88 - ANALYSIS OF GAIT SPACE-TIME VARIABLES: COMPARISON OF MALE AND FEMALE

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Introduction

As walking is an easily accessible aerobic activity, it is practiced by many people as an alternative physical activity. Despite the indubitable benefits of this kind of physical exercise, its inadequate practice can lead to changes in the locomotion system (AMER, 2001, ANDRADE et al, 1999). Although two people do not walk in an identical way, there are certain stride characteristics that are universal. These similar features may serve as a basis for the kinematic, dynamic description of the muscle activity and others. The kinematic study of the movement is fundamental for the biomechanical analysis of the sports gesture and the physical activity (ENOKA, 2000; HALL, 1995, HAMILL et. al., 1999). A sequence of repetitions of limb movements is used in walking to drive the body forward while simultaneously keeping a stable posture. Due to each sequence, a series of multisegmented interactions develops between the two lower limbs and the total body mass. The identification of the numerous events that occur requires a visual analysis of several aspects of the gait. There are three basic approaches. The simplest one subdivides the stride cycle according to the variations of reciprocal contact of the two feet with the surface. The second one uses gait time and distance criteria. The third approach identifies the functional meaning of the events of the stride cycle and the intervals as functional phases of stride (PERRY, 2005). As the body moves forward, one limb serves as a support while the other advances to a new support position. Next, the limb roles are inverted. For the body to transfer the weight from one limb to the other, both feet must be in contact with the ground. A single sequence of these functions for a limb is called stride cycle (MURRAY, DROUGHT & KORY, 1964; apud PERRY, 2005). The gait is made up of repeated step and stride cycles. A stride cycle is characterized by the start of a certain event by one limb and continues till before the same event is repeated with the same limb (SODERBERG, 1990, apud BARELA, 2005). Each cycle is divided in two periods - support and pendulum movement, frequently called stride phases. Support time is the term used to identify the period when the foot is in contact with the surface. The support starts with the initial contact. The term pendulum movement applies to the time when the foot is in the air for the advance of the limb. The pendulum movement starts when the foot is raised from the surface (raising the toes). The support is subdivided in three intervals according to the sequence of contact of the two feet with the ground. The initial double support marks the start of the stride cycle. This is the moment when both feet are on the ground after the initial contact. The simple support of the limb starts when the other foot is raised for the pendulum movement. The end double support is the third subdivision. It starts with the contact of the other foot with the ground (initial counter lateral contact) and continues until the original support limb is raised for the pendulum movement (ipsilateral raising of toes). The term end double support of the limb has been avoided as the weight support by the limbs is much asymmetrical (PERRY, 2005). The accurate duration of these stride cycle intervals varies with the individual's stride speed (ANDRIACCHI, OGLE, & GALANTE, 1977; apud PERRY, 2005). The duration of both stride periods present a counter relation with the stride speed. That is, both the total support and pendulum movement times decrease as the stride speed increases. The change in support and pendulum movement times becomes progressively larger as the speed decreases. The faster stride speed extends the simple support and shortens the two intervals of double support (OTIS, BURTEIN, 1981; apud PERRY, 2005). The reciprocal is true as the stride speed decreases. This pattern of change is curvilinear. An interval when both feet are in contact with the ground for the limbs to change support roles is a basic feature of stride. When the double support is omitted, the person enters the run mode (MANN, 1982; apud PERRY, 2005). In the beginning of the development of the analysis of stride, investigators recognized that each pattern of movement was related to a different functional demand. They called these movement patterns gait phases. A larger experience in data correlation has progressively expanded the number of gait phases already identified. Now it is evident that each stride has eight functional patterns. Technically, these are subphases, since the basic divisions of the stride cycle are support and pendulum movement, but the functional intervals are known as phases (CRAIK E OATIS, 1995; ROSE e GAMBLE, 1998).

Each of the eight gait phases has a functional objective and a critical pattern of synergetic selective movement to achieve this goal. The sequential combination of the phases also enables each limb to perform the three basic tasks, namely: weight acceptance (WA), simple support (SS), and limb advance (LA).

The events relative to the stride cycle are considered time events. Thus, measurements related to the speed, support and pendulum movement duration, and rhythm (or frequency) are normally investigated in walk studies (WINTER, 1983). There also are aspects related to the distance measures: step and stride length. Normally, the stride cycle is normalized by the cycle percentage, starting with the first contact of the foot with the ground (0%) till the next contact with the ground (100%). This normalization enables the comparison of individuals and conditions with different durations (WINTER, 1991, apud BARELA, 2005). The stride speed is considered a fundamental measure since it defines the rate of displacement of people as a function of the time necessary to cover a certain distance (PERRY, 1995).

The rhythm is the number of steps (or strides) performed in a given period of time. It is normally given as steps/minute (or strides/minute). Thus, the rhythm can be calculated as the ratio between stride speed and stride length, or yet, it can be calculated as the ratio between one and the duration of the stride. The free or natural rhythm of stride is the one that the individual performs when instructed to walk as naturally as possible (WINTER, 1991, apud BARELA, 2005). WHITE, et al (1998) demonstrated that the surface where the stride is performed also interferes with the stride kinetic parameters. The duration of the double support period is approximately 20% of the stride cycle, being 10% during the initial double support and 10% during the end double support (WHITTLE, 1996b, apud BARELA, 2005). It is important to notice that as the stride speed increases, the duration of the support period decreases and that of the pendulum movement period increases (ANDRIACCHI, OGLE e GALANTE, 1977; KIRTLEY, WHITTLE e JEFFERSON, 1985, apud BARELA, 2005). KANG et al. (2002) found differences in stride biomechanical variables of male and female in different slopes. Relative to the difference between genders and speeds, CROSBIE et al. (1997) suggest that both gender and speed affect the kinematics of the spine during the stride.

This study has the general objective of evaluating the space-time stride features of walkers considering gender and stride speed and the specific objectives of comparing the stride space-time features of male and female at 4, 5, and 6 km/h.

Methodology

Subjects

Twenty volunteers of both genders, beginner treadmill walkers, 50% male and 50% female with average age of 23.2 (+ 4.76 years) took part in this study. The average height and body mass were 1.63 m (+ 5.59 m) and 58.73 kg (+ 4.64 kg) for female and 1.76 m (+ 9.29 m) and 75.25 kg (+ 8.84 kg) for male. The experimental procedures and the selection of healthy individuals were in agreement with the American College of Sports Medicine's guidelines.

Procedures and instruments

The following procedures were adopted in data acquisition: **a)** the individuals were interviewed to collect personal data on aspects relative to treadmill walking, **b)** all individuals had their body mass and height measured, **c)** the individuals were instructed about the works and the correct use of the treadmill, **d)** adaptation of the individuals to the equipment at a comfortable speed for 2 min for each individual.

Data collection was carried out in a physical evaluation and physical therapy clinic at 4, 5, and 6 km/h with permanence of 2 min in each phase. Data acquisition time was 30 s. The space-time variables selected as stride analysis parameters were: stride length (SL), measured in meters, double support time (DST), measured in seconds, and single support time (SST) measured in seconds.

Each volunteer walked on a level ergometric treadmill set at low speed for adaptation. A mini DV Canon ZR600 video camera with capture frequency of 30 frames per second was used to record the images to a mini DV linear plus Panasonic-type video tape. The position of the equipment for the experiment is shown in figure 1. A camera on a tripod located 5 m to the side of the treadmill recorded the lower limb movement, thus allowing the definition of the stride cycle.

To obtain the double and single supports times, it was selected several videos of each individual grouped in two-second film duration, which were later divided according to the number of DST and SST (by dividing a second by the number of frames analyzed). To calculate the stride length, the number of steps taken in a 2-min walk at a given speed was divided by the distance covered.

The equipment used was an ergometric treadmill Life Fitness model 91 Ti (speed from 0.8 to 16 km/h, slope of 0-15%, 3.0 HP motor, CC, frontal and side bars ergonomically correct), video camera mini DV Canon ZR600, a PC Pentium 4, and software virtualdub 1.4.

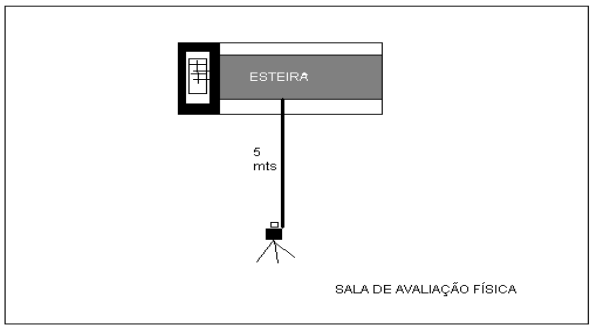

Figure 1. Schematic representation of the experimental arrangement for data acquisition in the physical evaluation room.

Statistical analysis

The data were analyzed by descriptive statistics by calculation of average, standard deviation, and variation coefficient. The values found for male and female at the different speeds were compared with T student test and ANOVA. All analyses were made with $p \leq 0.05$.

Results

The average SL, DST, and SST values at 4, 5, and 6 km/h are shown in tables 1, 2, and 3. It was observed significant differences between the space-time variables of male and female in the three different speeds.

Table 1 - Comparison of the space-time variables of male and female at 4 km/h.

Variables	Gender	Mean	p
CP	masculino	0,665m	0,003
	feminino	0,559m	
TDA	masculino	0,314s	0,007
	feminino	0,279s	
TAS	masculino	0,413s	0,002
	feminino	0,388s	

Table 2 - Comparison of the space-time variables of male and female at 5 km/h.

Variables	Gender	Mean	p
CP	masculino	0,759m	0,004
	feminino	0,691m	
TDA	masculino	0,269s	0,001
	feminino	0,234s	
TAS	masculino	0,396s	0,002
	feminino	0,374s	

Table 3 - Comparison of the space-time variables of male and female at 6 km/h.

It was also found significant differences ($p<0.05$) for SL, DST, SST at the different speeds, both for male and female.

Variables	Gender	Mean	p
CP	masculino	0,832m	0,001
	feminino	0,781m	
TDA	masculino	0,226s	0,007
	feminino	0,195s	
TAS	masculino	0,380s	0,002
	feminino	0,360s	

Discussion

Concerning the comparison of the variables analyzed for male and female, in general, male presented larger values for all variables: stride length (SL), double support time (DST), and single support time (SST). Male presented the larger SL value at 4 km/h comparatively to that of female, with a difference of 0.106 m in relation to those at 5 km/h (0.068 m) and 6 km/h (0.051 m).

The increase in SL and decrease in support times with the increase in stride speed corroborate the findings of ANDRIACCHI, OGLE e GALANTE, 1977; KIRTLEY, WHITTLE e JEFFERSON, 1985.

SL, DST, and SST presented higher values for male, which could be explained by anthropometric differences related to the length of the lower limbs of male and female. This phenomenon could indicate a form of compensation of some anthropometric factors, as for example the shorter length of the lower limbs and the resulting shorter stride length of female, which require a larger number of steps per time unit (WINTER, 1983, KANG et al. 2002).

Variables such as muscle force, flexibility, specificity, and running practice have not been considered.

These results confirm that stride is an individual characteristic and that it is possibly related to body size, mainly lower limb length, and to the flexibility of the muscles involved in walking.

Conclusion

Based on the results presented and the theoretical framework of this study, it can be concluded that male and female present differences in stride, being the variables stride length, double support time, and single support time at 4, 5, and 6 km/h larger for male. This difference may be caused by anthropometric factors. Furthermore, the increase in stride speed affects the behavior of the space-time variables of healthy individuals.

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ANALYSIS OF STRIDE SPACE-TIME VARIABLES: COMPARISON OF MALE AND FEMALE

As walking is an easily accessible activity, it is practiced by many people as an alternative physical activity. Although two people do not walk in an identical manner, there are certain stride characteristics that are universal. These similar features may serve as a basis for the kinematic and dynamic description of muscle activity and others. The kinematic study of movement is fundamental for the biomechanical analysis of sports gestures and the physical activity. This study aimed to evaluate the space-time characteristics of the stride of walkers as a function of gender and speed and to compare the space-time characteristics of stride of male and female at different speeds. Twenty volunteers, 10 male and 10 female aged 23.2 (+ 4.76 years), beginner treadmill walkers, took part in this study. Each volunteer walked on the treadmill at 4, 5, and 6 km/h for 2 min in each phase. Data acquisition time was 30 seconds. The following stride space-time variables were selected for analysis: stride length (SP), double support time (DST), and single support time (SST), which were measured by kinemetry. It has been concluded that male and female present differences in stride ($p < 0.05$), being the SL, DST, and SST values at 4, 5, and 6 km/h larger for male. This difference may be caused by anthropometric factors. Furthermore, the increase in stride speed affects the behavior of the space-time variables of healthy individuals.

Keywords: Stride speed, kinemetry, space-time variables.

ANALYSE DE VARIABLES SPATIO-TEMPORELLES DE LA MARCHE: COMPARAISON ENTRE LES HOMMES ET LES FEMMES

La marche, étant une activité d'accès facile, est pratiquée par beaucoup de personnes comme une alternative d'activité physique. Bien que deux personnes ne se déplacent pas de manière identique, il existe certaines caractéristiques de la locomotion qui sont universelles, et ces points similaires servent de base à la description cinématique et cinétique de la marche. L'étude cinématique du mouvement est fondamentale pour l'analyse biomécanique du geste sportif et de l'activité physique. Le but de notre étude est d'évaluer les caractéristiques spatio-temporelles de la marche, chez les pratiquants de ce sport, en prenant en considération le sexe et la vitesse, et de comparer les caractéristiques spatio-temporelles de la marche chez l'homme et chez la femme, soumis à des vitesses différentes. Cette étude a compté sur la participation de 20 volontaires des deux sexes, 10 hommes et 10 femmes à l'âge de 23,2 (± 4,76 ans), tous des débutants de la pratique de la marche sur tapis roulant. Chaque volontaire a marché sur un tapis roulant à la vitesse de 4km/h, 5km/h et 6km/h, en restant dans chaque phase pendant 2 minutes. Le temps d'acquisition des données a été de 30 secondes. Nous avons selectionné comme paramètres de l'analyse de la marche les variables spatio-temporelles suivantes: la longueur du pas (CP), le temps de double-appui (TDA), et le temps d'appui simple (TAS), obtenues au

moyen d'un équipement de cinemométrie. Nous avons conclu que les hommes et les femmes manifestent des différences de marche ($p<0,05$). Les variables suivantes: longueur du pas, temps de double appui et temps d'appui simple, à la vitesse de 4 km/h et 6 km/h, sont plus grandes chez les hommes. Il est possible que cette différence soit due à des facteurs anthropométriques. En plus, l'augmentation de la vitesse a influencé le comportement des variables spatio-temporelles de la marche de ces individus.

Mots-clés; Vitesse de la marche, cinémométrie, variables spatio-temporelles.

ANÁLISIS DE LAS VARIABLES ESPACIO-TEMPORALES DE LA MARCHA ENTRE HOMBRES Y MUJERES.

Por se tratar de una actividad de fácil ejecución, la caminata es practicada por muchas personas como una opción de actividad física.Aunque dos personas no puedan locomoverse de la misma manera,hay ciertas formas de locomoción que son universales y estos puntos similares sirven como base para la descripción cinemática y cinética de la marcha.El estudio cinético del movimiento es imprescindible para el análisis biomecánico del movimiento deportivo y de la actividad física.Este estudio tiene como objetivo evaluar las características espacio-temporales de la marcha de los practicantes de caminata teniendo en cuenta el sexo y la velocidad y comparar las características espacio-temporales de la marcha entre hombres y mujeres en diferentes velocidades.Estuvieron presentes en este estudio 20 personas de ambos los sexos,siendo 10 hombres y 10 mujeres con la edad mediana de 23,2(+ 4,76 años),iniciantes de la práctica de caminata en estera.Cada persona caminó en una estera con la velocidad de 4km/h,5km/h y 6km/h ,estando en cada fase por 2 minutos.El tiempo de adquisición de los datos fue de 30 segundos. Fueron selecionados como parámetros del análisis de la marcha las variables espacio-temporales:extensión del paso (EP),el tiempo de doble apoyo (TDA) y el tiempo de apoyo sencillo (TAS),obtenidos a través de la cinemetria. La conclusión fue que hombres y mujeres demuestran diferencias de la marcha ($p<0,05$) siendo las variables la extensión del paso,tiempo de doble apoyo y tiempo de apoyo sencillo en las velocidades de 4km/h,5km/h y 6km/h mayores para los hombres.Quizá esta diferencia sea causada por factores antropométricos. Además de eso el incremento de la velocidad influyó en el comportamiento de las variables espacio-temporales de la. marcha de estas personas

Palabras clave: marcha, cinemetria, variables espacio-temporales.

ANÁLISE DE VARIÁVEIS ESPAÇO-TEMPORAIS DA MARCHA: COMPARAÇÃO ENTRE HOMENS E MULHERES

A caminhada, por ser uma atividade de fácil acesso, é praticada por muitas pessoas como uma alternativa de atividade física. Embora, duas pessoas não possam se locomover de maneira idêntica, existem certas características da locomoção que são universais, e estes pontos similares servem como base para a descrição cinemática e cinética da macha. O estudo cinemático do movimento é fundamental para a análise biomecânica do gesto esportivo e da atividade física. Esse estudo tem como objetivo avaliar as características espaço-temporais da marcha de praticantes de caminhada considerando o gênero e a velocidade e comparar as características espaço-temporais da marcha entre homens e mulheres em diferentes velocidades. Participaram deste estudo 20 voluntários de ambos os gêneros, sendo 10 homens e 10 mulheres com a idade 23,2 (± 4,76 anos), iniciantes da prática de caminhada em esteira. Cada voluntário caminhou em uma esteira com velocidade de 4Km/h, 5Km/h e 6Km/h permanecendo em cada fase por 2 minutos. O tempo de aquisição dos dados foi de 30 segundos. Foram selecionadas como parâmetros da análise da marcha as variáveis espaço-temporais: comprimento do passo (CP), o tempo de duplo apoio (TDA) e tempo de apoio simples (TAS), obtidas por meio de cinemetria. Concluiu-se que homens e mulheres demonstram diferenças da marcha ($p<0,05$), sendo as variáveis comprimento do passo, tempo de duplo apoio e tempo de apoio simples nas velocidades de 4 Km/k, 5 Km/h e 6 Km/h maiores para os homens. Possivelmente essa diferença seja causada por fatores antropométricos. Além disso, o aumento da velocidade influenciou o comportamento das variáveis espaço-temporais da marcha desses indivíduos.

Palavras-chave: Velocidade da marcha, cinemetria, variáveis espaço-temporais.