THE GAIT OF 230 NORMAL CHILDREN 3-16 YEARS OLD AS ANALYZED WITH FOOTSWITCHES

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ABSTRACT

The gait patterns of 230 normal children, 3-16 years old, were studied by means of footswitches. They walked in three different requested velocities. Velocity, stride length, cadence, and the temporal phases of the stride were recorded along with leg length of the subjects. These gait parameters change with age and the chages are most pronounced up to 8-10 years. Thereafter only minor chages take place and leg length becomes the dóminating factor.

INTPODUCTION

It is obvious that children develop their gait with increasing age. But there are two questions: 1) When does this development cease? 2) Are the chages in gait patterns due to development in gait ability, or are they due to body growth?

The purpose of our study is to provide control data which may be used in the evaluation of pathological gait. In order to make relevant comparison it is necessary to know more about the development of gait in the normal child.

To achieve this we have investigated gait patterns of 230 normal children 3-16 years old with the aid of footswitches. To exclude abnormal children a questionaire was distributed to the parents. It contained questions about delivery, early pattern of locomotion, present physical activities and diseases in the motor system.

The measurements were made in schools as well as in our gait laboratory. Foot switches were placed under the heel and the metatarso-phalangeal joints and are hence called the heel and ball switches. To simulate bare foot walking, we used thin socks with the soles dipped in plastic. Signals from the switches were recorded on an analoge tape recorder for later work-up in a computer.

In order to study the depencence of gait velocity on the gait parameters, each child walked at three different velocities, freely chosen by the subjects themselves, but with the instruction that they should correspond to 1) Ordinary, 2) Very slow, 3) Very fast. No other instructions were given.

EVALUATION OF DATA

The variables that describe the gait are correlated to the

gait velocity and the evaluation of all observated variables must consequently be related to the actual walking velocity.

As the velocity is equal to the quotient between stride length and stride duration it is possible to use any of the three variables as independent in the analysis.

In the evaluation of the temporal phases of the stride, we have chosen the stride duration as independent for two reasons: 1) The relation between stride duration and other phases tend to be linear in a high proportion of cases. 2) The variance of the estimated values becomes smaller if we use the stride duration as independent variable than if we use the velosity.

In order to describe the relationships between the variables, we have applied the simple linear regression mode. Due to the fact that the different observations are interdependent, it is not possible to pool all observations of all subjects. Accordingly we have performed the evaluation in the following way.

For each subject we calculate a linear regression for every relation (fig. 1). The equations of the regression are then considered as observations, which means that we have obtained one observation instead of three interdependent observations. These new observations are independent between subjects. If these regresion lines are put together for those subjects we are interested at, we can calculate the mean value and standard deviation for the variable at any value on the abscissa (fig. 2). This makes it possible to compare observations at the same stride duration or velocity. It also makes it very easy to compare two groups of subjects by calculating mean value and standard deviation at the same stride duration or velocity for each group. Prediction intervals may as well be calculated making it possible to compare a single or grouped observation with the control material.

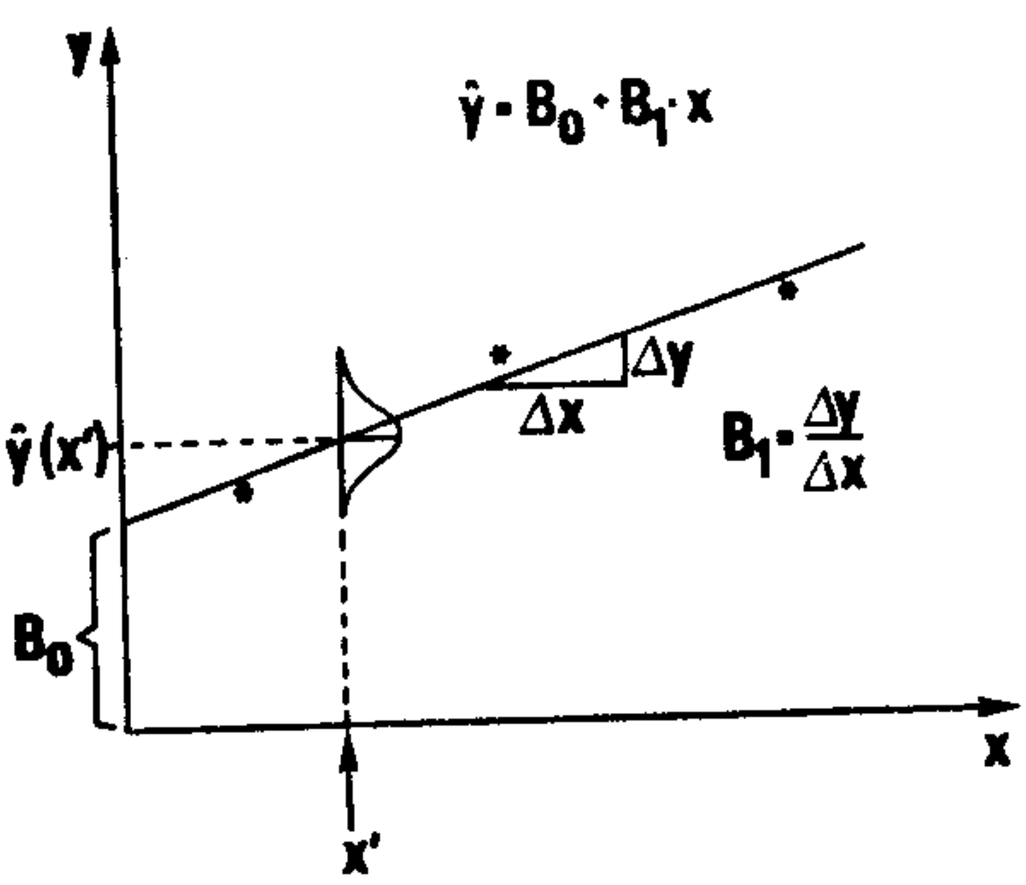


Figure 1.

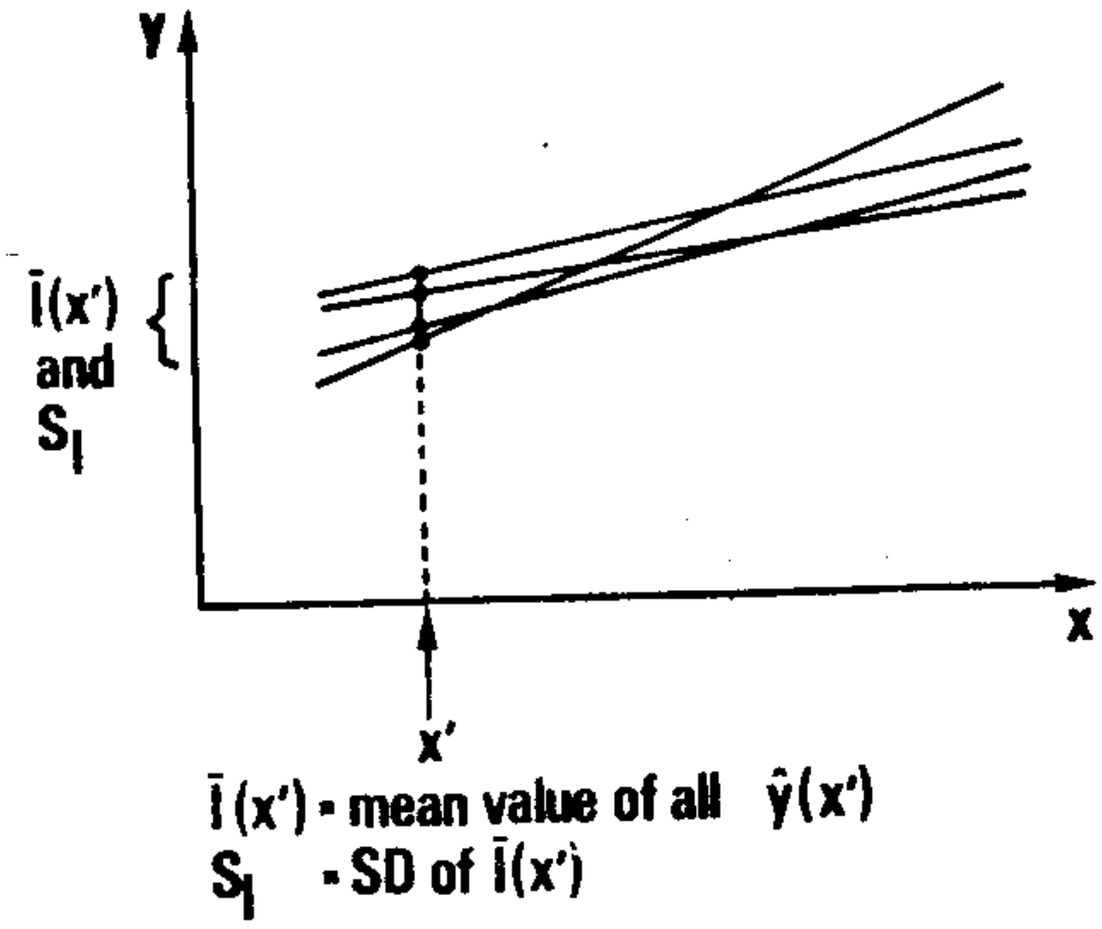


Figure 2.

RESULTS- A. Velocity, stride length, and cadence

In describing gait ability, velocity is the sole most im-

portant variable to measure: 1) It is most descriptive variable. 2) All other gait variables are correlated to velocity and accordingly the analysis of each observated variable must be related to the actual velocity.

The velocity presented at each requested velocity increases with increasing age according to equations (1),(2) and (3) (see fig. 3).

Very Slow:	V=0.42+0.014* AGE	(m/s)	(1)
Ordinary:	V=0.77+0.031* AGE	(m/s)	(2)
Very Fast:	V=1.09+0.087* AGE	(m/s)	(3)

As the relation between stride length and square root of velocity tends to be linear for all individuals, we calculated linear regressions between these variables, making it possible to predict the stride length for any velocity. The stride lengths were evaluated at the mean velocity for the entire material at very slow, 0.60 m/s, ordinary, 1.12 m/s, and very fast gait, 2.06 m/s.

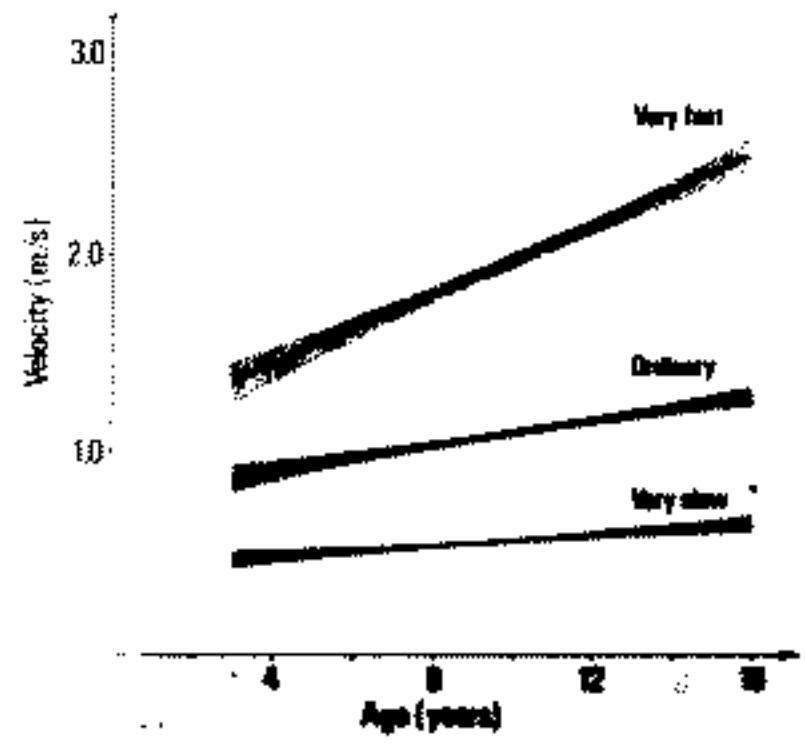


Figure 3

Stride length is then correlated to bothe age and sex according to equation (4) - (9) (see fig. 4).

Very Slow:	L=0.59+0.026*	AGE	(m)	(female)	(4)
	L=0.55+0.030*	AGE	(m)	(male)	(5)
Ordinary:	L=0.84+0.028*	AGE	(m)	(female)	(6)
	L=0.73+0.039*	AGE	(m)	(male)	(7)
Very Fast:	L=1.16+0.031*	AGE	(m)	(female)	(8)
	L=0.96+0.052*	AGE	(m)	(male)	(9)

Boys have larger coefficient than girls at ordinary and very fast gait ($p < 0.001$). The regression lines intersect just below 10 years of age.

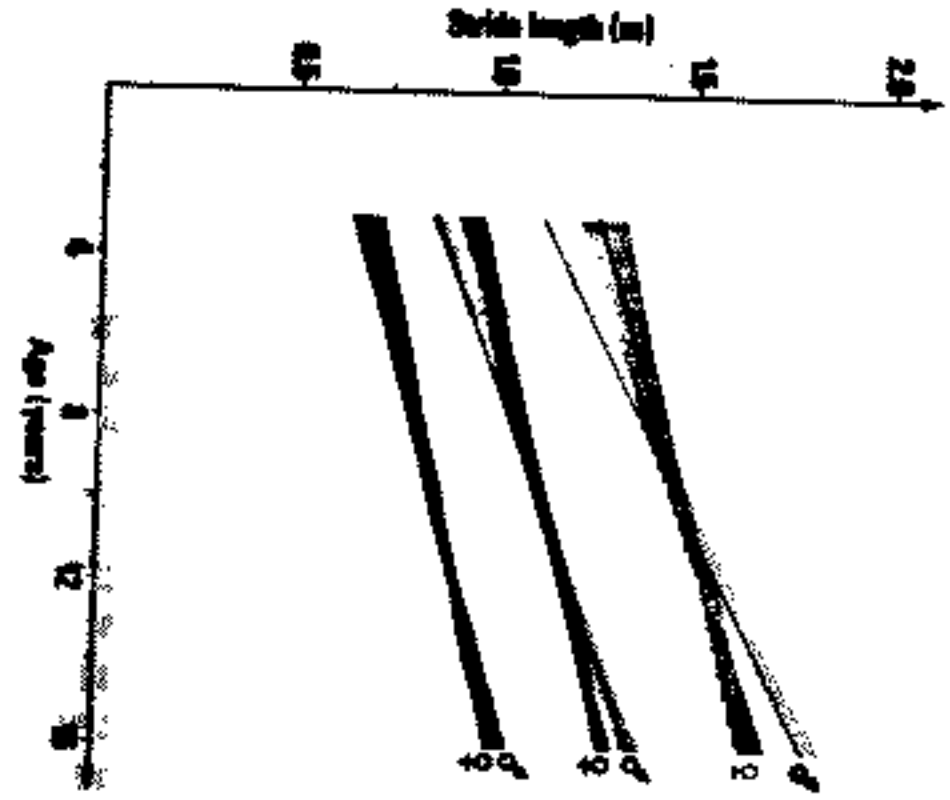


Figure 4.

The fact that the regression lines intersect implies that for children less that 10 years, the girls walk with longer stride lengths for a given velocity, and for children more that 10 years, the boys walk with longer stride lengths. The wellknown fact that men walk with longer

steps than women is then shown to exist after 10 years of age.

It is obvious that stride length in some degree is dependent on leg length. However, a close analysis on the relations between stride length, leg length, and age shows that for children younger than about ten years old, stride length and also velocity are dependent on leg length, but also on other age dependent factors. For older children leg length alone becomes the dominating factor.

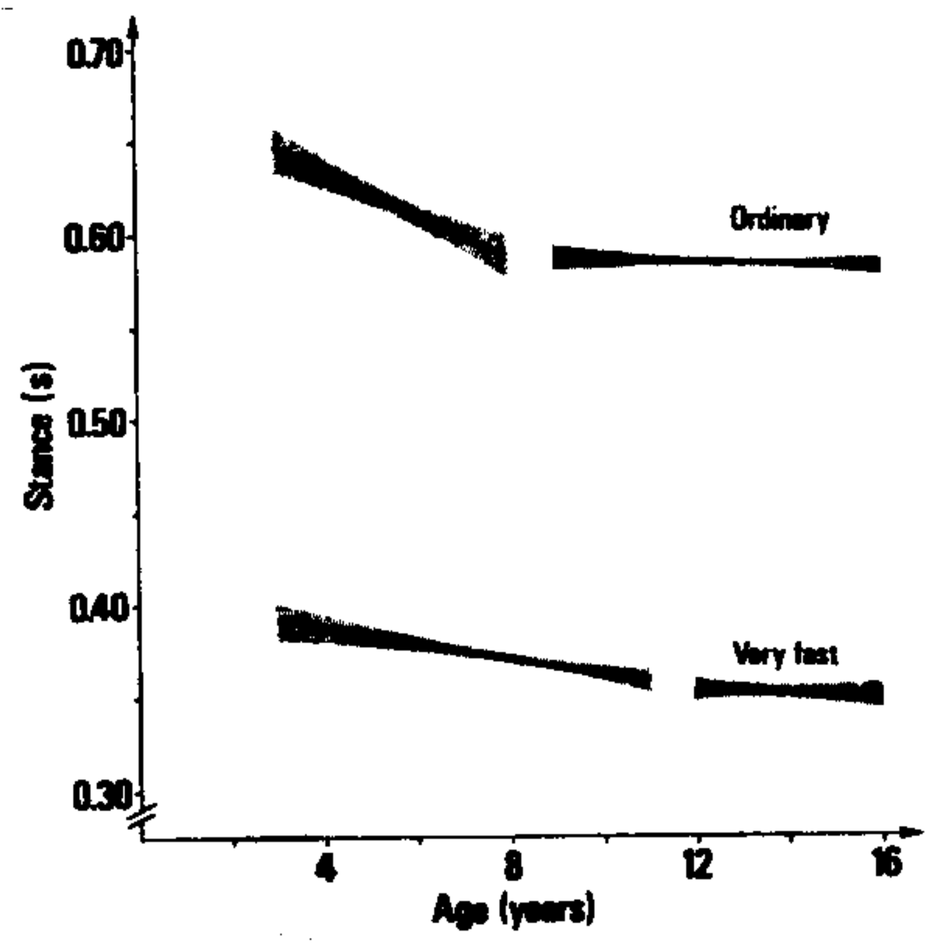
B. Stance, swing, and double support

The duration of stance, swing, and double support dependent linearly on stride duration. No differences were found between boys and girls. Stance, swing, and double support are correlated to age only for children younger than 8-10 years old. Figure 5 shows the stance versus age. Te equations are:

Ordinary:	Stance=680-11.30*	AGE	(ms)	(AGE	8)	(10)
	Stance=594-0.77*	AGE	(ms)	(AGE	8)	(11)
Very Fast:	Stance=403-4.03*	AGE	(ms)	(AGE	11)	(12)
	Stance=365-0.92*	AGE	(ms)	(AGE	11)	(13)

The coefficients are separated from 0 for the younger children (p 0.001), but not for the older children. This fact shows that there is no correlation between age and stance for the older children.

Similar changes appear in double support and swing versus age.



DISCUSSION

Despite the obvious shortcomings of footswitches, they represent a very useful tool which gives basal information on gait. It is also one of the few methods well adepted to children, mainly because it is quickly carried through (10-20 minutes).

Velocity, stride length, and the temporal phases change with age. But in several cases not continuously. A close look on, for instance, stance shows that it constantly decreases up to 10 years of age but thereafter changes very little. Swing and double support also show the same type of development. Velocity and stride length are for children younger than 10 years mainly dependent on other age dependent factors than leg length. For the older children leg length determines both the velocity and stride length.

The development of gait continues at least up to the age of 16 years. It is most intense up to 10 years when the motor system maturates. Thereafter only minor changes take place due to body growth.

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