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Relationship of tibialis anterior muscle reaction time and gait characteristics

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ABSTRACT

This study investigated the relationship of the reaction time of tibialis anterior muscle in association with walking speed, stride length, and cadence. Prior to undergoing the experiment 18 healthy young men had their height, body weight and reaction time of their tibialis anterior muscle measured in a seated position, they then underwent a fast walk on a 10-metre gait path. There was a significant positive correlation between the walking speed and both stride length and cadence, indicating that a lighter body weight and shorter reaction time would be the predictive factors for a larger stride length. There was a significant negative correlation between the stride length and cadence, indicating that a larger stride length and lower cadence would be a predictor of fast walk. These findings could be useful parameters for assessing the walking ability of clients in their twenties with gait abnormalities.

KEY WORDS

gait, reaction time, tibialis anterior muscle

INTRODUCTION

The shift in center of gravity, trunk and limb movements, and muscular activity in each phase of the gait cycle are well known[1,2,3,4]. Many investigations concerning gait have been carried out using various methods of measurements such as electromyography, ground reaction force measurement and acceleration measurement[5,6,7,8]. However, observation of individuals' gait pattern reveals slight differences ; some walk relatively slowly and others quickly, while others walk with a smaller or larger stride length. Moreover, one can voluntarily change stride length and/or cadence, so that the walking speed is increased or decreased at will[9].

Walking speed, stride length, and cadence are indices of one's normal or abnormal walking pattern. The relationship between these three indices and reaction time of the knee joint to achieve extension in a gait cycle has been investigated[10]. However, a multiple complexity of muscles are involved in gait, and, in this study, we focused our attention only on the tibialis anterior muscle which is involved primarily with dorsiflexion of the ankle joint and demonstrates the largest muscular activity immediately after the heel strike phase during each gait cycle[2]. The purpose of this study was, therefore, to investigate the relationship between the reaction time of the tibialis anterior muscle *vis-à-vis* walking speed, stride length, and cadence in one gait cycle for young adults during a fast walk. We also included in our investigation the influence of height, body weight, and age, which may have affected this relationship. The significance of

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this study would be that it could be a valuable assessment tool of the walking ability of young adult clients with gait abnormalities. Specifically, it could further the understanding of the time required from the immediate toe-off phase to the initiation of the tibialis anterior activity, or the relationship between the speed of the so-called 'switchback' at the moment of foot clearance and walking speed. This study may also provide us with some unanswered questions concerning the time required to process incoming information within the central nervous system and/or the relationship between the nerve conduction velocity and walking speed.

PARTICIPANTS AND METHOD

Selection of the participants We selected 18 healthy male college students in their twenties (Table 1). The reason for choosing young participants was to keep the variability of stride length to a minimum[3].

Experimental procedure Upon entering the laboratory the participant was weighed and his height measured.

1. *Measurement of walking speed, stride length, and cadence* A 15-millimetre (mm) wide and 0.2-mm thick vinyl tape was stuck in a straight line onto a flat floor surface 15 metres (m) long. In addition, in order to mark of a 10-m length walking path in the mid-15-m gait path two 20-centimetre long pieces of vinyl tape were stuck breathwise 2.5 m from either end of the 15 m path (Fig.). The participant was asked to walk at their fastest speed with their normal gait pattern, but not to run, on the gait path. The participant themselves decided with which limb to commence the walking pattern. We measured the number of steps and time required to walk on the 10-m gait path, the latter of which is frequently included in the physiotherapist's assessment as an objective measurement of a client with a gait disorder. The participants were lightly dressed with a T-shirt and shorts so that nothing interfered with carrying out their walking on the path. The laboratory was kept fairly quiet with the ambient room temperature at around 20° Celsius during the procedure.

Table 1 Mean and standard deviation for seven variables.

Variables	mean (SD)	
Velocity	2.96 (0.55)	*m/sec*
Stride length	0.98 (0.11)	*m*
Cadence	3.03 (0.37)	*steps/sec*
Age	21.9 (2.0)	*years*
Height	170.6 (4.8)	*cm*
Weight	65.4 (2.5)	*kg*
Reaction time	195.9 (10.6)	*msec*

2. *Measurements of the reaction time* These were carried out in a seated position with the knee and hip joints kept at 90° of flexion and the feet were placed flat on the floor, and the participant was asked to dorsiflex the left ankle joint in reaction to an auditory stimulus of 1,000 Hertz which was given one or two seconds following a preliminary verbal cue by the investigator. Electrical activity of the left tibialis anterior muscle was recorded from a surface electrode on a type 7T07A/7T0A electromyogram (San-ei Instruments, Inc., Japan). One connecting lead of an auditory stimulator was connected to the machine to record the electromyogram and the other lead to a headphone. The reaction time was operationally defined as the latent period between when the presentation of the auditory stimulus was received and the commencement of the electrical activity recording of the tibialis anterior muscle on the electromyogram.

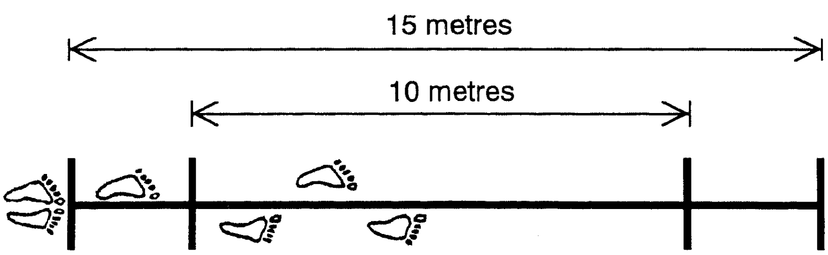

Fig. Schematic illustration of the gait path.

The latent period was measured at intervals of 0.1 second. This measurement took place following five practice sessions for each participant. Ten trials were carried out with a measurement interval of 10 and 20 seconds. The average latent period was calculated from these 10 trials to represent each participant's reaction time.

Data analysis Walking speed, stride length, and cadence were calculated from the number of steps and time required to walk on the 10-m gait path. Correlation coefficients and regression equations were calculated to examine the relationship among the seven variables ; namely, walking speed, stride length, cadence, age, height, weight, and reaction time. The correlation coefficient was analyzed using a paired t test with the level of significance at 0.05. A multiple regression analysis was carried out among the six variables of walking speed, stride length, cadence, body weight, height, and reaction time.

RESULTS

The mean and standard deviation (SD) for walking speed, stride length, cadence, age, height, body weight and reaction time are shown in Table 1. The walking speed showed a significant positive correlation for both the stride length and cadence (Table 2). Correlation coefficient (r) for the walking speed and stride length was 0.753 ($p<0.01$) and that for the walking speed and cadence 0.718 ($p<0.01$).

The multiple-regression equation for stride length and cadence in opposition to walking speed was $3.000+3.207x$ (stride length) + $0.930x$ (cadence) [$R=0.964$, $p<0.01$]. There was no significant correlation between walking speed and any of the other variables.

There was a significant negative correlation be tween the stride length and cadence, and r was -0.41 ($p<0.05$). Also, there was a significant negative corre lation for stride length and body weight, with r being -0.438 ($p<0.05$). In addition, multiple regression equa tion for body weight and reaction time in oppositio to stride length was $1.001-0.012x$ (body weight) - $0.005x$ (reaction time) [$R=0.324$, $p<0.05$]. However there was no significant correlation between the stride length and other variables.

DISCUSSION

The walking speed and stride length demonstrate a high correlation throughout this investigation, as di walking speed and cadence. Also, the results from th multiple regression analysis showed that greater strid length and lower cadence were the predictors for fas walk. Itoh and his associates[5] investigated the rela tionship between the reaction time for the quadricep femoris muscle in quick extension of the knee in fas walk including maximum torque, walking speed stride length, and cadence. They also concluded tha fast walk was achieved when the body weight wa lighter. Nakamura states that walking speed differ with body weight, height and age[10]. Therefore, th above findings are in agreement with those of Ito and his associates and Nakamura.

Walking speed has been shown to correlate wit one's stride length, cadence, and weight[9]. In our pre sent study similar findings were evident and, conse quently, larger stride length and lower cadence wer factors for fast walk. However, there was no relation ship between walking speed and weight in our result which was not in agreement with the findings of Ito and his associates[9]. This fact may be explained b

Table 2 Correlation matrix for the variables.

Variables	Velocity	Stride length	Cadence	Age	Height	Weight
Stride length	0.753**					
Cadence	0.718**	-0.427*				
Age	0.142	0.209	0.017			
Height	-0.148	0.032	-0.236	0.242		
Weight	-0.312	-0.438*	-0.144	-0.218	0.375	
Reaction time	-0.031	-0.298	-0.197	0.058	0.094	0.372

*$p<0.05$, **$p<0.01$

the rather light body weight of the participants in this study ; specifically, there was little variability amongst the participants.

Itoh and his associates[10] also found in their experiment that the shorter the reaction time, the greater was the stride length, and the longer the reaction time, the higher was the cadence. The multiple regression analysis in our study demonstrated that lighter body weight and shorter reaction time were the predictors for longer stride length. The body weight and reaction time may, therefore, be related to stride length in that the heavier one's physique, the stronger the muscle contraction required to move the limb. Thus, more time is required to execute the limb movement, hence shorter stride length, and vice versa. Normally, one expects reaction time to be fast so as to assure adequate foot clearance during the swing phase of gait. This would be of greater significance for clients with a heavier physique than for those with a lighter physique ; the former being more likely to fall if the tip of the toes hits the floor while walking.

According to Tokuda and his associates[11], age and walking speed show a relatively close relationship. However, no significant relationship between these two variables was found in our present study. The reason for this may be due to the fact that the choice of participants was limited to young adults in their twenties.

The findings in the present study showed that the greater the stride length, the lower the cadence. In view of developmental changes, the walking speed depends primarily on an increase in stride length, so that cadence decreases. The findings of the present study are, therefore, in agreement with Nakamura and his associate's statement that the relationship between developmental change and any negative correlation between the stride length and cadence is regarded as a similar phenomenon[12].

As for the reaction time, there was no relationship between the stride length and cadence. However, results from the multiple regression analysis showed that stride length was related to the amount of body weight and reaction time, indicating that the lighter the body weight, the larger the stride length. Therefore, this finding suggests that, for fast walk, reaction time is the sole predictor of stride length.

Human bipedal locomotion is a very complex mechanism involving synergistic movement of a number of muscle groups in addition to incorporating other actions such as the anti-gravity mechanism, dynamic equilibrium, and rhythmic acceleration, all of which have to be coordinated, processed and carried out by the central nervous system. Reaction time is known to be involved in dynamic balance and rhythmic acceleration, both of which are required for fast motion in human bipedal locomotion[10]. Further, a large number of muscles are involved in gait, and efficient gait is only possible with efficient and coordinated functioning of lower limb muscles and a high degree of flexibility present in the ankle joint. When such factors are present, balance and stability in walking is possible not only anteroposteriorly, but also sideways.

There was no relationship between reaction time of the tibialis anterior muscle and either the stride length or cadence. This finding can be accounted for by the fact that the seated position for measurement of the reaction time may have been inappropriate since the reaction time in healthy individuals fluctuates as the posture and/or position of the limb(s) change, so that afferent proprioceptive stimuli from the periphery of the body fluctuate during volitional movements. Another factor would be the effect of biological rhythms such as heart rate and respiration on human locomotion.

In future studies of this kind thought should be given to what position the body is in for measurement of reaction time to stimuli ; eg., in standing position only or measurement taken with the knee in various degrees of flexion.

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前脛骨筋の反応時間と歩行速度，歩幅，歩行率の関係

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要　旨

歩行能力の指標と前脛骨筋の反応時間との関係を検討するために以下の実験を行った。平均年齢（標準偏差）21.9（2.0）歳の健常大学生18名に対し，身長および体重を測った後，平地上を10メートルできるだけ速く歩かせ，速度，歩幅，および歩行率を計算した。次に，椅座位で音刺激に対して前脛骨筋を素早く収縮できる反応時間を測った。7個の変数間の相関係数を求め，分析した。また年齢を除いた6個の変数について重回帰分析を行った。速い歩行では，速度と歩幅，速度と歩行率，および歩幅と歩行率との間にそれぞれ有意な相関関係が認められ，歩幅の長いことおよび歩行率の小さいことが速い歩行の予測要因であった。歩幅は，体重および反応時間と有意な重相関性を示し，反応時間の短いことや，体重の軽いことが歩幅を長くする予測要因であった。本所見は，歩行障害を来たした20歳代男性の歩行検査における指標になりうる。