Quantification of Gait Coordination Variability of Pelvis-Thigh Segments in Young Sedentary and Practitioners People Walking in Different Slopes Using the Vector Coding Technique

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Abstract— **The present study aimed quantify the variability of segmental coordination, during the gait of young practitioners and sedentary people on different slopes (Horizontal, 8% and 10% Upward (Up) and Downward (Down) conditions) maintaining the self-selected speed (VAS), using the Vector Coding technique. Thirty young people participated in this study, of which 15 were sedentary and 15 practiced physical exercises at least one hour a day, three times a week. They performed a protocol of walking 1 minute on a treadmill on each inclination for data collection, in randomized order. For the Pelvis-Thigh segment, the angles were computed during the four phases of the gait (first double support, single support, second double support, and swing), in the sagittal Flat. The data were analyzed using a customized Matlab code. As the data had a normal distribution, an ANOVA was used to classify the data There were significant statistical differences for the Simple Support and Swing phases, with greater variability for the slope situation.**

Keywords— **Variability, Coordination, Vector Coding, Slope**

I. INTRODUCTION

The practice of physical activities in adolescence is related to a lower risk of diseases when aging, better skeletal muscle development, and greater social interaction among other benefits [1].

Outdoor walking surfaces are generally not horizontal, and the topography of the surface varies in terms of unevenness and inclination. The slope of the path can be man-made, like ramps for access to buildings, or it can be a consequence of the environment, like a hill. Inclined surfaces, compared to level surfaces, impose a different demand for gait Swing. Thus, kinematic changes in gait have been studied on multiple surfaces to determine the effects of aging on coordination and gait variability [2]. The acceleration patterns of the head and pelvis have been studied when walking on uneven surfaces [3] and different inclined surfaces[4,5].

Coordination is an organization of and between elements in time. Coordination is a process in which movement components are sequentially organized over time, and their relative magnitude determined to produce a functional or synergistic movement pattern [6]. Coordination between movements of body parts is essential for gait and is coded, often in a subtle way, to accommodate variations required by the task which may be, for example, speed [7], curves in the path [8] or even an obstacle in the middle of the path [9].

Vector Coding assesses the continuous dynamic chaining of movement between segments by means of vectorial orientation between two adjacent points in time representing them in the angle-angle diagram concerning the positive horizontal axis. The result of this process is called the coupling angle γ, which assumes values between 0 ° and 360°. Since γ is directional, circular statistics are used to calculate the mean $\overline{\gamma_i}$, and the variability of the coordination angle ($CAVi$) is calculated from multiple gait cycles [10].

The aim of this study was to quantify the variability of coordination of the Pelvis-Thigh segment of two groups of young people (practitioners of physical and sedentary activities) during walking on a treadmill with self-selected constant speed (VAS) by varying the inclination (Flat, 8% and 10% Upward (Up) and Downward (Down) conditions). The hypotheses raised were that there would be: 1) greater coordinative variability in young practitioners compared to sedentary ones; 2) at the same speed, different inclinations would exacerbate the difference in variability between groups of young people; and 3) the inclines would induce greater variability than the horizontal condition, as their imposes a greater biomechanical demand.

II. MATERIALS AND METHODS

A. Subjects

Thirty young adults (eight sedentary men and seven women, and nine physically active men and six women, who performed physical activities at least three times a week, one hour a day) participated in this study. The study was approved by the local Ethics Committee for Human Research, and the participants signed inform consent (Protocol 1.003.935).

B. Protocol

For data collection, 16 reflective markers were fixed at anatomical points according to Vicon's lower limb gait model (Vicon, Oxford Metrics, Oxford, United Kingdom). A 3D capture system containing 10 infrared cameras operating at 100 Hz was used. The data were filtered using the Butterworth filter, low pass, zero delay, fourth-order, with the cutoff frequency 8 Hz. The kinematic data were exported as a text file and analyzed with a customized MATLAB code (R2018a, MathWorks, Natick, MA).

The Auto Selected Speed (VAS) on the treadmill was determined according to the protocol of Dingwell and Marin (2006). A four-minute walk on the treadmill was allowed for familiarization and immediately followed by a two-minute rest [11]. Then, the participants took five walks of 1 minute each in the VAS for each of the five inclinations, in a randomized way.

The Pelvis-Thigh segment was analyzed for 25 strides, normalized to 100 points each, for each one-minute walk period. The segmental angles were calculated with respect to the global coordinate system of the laboratory. Then, the coupling angles were calculated using of vector coding algorithm, in four phases of the gait cycle: first double support, single support, second double support and Swing. The coupling angles represent the coordination patterns and the standard deviation of the coupling angle at each moment of the gait cycle represents the coordination variability.

C. Statistical Analysis

The analysis of variance of repeated-measures with mixed design (ANOVA) was used to compare the two groups, the effect of the slope and the effect of the interaction between the groups and the slopes, followed by a post-hoc test with Bonferroni correction in the cases. Where the main effect was significant. Statistical analysis was performed using SPSS software, version 23 (SPSS Inc., Chicago, IL, USA), with a significance level of α <0.05.

III. Results

The statistical results for each phase are shown in Table 1. There were no significant main effect of group and interaction. For the main effect of inclinations, there were significant differences in the Single Support (p = 0.004) and Swing (p <0.001) phases. In Single Support, there were differences between Up 8% and Down 8% (p <0.001) with greater variability in Down 8%, and between Up 10% and Down 8% (p <0.001) with greater variability in Down 8%. In the Swing phase, such differences occurred for Flat and Down 8% (p <0.001), for Flat and Down 10% (p <0.001) with the highest coordinative variability in Down 8% and 10% in relation to the Plan, respectively. In Up 8% and Down 8% (p <0.001), the variability was greater in Down 8%. Between Up 8% and Down 10% (p <0.001), the variability was greater in Down 10%. For Up 10% and Down 8% (p <0.001), the variability was greater in Down 8%. Between Up 10% and Down 10% (p <0.001), the variability was greater in Down 10%. All segments had a coordination pattern in phase.

Table 1 Coordinative variability of the Pelvis-Thigh segment

Effect	Phases	F	P	η^2
Groups	FDS	<0,001	NS	<0,001
	SS	0,008	NS	<0,001
	SDS	<0,001	NS	<0,001
	SW	<0,001	NS	<0,001
Slopes	FDS	8,432	0,000	0,231
	SS	7,937	**0,004**	0,221
	SDS	1,070	NS	0,037
	SW	31,07	**<0,001**	0,526
Groups vs Slopes	FDS	<0.001	NS	<0.001
	SS	0,019	NS	0.054
	SDS	<0,001	NS	<0,001
	SW	<0,001	NS	<0,001

Analysis of Repeated Measures (ANOVA). FDS= First Double Support; SS= Single Support; SDS= Second Double Support; NS= Not Significant

Figures 1 and 2 show a typical example of Coupling Angle (γ_{mean}) for the Pelvis-Thigh segment.

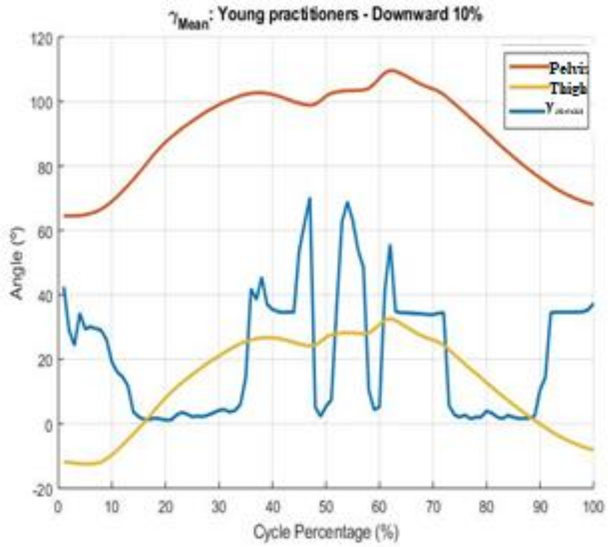

Fig. 1 Coupling angle (γ) for the Pelvis-Thigh segment, for the Downward situation with a 10% inclination, for the group of young practitioners

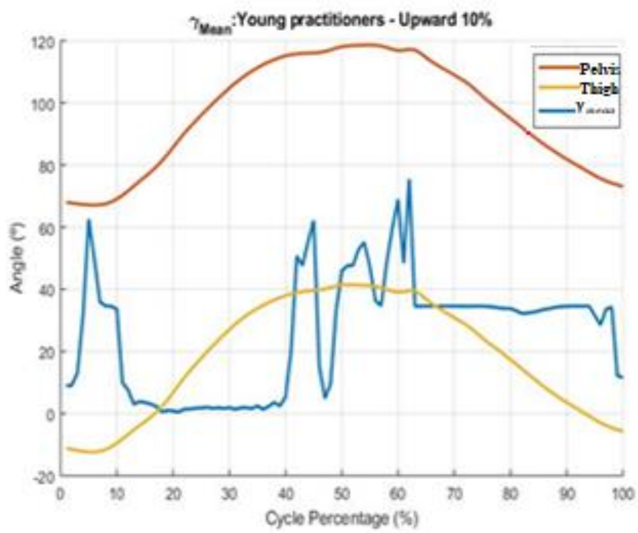

Fig. 2 Coupling angle (γ) for the Pelvis-Thigh segment, for the Upward situation with a 10% inclination, for the group of young practitioners

IV. Discussion

The coordinative variability in the Downward was greater than in the Flat or Upward in single support and swing. Regarding the slope, similar results have been reported [5,12]. The differences observed during these gait phases suggest that the greatest demands on coordination of the Pelvis-Thigh segment occur during foot contact and subsequent loading of body weight on a single limb, which can lead to altered coordination of the segments inducing different gait pattern. Such an altered coordinative patten can increase the risk of injuries [15]. Such injuries can be recurrent due to the occurrence of stress in tissues that are not adaptable to repetitive loading during the gait phases on inclined surfaces [16].

V. Conclusions

The groups showed similar results, suggesting that the level of physical activity of the practitioners group was not sufficient to produce significant changes in the Pelvis-Thigh coordination during gait. The results confirm hypotheses 2 and 3: significant differences were found in the Simple Support and Swing gait phases and were sensitive to the inclination. Additionally, the Downward condition exhibited the bigger coordinative variability compared to the other con-ditions.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Aaron D J, Dearwater S R, et al (1995) Physical activity and the initiation of high-risk health behaviors in adolescents. Med Sci Sport Exerc 27:1639-1645 DOI 10.1249/00005768-199512000-00010
2. Marigold D S, Patla A E (2005) Adapting Locomotion to Different Surface Compliances: Neuromuscular Responses and Changes in Movement Dynamics. J. Neurophysiology 94:1733–1750 DOI 10.1152/jn.00019.2005.
3. Menz R C, Lord H B, Fitzpatrick S R (2003) Age related differences in walk stability. Age Ageing 32(2):137–142 DOI 10.1093/ageing/32.2.137
4. Scaglioni-Solano L F, Aragón-Vargas P (2014) Age-related differences when walking downhill on different sloped terrains. Gait Posture. 41:153–158 DOI 10.1016/j.gaitpost.2014.09.022

5. Vieira M F, de Sá e Souza G S et al (2017) Gait stability, variability and complexity on inclined surfaces. J. Biomech. 54:73–79 DOI 10.1016/j.jbiomech.2017.01.045
6. Scholz J P (1990) Dynamic Pattern Theory—Some Implications for Therapeutics. Phys. Ther. 70:827–843 DOI 10.1093/ptj/70.12.827
7. Donker P J, Daffertshofer S F, Beek A (2005) Effects of velocity and limb londing on the coordination between limb movements during walking, Motion Behav. 37:217–230 DOI 10.3200/JMBR.37.3.217-230
8. Courtine M, Schieppati G (2004) Tuning of a basic coordination pattern consturcts straight-ahead and curved walking in humans. J. Neurophysiol. 91:1524–1533 DOI 10.1152/jn.00817.2003
9. Moraes A E, Lewis R, Patla M A (2004) Strategies and determinants for selection of alternate foot placement during human locomotion: influence of spatial and temporal constrait. Exp. BRAIN Res. 159:1–13 DOI 10.1007/s00221-004-1888-z
10. Robertson E G, Caldwell G E et al (2004) Research Methods in Biomechanics, Human Kinetics, Champaign, IL, USA.
11. Dingwell L C, Marin J B (2006) Kinematic variability and local dynamic stability of upper body motions when walking at different speeds., J. Biomech. 39:444–452 DOI 10.1016/j.jbiomech.2004.12.014
12. De Souza R M, Rodacki A L F (2012) Análise da marcha no plano inclinado e declinado de adultas e idosas com diferentes volumes de atividades semanais, Rev. Bras. Med. Do Esporte. 18: 256–260 DOI 10.1590/S1517-86922012000400008
15. DeLeo A T, Dierks T A et al (2004) Lower extremity joint coupling during running: a current update, Clin. Biomech. 19:983–991 DOI 10.1016/j.clinbiomech.2004.07.005
16. Hafer J F, Freedman J S et al (2016) Changes in coordination and its variability with an increase in running cadence, J. Sports Sci. 34:1388–1395 DOI 10.1080/02640414.2015.1112021

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