, which included subjects from diverse cultural backgrounds, would be an extremely useful resource for those involved in measuring gait, since virtually all gait analyses include some, if not all, of these basic measurements.

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