Knee-Ankle Joints Coordination Variability in Sedentary and Practitioners Young People at Different Speeds

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Abstract— **The aim of the present study was to quantify the variability of joint coordination of the Knee-Ankle pair, during gait, of sedentary and active young people at different speeds (preferred walking speed (PWS), 120% of PWS and 80% of PWS) using the Vector Coding technique. Thirty young people participated in this study, of which 15 practiced physical activity at least one hour a day and three times a week, and 15 were sedentary. To collect data from this joint pair, they performed a one-minute treadmill walking protocol at each speed, in a random order. Coordination was computed for four gait phases (first double support, single support, second double support and swing phase), in the sagittal plane. Data were analyzed using a custom Matlab code. There were statistical differences for the speed factor, with the greatest variability in 80% of the PWS, with predominant dominance of the ankle under the knee.**

Keywords— **variability, knee-ankle, young, active, sedentary, vector coding.**

I. Introduction

Human body demand an expressive portion of physical activity to ensure good health [1]. Physical activity reduces the risk for heart disease, diabetes mellitus, osteoporosis, high blood pressure, obesity, and metabolic syndrome; improves various other aspects of health and fitness, including aerobic capacity, muscle and bone strength, flexibility, insulin sensitivity, and lipid profiles; and reduces stress, anxiety, and depression [2].

Coordination quantify the variety of movement patterns that an individual can use during a movement and its variability can provide a measure of the adaptability of individual's motor system [3]. Thus, the aim of the present study was to quantify the coordination variability between knee-ankle joints in young sedentary and practitioners adults during gait at different speeds. It would be expected to identify the effects of gait speed and level of physical activities in knee-ankle coordination at different phases of gait. For this purpose, vector coding [3]–[8] was used to analyze the coordination variability between knee-ankle joints in the sagittal plane when walking at: preferred walking speed (PWS), 120% of PWS, and 80% of PWS.

This technique has been widely used because it allows viewing additional information about the dominance of one limb/joint over another and assesses coordination based on angle-angle plots of positional kinematic data, which make easier clinical interpretation.

We hypothesized that (1) lower walking speed present greater variability and (2) active young people present greater coordination variability in relation to 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±15.90(kg), 1.71±0.18(m), 23.9±5.05(years)). Young adults were classified as active if they practice physical activity at least one hour a day, three times a week. The study was conducted in accordance with the Declaration of Helsinki after local approval by the Ethics Committee. All subjects signed a consent form before the experiment.

B. Protocol

Thirty-nine reflective markers were fixed at precise locations according to Vicon's full body plug-in- gait model (Vicon, Oxford Metrics, Oxford, UK). Next,after four minutes for familiarization on a treadmill, the preferred walking speed (PWS) on the treadmill was determined according to a previously reported protocol [9]. Next, the participants executed three 1-minute walking at PWS, 120% PWS and 80% PWS, in a randomized order, with a 1 minute of rest between them.. Kinematic data was acquired by a motion capture system comprising 10 infrared cameras at 100 Hz, and low-pass filtered at 8Hz. 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 [4], [7].The variable analyzed was the knee-ankle joint coupling angle using vector coding technique, for 20 strides, normalized to 100 points, for each 1-minute walking, 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 angle (γ) were calculated as the angle of a vector connecting consecutive data points where $0 \leq \gamma \leq 360º$ [10].

The coupling angle represent the coordination patterns and the standard deviation of the coupling angle at each instant of the gait cycle represents the coordination variability [10].

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

Regarding Table 1, comparing the coordination variability of the two groups, no significant main effect of groups and interaction effect of group vs speed were found. For speed, significant differences were found at the speeds of 80% and 120% of PWS, when compared to PWS, in all phases of gait.

Table 1: Coordination variability of Knee-Ankle pair.

Effect	Phases of Gait	F	p	η^2
Group	*FDS*	1.266	0.279	0.083
	SS	0.031	0.862	0.002
	SDS	0.015	0.906	0.001
	SG	3.339	0.089	0.193
Speed	*FDS*	16.152	**0.000**	0.536
	SS	10.725	**0.001**	0.434
	SDS	5.025	**0.014**	0.264
	SG	10.540	**0.001**	0.430
Group x Speed	*FDS*	0.319	0.078	2.376
	SS	0.812	0.454	0.055
	SDS	0.269	0.766	0.019
	SG	1.300	0.273	0.085

Figure 1 show the mean knee and ankle joint angles for the three speeds and the two groups (A = active and S = Sedentary). 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 the joint pair rotate in opposite directions being in anti-phase (Figure 1).

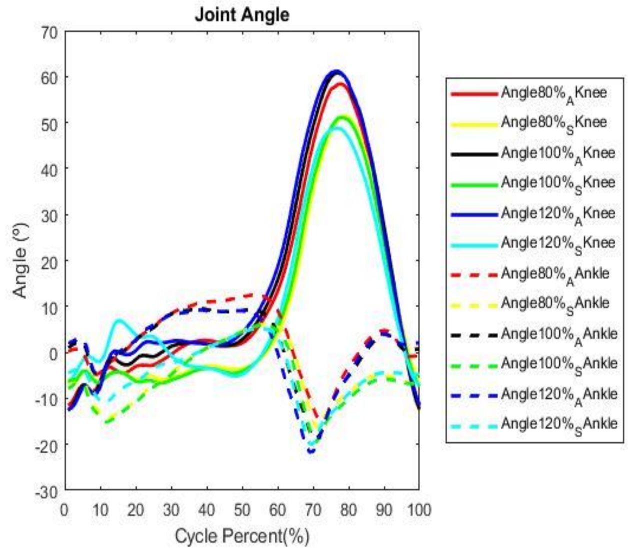

Figure 1: Mean knee and ankle joint angles at the different speeds and groups. A, active group; S, sedentary group.

Figure 2 show the mean Coupling Angle Variability (CAV) for the Knee-Ankle pair, for the three speeds.

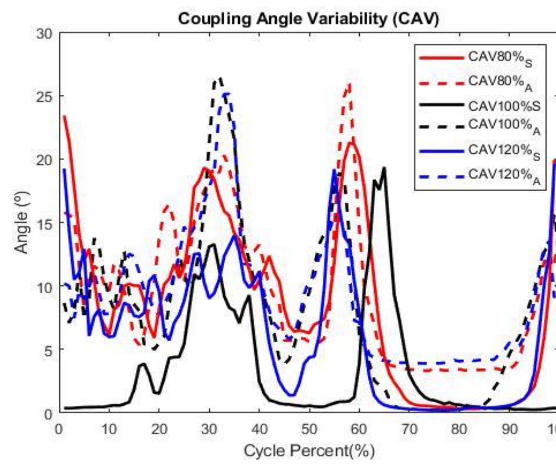

Figure 2: Coupling angle variability (CAV) for the Knee-Ankle joint pair at 100%,120% and 80% of preferred walking speed (PWS). A, active group; S, sedentary, group.

For the knee-ankle joint pair, the statistical differences occurred in the first double support, single support and second double support, with differences between 100% of PWS and 120% of PWS, and between 120% of PWS and 80% PWS, with greater variability for 80% of PWS. Finally, for the swing phase, there were differences between 100% of PWS and 80% of PWS only, with greater variability for 80% of

PWS. The coordination pattern of the analyzed joint pair is distal phase, i.e., ankle dominated the gait cycle.

IV. Discussion

There were significant differences in all gait phases for the analyzed joint pair, with the greatest differences were observed in 80% PWS and 120% PWS, with the greater variability for 80% PWS in distal phase coordination pattern, showing that this variation of 20% in speed is sufficient to cause variations in the coordinative variability. However, the level of physical activity in this sample did not influence the results between groups. The results also indicate that there were variations in the coordinative variability are in line with the findings by Bailey et al. (2018) who observed reductions in coordination variability with increasing speed [11]. Also, regarding speed, similar results have been previously reported that people tend to have more difficulty walking at a slower speed than at a higher speed compared to the PWS [4], [11]. The dominance of the ankle in phase with the knee suggests that young people use more ankle plantar flexion and less knee extension for forward progression.

V. Conclusions

The greater variability for 80% PWS in distal phase coordination pattern found in this study, showed that this variation of 20% in speed is sufficient to cause variations in the coordinative variability, in support to hypothesis 1. However, the level of physical activity in this sample did not influence the results, discading the hypothesis 2. Future studies can investigate the influence of the intensity of physical activity and speed in the coordination and coordination variability for this joint pair during gait.

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Conflict of interest

The authors declare that they have no conflict of interest.

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