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Estimation of the Coordination Variability between Pelvis-Thigh Segments during Gait at Different Walking Speeds in Sedentary Young People and Practitioners of Physical Activities

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Abstract— **The aim of this study was to analyze the variability of coordination during gait of sedentary young people and practitioners of physical activities, at different speeds (Preferred walk speed (PWS), 120% of PWS and 80% of PWS) using the Vector Coding technique (VC). Thirty young people participated in this study, of which 15 are sedentary and 15 practiced exercise regularly at least three times a week. They performed a protocol of walking 1 minute at each speed for data collection on a treadmill in a randomized order. For the Pelvis-Thigh segment, the angles were computed during four phases of the gait (first double support, single support, second double support, and swing) in the sagittal plane. The data were analyzed with a customized MatLab code. Significant differences were observed in 120% and 80% of the PWS for both groups, with greater variability in 80% of the PWS, suggesting that walking at slower speeds is a greater challenge for the neuromuscular system, when compared to higher speeds.**

Keywords— **Variability, coordination, practitioners, sedentary, Pelvis-Thigh.**

I. INTRODUCTION

Regular physical activity during childhood and adolescence contributes to a better bone and muscle condition, helps in controlling body mass, preventing or delaying hypertension, and reduces levels of depression and anxiety [1]. However, the reasons, if any, for how exercise practice affects pelvic-thigh segmental coordination in young people is still unclear.

Coordination can be defined as a process in which movement components are sequentially organized over time, and their relative magnitude determined to produce a functional or synergistic movement pattern [2], and can evaluated by using nonlinear techniques, as Vector Coding. 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 [3], curves in the path [4] or even an obstacle in the middle of the path [5].

In the Vector Coding technique, the phase angles represent the segment coordination pattern, while the standard deviation of the phase angle at each point of the gait cycle represents the variability of the coordination of this segment [6].

Coordination between lower limb segments can be influenced by the level of activity of an individual. Thus, the examination of coordination and its variability can contribute to understand how active lifestyle influences joint coupling biomechanics during gait, with respect to individual skills, speed, and injury risk.

Therefore, the objective of the present study is to analyze the variability of Pelvis-Thigh segments coordination during gait of sedentary young people and regular practitioners of physical activity at different speeds (preferred walking speed (PWS), 120% of PWS and 80% of PWS) using the technique of vector coding (VC).

II. MATERIAL AND METHODS

A. Subjects

Thirty young adults, 15 sedentary (age:21.64±3,65 years; body mass:61.9±8,7 kg; height:1,71±0,11 m) and 15 practitioners (age:21.91±2,32 years; body mass: 60.1±7,2 kg; height:1,73±0,09 m) participated in the study.
Young adults were classified as practitioners if they practiced physical activity at least three times a week, one hour a day.

B. Protocol

All participants agreed to sign an informed consent form. Next, they submitted to protocols previously approved by the Local Research Ethics Committee. For data collection, 16 retro-reflective markers were fixed at specific anatomical points according to Vicon's lower limb plug-in-gait model (Vicon, Oxford Metrics, Oxford, UK). PWS was evaluated based on the method described by Dingwell and Marin (2006) [11]. All participants performed a protocol with three 1 min-trials on a treadmill at each data collection speed, in a randomized order. Data was collected using a 3D motion capture system containing 10 infrared cameras operating at 100 Hz. Data were filtered using a low pass, zero-lag, fourth order, Butterworth filter with a cut-off frequency of 8 Hz. The number of gait cycles required to quantify the exact coordinative variability and how gait is divided to obtain and compare results are also two variables that need to be highlighted. First, it is still unclear exactly how many gait cycles are needed to safely estimate the variability of coordination. Recent literature estimates five [7], ten [8,9] to fifteen gait cycles [10] are necessary. As most studies used ten steps for everyone, we follow this convention, because it is already a consolidated number of steps reported in recent literature and a way of optimizing computational time. The gait was divided in four phases: first double support, single support, second double support, and swing phases.

Thus, for each part of the gait cycle (first double support, single support, second double support, and swing), each coordination range was determined, and the segmental coordination was classified according to Table 1. For the pelvis and right thigh segmental pair, the angles were calculated during four phases of the gait: (first double support, single support, second double support, and swing phase) and it was used the whole waveform of specific joint angle. The kinematic data was exported as a c3d file and analyzed with a customized MatLab code (R2018a, MathWorks, Natick, MA).

C. Classification of Coordination Patterns

Regarding the classification of coordination patterns, for each phase of the gait cycle, the range of each coordination pattern was determined and classified according Table 1.

Table 1 Ranges of the coupling angles used to classify the variability coordination segment patterns (Anti-Phase, In-Phase, Proximal-Phase and Distal-Phase)

Coordination pattern	Coupling Angle Definitions
In-Phase	22,5°≤ γ <67,5°; 202,5°≤ γ <247,5°
Anti-Phase	112,5°≤ γ <157,5°; 292,5°≤ γ <337,5°
Distal-Phase	67,5°≤ γ <112.5°; 247,5°≤ γ <292,5°
Proximal-Phase	0°≤ γ <22,5°; 157,5°≤ γ <202,5°; 337,5°≤ γ <360º

D. Statistical Analysis

The results were tested by repeated measures analysis of variance (ANOVA) with mixed design, comparing main effects of group (practitioners and sedentary), main effect of speed (100%, 120% and 80% of PWS) and the interaction effect between groups and speeds, followed by a post-hoc test with Bonferroni correction in the cases where the main or interaction effect was significant. Statistical analysis was performed using SPSS software, version 23 (SPSS Inc., Chicago, IL, USA), with a significance level set at α <0.05.

III. Results

There was no significant main effect of group and interaction effect between groups and speeds. However, significant main effect of speed was observed during second double support and swing phases, as shown in Table 2. Post-hoc tests revealed that there were significant differences for the second double support between 120% and 80% of the PWS (0.009), with greater coordinative variability for 80% of the PWS. Likewise, there were significant differences for the swing phase between 120% and 80% of the PWS (0.002) with greater variability for 80% of the PWS. For all phases, the pelvis and thigh segments were in phase.

Table 2 Coordinative variability for the Pelvis-Thigh pair. Analysis of repeated measures ANOVA. F is used to test the general fit of a regression model for a data set; p is the significance of the test; η^2 is a measure of the effect size; NS = Not significant

Effect	Phases of Gait	F	p	η^2
Group	First Double Support	0.176	NS	0.060
	Single Support	0.520	NS	0.018
	Second Double Support	0.714	NS	0.050
	Swing	0.620	NS	0.022
Speed	First Double Support	5.906	0.006	0.174
	Single Support	2.153	NS	0.071
	Second Double Support	6.017	**0.018**	0.177
	Swing	8.518	**0.043**	0.233
Group x Speed	First Double Support	0.049	NS	0.952
	Single Support	2.153	NS	0.071
	Second Double Support	1.304	NS	0.054
	Swing	3.055	NS	0.098

Figures 1 and 2 below show the behavior of the coupling angle and the frequency of the observed coordination pattern for between Pelvis-Thigh segments, respectively.

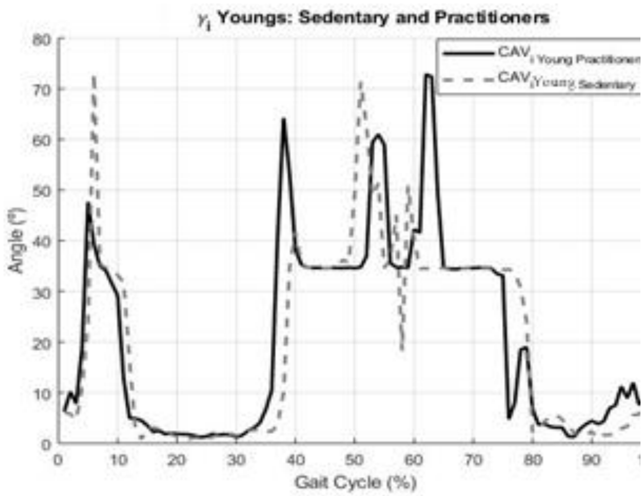

Fig. 1 Coupling angle (γ) for the Pelvis-Thigh segment

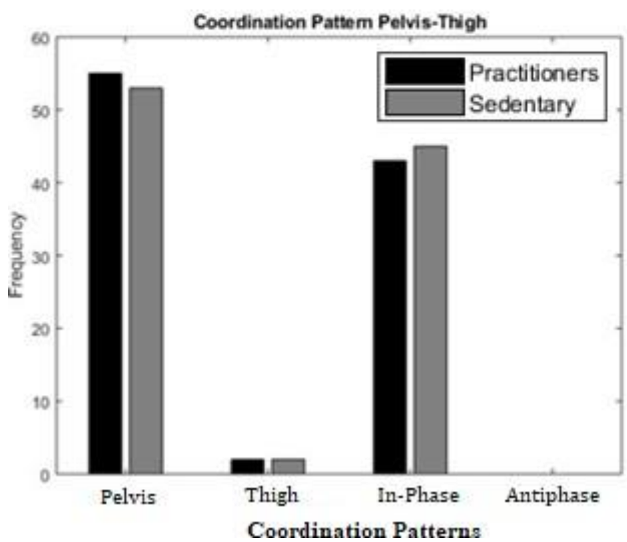

Fig. 2 Frequency of the observed coordination patterns between Pelvis-Thigh segments

IV. Discussion

In the present study, the variability of coordination of Pelvis-Thigh segments in the sagittal plane during gait in two groups of young people, sedentary and practicing physical activities, was quantified by the vector coding technique. The participants walked on a treadmill varying the 20% speed around the PWS (100%, 120% and 80% of PWS). The objective was to analyze whether there are significant differences in the variability of coordination between these groups for the Pelvis-Thigh segment, during four phases of gait (first double support, single support, second double support, and swing). For that, statistical comparisons between the groups evaluated were used.

It seems that the physical activity practiced in the intensity of the participants in this study, does not cause detectable changes in the Pelvis-Thigh coordination. On the other hand, the variability of coordination for the Pelvis-Thigh segment was significantly greater in 80% of PWS during the second double support and swing phase. Second double support phase corresponds to push-off phase of the analyzed side, suggesting that the coordination between Pelvis-Thigh is compromised in lower speeds, presenting greater variability. Similar results were found in [12], suggesting that the slower walking speed is more challenging for neuromuscular control, especially in more proximal segments.

V. Conclusion

There were significant differences in coordination variability concerning gait speed. In relation to the Pelvis-Thigh segment, the greatest differences were observed in 80% of the PWS with greater variability for the second double support and swing phases. Such results suggest that walking at slower speeds is a greater challenge for the neuromuscular system, when compared to higher speeds. Understanding these characteristics of young people's gait may contribute to the development of effective physical exercise protocols for sedentary people.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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