

NORMAL GAIT OF YOUNG AND OLD MEN AND WOMEN

Ground Reaction Force Measurement on a Treadmill

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Forty normal persons had their gait tested using an instrumented treadmill. All were tested at the same speed of gait. The temporal factors of gait, the ataxia, and the external work of the gait were all calculated from the ground reaction forces. Ten women and ten men aged 20–29 years and ten women and ten men aged 60–69 were tested. The study demonstrated a constant pattern of gait independent of age and sex.

Key words: ageing; gait

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Gait analysis is becoming increasingly necessary for the treatment of patients with gait disorders. To evaluate abnormal gait it is equally important to perform studies of normal gait. The present study aims to investigate the differences in the gait of young and old men and women, and to produce a table of normal values with information regarding temporal factors, ataxia and external work. All information is obtained during gait tests on an instrumented treadmill with the persons walking at a constant speed of 4 km/h. No previous studies of this type were found in the literature.

SUBJECTS AND METHODS

The study comprised 10 women and 10 men aged 20–29 years, and 10 women and 10 men aged 60–69 years.

The following criteria were met by all of the persons tested:

1. no neurological diseases.
2. no disease of the spine.
3. no abnormality of the lower limbs.
4. no signs of vascular insufficiency of the legs.
5. no signs of cardiopulmonary insufficiency.

6. no medicine at all had been taken by the person during the previous week, and no medicine had been taken regularly in the previous month.
7. no intake of alcohol during the last 12 hours before the test.

The gait tests were performed on an instrumented treadmill (Jansen 1974). The treadmill consists of two parallel conveyor belts providing a walking area of 2 meters in length and 60 cm in width. The ground reaction forces of the persons' feet are measured by a force plate system supporting each of the conveyor belts. In this way a treadmill is obtained which is able to measure the vertical, the transversal and the sagittal forces of each foot separately for an, in principle, unlimited length of gait (Figure 1).

The ground reaction forces are measured by the strain gauges of the force plates, and the signals are transmitted to a PDP 11/10 digital computer. The vertical forces are scanned by the computer, and the events heel-on and toe-off are found for each of the two feet. From this information it is a simple matter to calculate the temporal events of gait, such as the stance phase, the double support time, and the fraction of double support time when the heel of one side and the toe of the opposite side are touching the ground. In addition step length and stride length are calculated.

Measurement of ataxia or unsteadiness of gait is performed by representing the force curves in each of the measured directions as mean curves "shaded" by one standard deviation. The average standard deviation



Figure 1. A person walking on the instrumented treadmill.

is taken as the measure of ataxia. The ataxia has the dimensions of force and is expressed as a percentage of body weight (Jansen et al. 1979).

The external work of the gait can be calculated from the ground reaction forces. If the vector systems of each of the feet are added and integrated, the velocities of the centre of gravity are found. By integration over a stride, the product of the velocities and the forces of each foot, the external work, is found in the three directions for each foot. Positive work is represented by accelerative movements. The calculations are a further development of the method described by Cavagna (1975).

Each person was tested at a fixed speed of gait; 1.11 m/s was chosen for all tests. All persons had bare feet during the tests. After 2 minutes of adaptation to the treadmill the ground reaction forces were measured for 60 seconds. All subsequent calculations of results are based on these 60 seconds of continuous gait.

For practical reasons, only figures from the left foot are evaluated.

All data were compared by Wilcoxon rank sum test; the level of significance was $P < 0.05$, two-tailed.

RESULTS

The results are shown in Table 1. Significant differences were as follows: The stride length of elderly women was shorter than the stride length of elderly men ($P < 0.05$). A similar difference was found between young women and young men ($0.05 < P < 0.10$). Total ataxia was greater in young women than in young men ($P < 0.01$), and in the younger group the same tendency was found for the left vertical direction ($0.05 < P < 0.10$). No other parameters showed any significant differences either between men and women, or between younger and older persons.

DISCUSSION

The study was designed so as to have as few variables as possible. Only four variables were present: age, sex, body height and body weight.

All persons walked at a constant speed, which is simple to achieve when using a treadmill. A fixed and uniform speed of gait was chosen because previous studies (e.g. Cavagna & Margaria 1966) had demonstrated that stride length increases with increasing speed of gait. However, there was a tendency towards a stride length difference between younger men and women, and there was a significant difference in stride length between elderly men and women. But these differences are only apparent, as they reflect the differences in body height of the groups of persons. If the stride length is expressed as a percentage of the person's height (Foley et al. 1979) no difference is found as the percentage is virtually constant (range 58 to 59 per cent).

Among the other temporal factors no differences were found when the factors were expressed as a percentage of stride length. It is demonstrated that no differences are found in the stance phase, the double support time (or the fraction this represents) or in the step length.

As regards ataxia in the vertical direction the young women were found to have a tendency towards larger values in the vertical direction than the young men. This finding is significant when calculating the total ataxia of both feet. We have no clear explanation for this. Although the find-

Table 1. Results of 40 gait tests. The standard deviations of the calculated parameters of gait are indicated in brackets. For ataxia the symbol § represents force as a percentage of body weight

	Younger women	Younger men	Old women	Old men
Number of persons	10	10	10	10
Age, years (range)	26 (22-29)	26 (20-29)	65 (60-69)	64 (60-69)
Body weight, kg (range)	57 (47-74)	71 (60-86)	66 (50-88)	81 (72-96)
Body height, cm (range)	165 (159-175)	180 (176-190)	160 (148-174)	176 (162-186)
Stance phase, % of a stride	69 (2.9)	69 (3.6)	69 (2.2)	69 (3.0)
Double-support-time, % of a stride	36 (4.1)	36 (3.5)	37 (3.5)	36 (5.5)
D-s-t., left heel/right toe, % of a stride	18 (2.2)	18 (1.9)	18 (1.9)	18 (2.6)
Left step, % of a stride	51 (1.3)	51 (2.7)	51 (1.0)	51 (2.2)
Stride length, cm	97 (7.6)	105 (8.7)	92 (9.1)	103 (10.6)
Speed of gait, km/h	3.96 (0.46)	4.10 (0.52)	3.90 (0.17)	3.98 (0.08)
Ataxia, left vertical, §	1.9 (0.5)	1.4 (0.4)	2.0 (0.8)	1.6 (0.5)
Ataxia, left transversal, §	0.3 (0.1)	0.3 (0.1)	0.3 (0.0)	0.4 (0.1)
Ataxia, left sagittal, §	0.8 (0.1)	0.7 (0.1)	0.7 (0.1)	0.8 (0.2)
Ataxia, total, §	6.4 (1.1)	4.8 (1.3)	6.2 (1.9)	5.6 (1.3)
External Work, left vertical 10 ⁻³ Joule/kg body weight/m gait	185 (89)	193 (64)	208 (44)	208 (41)
External Work, left transversal 10 ⁻⁴ Joule/kg body weight/m gait	92 (35)	88 (35)	96 (37)	115 (59)
External Work, left sagittal 10 ⁻³ Joule/kg body weight/m gait	241 (48)	249 (44)	232 (56)	240 (26)

ing is statistically significant, the actual value of ataxia is so close to the other ataxia values that it is of no clinical significance.

The results of the calculations of external work are expressed in Joules per kg body weight per metre of gait. The external work in the vertical, in the transversal and in the sagittal directions was similar among younger and older persons and among men and women.

Murray et al. (1969) performed a study on walking patterns in healthy men. The study comprised men aged 20 to 87 years. The test included analysis of gait components during both free and fast speed walking. They found that walking speed and stride length both decreased after the 67th year. At the same age they found an increase in the stance phase, a finding which may also be correlated with the decrease in the speed of gait (Ogle et al. 1975).

In 1969, Finley et al. published a study of

locomotion patterns in elderly women. The elderly women, with an average age of 74 years, were compared with a group of younger women aged, on average, 30 years. The speed of gait was found to decrease in the older group. The step length also decreased. The stance phase was found to be shorter. This differs from the above-mentioned study of Murray et al. However, in the study by Finley et al., 78 per cent of the elderly women had arthritic symptoms, and 89 per cent of them were taking one or more drugs.

The previous studies demonstrate that the spontaneous speed of gait decreases in old age. The present study demonstrates that provided the speed of gait is kept constant, and the stride length is evaluated in relation to the height of the person no clinical difference in ground reaction parameters is found among younger and older normal persons, and no difference is found between normal men and normal women.

This study has demonstrated a constant pattern of gait regardless of the age or sex of normal persons. This observation simplifies the distinction between normal and abnormal gait.

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