Quantification of Coordinative Variability of Hip-Ankle Joints for Sedentary and Active Young Groups

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November 17, 2023

Quantification of Coordinative Variability of Hip-Ankle Joints for Sedentary and Active Young Groups

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Abstract— **The aim of the present study was to quantify the variability of joint coordination, during gait, of young sedentary and active at different speeds (preferred walking speed (PWS), 120% of PWS and 80% of PWS) using the previously reported modified Vector Coding technique. Thirty young people participated in this study, of which 15 practiced physical activities at least an hour a day and three times a week, and 15 were sedentary. For data collection they executed a protocol of one-minute walking on a treadmill at each speed, in a randomized order. For the Hip-Ankle joint pair, the coordination was computed during four phases of the gait (first double support, single support, second double support and swing phase), in the sagittal plane. The data were analyzed using a customized Matlab code. There were no statistical differences for the Hip-Ankle coordination between groups.**

Keywords— **variability, Hip-Ankle, young, active, sedentary, vector coding**

I. Introduction

Human biology requires an appropriate and constant amount of physical activity to ensure good health and well-being [1]. The practice of physical activity by young adults is related to better social interaction, lower risk of diseases with aging, healthy musculoskeletal development, among other advantages [2].

The gait is a cyclical movement and unique to each individual. Gait coordination between different segments or joints plays an important role for effective movement. Aiming at important characteristics for studying the gait of different groups of individuals, coordination and coordination variability between segments or joints can provide adequate information. While coordination provides a measure of the relative time and magnitude of movement[3], [4], coordination variability measures the varied patterns of movement an individual uses during locomotion [3]. Changes in coordination point toraise the need to change the movement pattern and changes in coordination variability can point toare related to the degree of adaptability that the individual needs to respond to new limitations/perturbations in the task [5].

The aim of this study, therefore, was to estimate the coordinative variability between the Hip-Ankle joints of two groups of young people (sedentary and active), while walking on a treadmill at different speeds, using the modified vector coding (VC) technique [6]. This technique has gained evidence especially because it provides additional information about the dominance of one limb/joint over another and assesses coordination based on angle-angle plots of positional kinematic data, which facilitates clinical interpretation.

We hypothesized that (1) active young people present greater coordination variability in relation to the other group, as greater coordination variability indicates greater adaptability of individual's motor system, (2) and the phases of support would have lower values for the sedentary group.

II. Material and Methods

A. Subjects

A total of 30 young adults, 15 sedentary and 15 actives participated in this study (68.88$\pm$15.90(kg), 1.71$\pm$0.18(m), 23.9$\pm$5.05(years)). Young adults were classified as active if they practice physical activity at least one hour a day, three times a week.

B. Protocol

Sixteen retroreflective markers were fixed at specific anatomical points according to the Vicon lower limb plug-in-gait model (Vicon, Oxford Metrics, Oxford, UK) for data collection. A 3D capture system containing 10 infrared cameras operating at 100 Hz was used to capture kinematic data. The data were filtered using a low-pass, zero-lag, fourth order Butterworth filter with a cut-off frequency of 8 Hz. The kinematic data were analyzed with a custom MatLab code (R2020a, MathWorks, Natick, MA).

The preferred walking speed (PWS) on the treadmill was determined according to a reported protocol [7]. A four-minute walk on the treadmill was allowed for familiarization, followed by two minutes of rest. After this period, the participants performed three walks of 1 minute each, in the PWS, 120% of the PWS and 80% of the PWS, in random order, with a 1 minute of rest between them.

Studies indicate that between five [8] to fifteen [9] gait cycles are the minimum number of gait cycles needed to calculate reliable coordination variability. For better results, in this study we used 20 gait cycles for all subjects. Thus, the Hip-Ankle joint pair was analyzed for 20 strides, normalized to 100 points each, for each one-minute walking trial. Joint angles were calculated in relation to the laboratory's global coordinate system. The analysis was performed in the sagittal plane, as this is the plane that presents expressive extension and flexion excursions in the segment that connects the joints of the lower limb, so that the analysis of the sagittal plane can clearly show the phase and antiphase relationships between the joints [6], [10]. Then, coupling angles were calculated using the previously reported modified vector coding technique, in four phases of the gait cycle: first double support (0 to 10% of cycle) (FDS), single support (11 to 50%

of cycle) (SS), second double support (51 to 60% of cycle) (SDS) and swing phase (61 to 100% of cycle) (SG). The coupling angles represent the coordination patterns and the standard deviation of the coupling angle at each instant of the gait cycle represents the coordination variability.

C. *Statistical Analysis*

The repeated measures analysis of variance (ANOVA) with mixed design was used to compare the two groups, the main effect of speed and the interaction effect between groups and speed, 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 $\alpha < 0.05$.

III. RESULTS

The statistical results for each gait phase are shown in the Table 1. Regarding Table 1, comparing the two groups, there were no significant differences for Group, Speed or Groups vs Speeds.

TABLE I. COORDINATION VARIABILITY OF HIP-ANKLE PAIR.

Effect	Phases of Gait	F	p	η^2
Group	***FDS***	0.255	0.621	0.018
	SS	0.598	0.452	0.041
	SDS	0.413	0.531	0.029
	SG	0.367	0.555	0.026
Speed	***FDS***	1.221	0.289	0.08
	SS	1.691	0.203	0.108
	SDS	0.159	0.824	0.011
	SG	0.79	0.389	0.053
Group x Speed	***FDS***	1.907	0.167	0.12
	SS	0.79	0.452	0.053
	SDS	1.412	0.261	0.092
	SG	0.823	0.38	0.056

Analysis of Repeated Measures (ANOVA).

Figure 1 show the mean hip and ankle joint angles for the three speeds and the two groups. For the FDS and SG gait phases the joint pair rotated in the same direction being in-phase, however, in the SS and SDS gait phases being in anti-phase (Figs. 1 and 3).

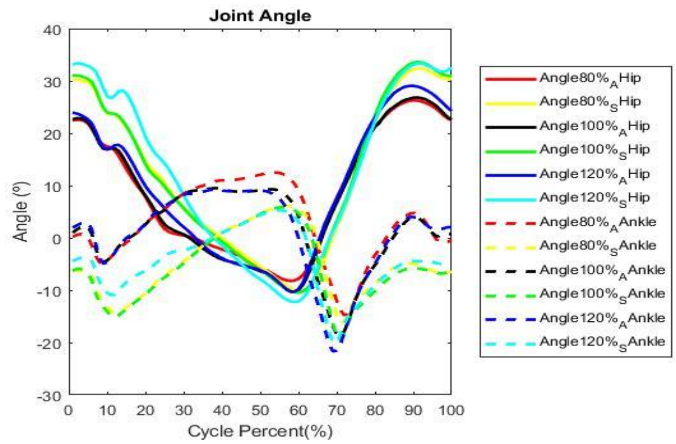

Fig. 1 Mean hip and ankle joint angles at the different speeds and groups.

The standard deviation of the coupling angle provides the coupling angle variability (CAV). The measurements of this variability can allow quantifying information about the organization and flexibility of gait patterns[11]. Figure 2 show the mean CAV for the Hip-Ankle pair, for the three speeds.

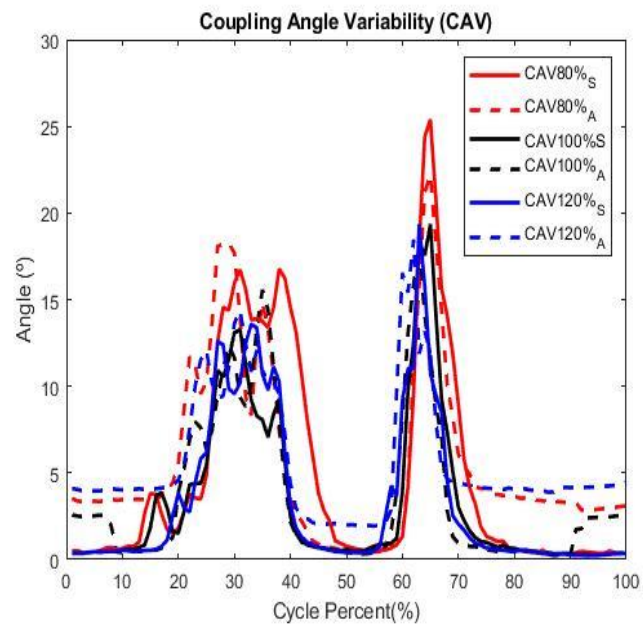

Fig. 2 Coupling angle variability (CAV) for the Hip-Ankle joint pair at 120% and 80% of preferred walking speed (PWS).

Even though it is not the focus of the article, in Figure 3 the mean coupling angle (Gamma - ϒ) of this joint pair are presented. This average coupling angle is expressed in angular values between 0° and 360º, of the proximal (hip) and distal (ankle) joints at each instant of time. Comparing figures 2 and 3, we can see how the coordination variability behaves in relation to the hip-ankle coordination.

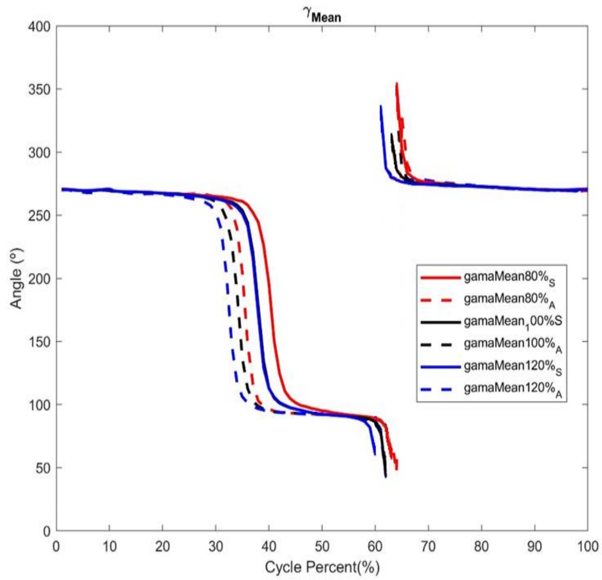

Fig. 3 Coupling angle mean (ϒ) for the Hip-Ankle joint pair at preferred walking speed (PWS), 120% of PWS and 80% of PWS.

IV. Discussion

The groups presented similar results, showing that the level of physical activity of the active's group was not enough to produce significant changes in Hip-Ankle coordination variability during walking. Thus, the hypotheses that active young people present greater coordination variability in relation to the other group, and the phases of support would have lower values for the sedentary group, were not confirmed.

The results showed that the coordinative variability and the values of the coordination patterns were not sensitive to gait speed in the two analyzed groups. Floria et al. (2019) studying the gait of recreational runners, concluded that no effect of speed was observed on coordination variability in the range of ± 15% around the preferred speed[5], what does not agree with the results related to speed with Bayley et al. (2018) who concluded that a 20% change in speed changes angular data in young people; however, the study focused at body segments and not joints [12].

Despite not revealing statistical differences, the values in red in Fig.2 and Fig.3 indicate that higher values of CAV and Gamma occurred, respectively, for the condition of 80% PWS. This agrees with the findings of Bailey et al. (2018) who observed increasing in coordination variability with decreasing speed [12]. Furthermore, regarding speed, similar results have been previously reported for young adults and older adults [13], [14], where people tend to have more difficulty walking at a slower speed than at a higher speed compared to the PWS [15], which can lead to higher angular values in s different phases of gait.

Finally, some limitations of the study need to be highlighted. First, we examined the pattern of inter-articular coordination and its variability only in the sagittal plane; however, they need to be quantified in other planes of movement, for a better understanding of the coordination. Another limitation is the comparison between gait data analysis techniques that address studies that quantify coordination variability, vector coding [6], [16]–[19] or continuous relative phase[20]–[22]. Recent literature [21] indicates that such comparisons must be done with caution, with respect of the characteristics of each technique and each type of data being studied.

V. Conclusion

There was no significant main effect of groups, speed and interaction effect between group and speed in this study. It is reported in the literature that changes in walking speed produce changes in the range of motion or relative time of the analyzed segments which, in turn, change the variability of coordination during the single stance phase. However, there were no differences in the present study, even varying 20% of the PWS for the joint pair analyzed. Future studies can investigate the relationship between the level of physical activity and speed for this joint pair increasing this percentage of speed variation, or taking other variables into account, such as the strength of the muscles close to these joints, the exercise practice time of the group of practitioners, among other factors.

Acknowledgment

The authors would like to thank the financial support of the National Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (CAPES) and the Foundation for Research Support of State of Goiás (FAPEG). M. F. Vieira is CNPq fellow, Brazil (304533/2020-3).

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