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# Development of temporal and distance parameters of gait in normal children

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ABSTRACT

Temporal and distance parameters of 33 normal children were obtained from instrumented gait analysis prospectively over five consecutive years. The parameters were normalised to minimise the confounding effects of increasing height and leg length. Rank correlations were performed on normalised speed, normalised stride length, normalised cadence and normalised walk ratio across consecutive pairs of years to examine the ranking of these parameters for an individual child over time. Consistent trends of increasing rank correlation were observed in normalised stride length and normalised walk ratio suggesting that individual children were continuing to adjust these gait parameters towards their own characteristic position within the normal range. Consistent trends were not observed in the rank correlations for normalised speed and normalised cadence. These findings support the concept that individual children predominantly adjusted their cadence to effect changes in speed, while the development of stride length was dictated by other factors specific to the individual child. Rank correlation coefficients for walk ratio between consecutive years increased from the ages of 7–11 years of age and hence walk ratio appears be a feature of gait that matures beyond the age of 7 years. This accords with the proposal that it is an invariant parameter for an individual.



## 1. Introduction

A number of researchers have examined the development of gait in normal children. Sutherland et al. [1] in their landmark study of 186 children aged between 1 and 7 years identified the following five important determinants of mature gait: cadence, velocity, duration of the single support phase, step length and the ratio of the pelvic span to ankle spread. They concluded that gait was largely mature by the age of 3 years although the temporal and distance parameters were continuing to change at age 7 years which was the upper limit of the study. In a subsequent larger study of 309 children Sutherland et al. [2] conclude that the interrelationships between time and distance parameters were fixed by age 4 years. The findings of Beck et al. [3], who measured the temporal and distance parameters, and ground reaction forces, in a sample of 51 children aged 11 months to 14 years were in broad agreement with Sutherland et al. [1,2] and concluded that changes after the age of 5 years were more attributable to height than age.

Other investigators, however, have come to different conclusions. For example, Rose-Jacobs [4] concluded that gait had not matured fully by the age of 5 years, which was the upper age limit in her study of 31 children. Her study included consideration of the effect of speed on gait and the children were evaluated at slow, free and fast speeds of walking. Grieve and Gear [5] identified 5 years of age as a significant milestone in gait maturation in their study of the spatial and temporal gait parameters in a sample of 50 subjects aged between 1 and 35 years of age. They concluded that the product of step frequency and the square root of body height remained approximately constant after 5 years of age. In their study [5] the distance parameters were normalised to body height to minimise the effect of different statures. Norlin et al. [6], by contrast, included adolescents in their study of 230 individuals from 3 to 16 years and concluded that the temporal and distance parameters of gait depended on age up to the age of eight, but thereafter leg length was more dominant. They also concluded that gait continued to change up until at least the age of 16 years. Menkveld et al. [7] also concluded that gait patterns continued to develop into adolescence but stated that all of their subjects, aged 7–16 years, "demonstrated gross temporal maturity in gait".

It is likely that the reported variation in age by which gait is thought to have matured is a reflection of the gait parameters considered in the various studies [1–7]. A major limitation in the

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the walk ratio is maturing towards a stable value for each individual since subjects could have been adjusting towards their final walk ratio value at either a constant or an erratic rate of change.

The reasons for the absence of any trend in the rank correlations for normalised cadence between consecutive pairs of years are not clear, although this parameter may be more dominant in the adjustment of speed. It is not possible to say whether the absence of a trend is because this parameter was already stable by age seven, and only random variation has been observed, or whether further maturation should be expected after the age of 11 years. It may be relevant to note that the final rank correlation coefficient for cadence was 0.8, which is of a similar magnitude to the final rank correlation for walk ratio. Also, as already noted, the final rank correlation for cadence was markedly greater than any found in previous consecutive pairs of years, which may suggest a rapid maturation of this parameter between the ages of 10 and 11.

## 5. Conclusions

It appears that normalised walk ratio and normalised stride length may be idiosyncratic features of gait which were not mature by the age of 7, and may not even be mature by age eleven, even though, when considered en masse, all age groups produced similar means and standard deviations for normalised parameters. The walk ratio, in particular, appeared to show increasing rank stabilisation from the ages of 7–11 years, and accords with the proposal [11] that it is an invariant parameter for the individual. Clearly, further work needs to be done to establish whether walk ratio is a robust and sensitive indicator of gait maturity, but the identification of such a parameter may contribute to our understanding of the development of the control of gait. This may then be of interest in the clinical context when the potential success of intervention is related to the maturity of the patient.

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## Conflict of interest

None.

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