Gait Coordination Quantification of Thigh-Leg Segments in Sedentary and Active Youngs at Different Speeds Using the Modified Vector Coding Technique

G. A. G. De Villa, F. B. Rodrigues, A. Abbasi, A. O. Andrade, and M. F. Vieira

Abstract

The aim of the present study was to quantify the variability coordination of Thigh-Leg segments, during gait, of young sedentary and active at different speeds (preferred walk- ing speed (PWS), 120% of PWS and 80% of PWS) using the previously reported modified Vector Coding technique, to record the segmental angles. 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 Thigh-Leg segments, the angles were computed during four phases of the gait (first double support, single support, second double support, and swing), in the sagittal plane (flexion/extension angles). The data were analyzed using a customized Matlab code. There were statistical differences for the Thigh-Leg segment pair, with great differences observed in 120 and 80% of PWS for both groups.

Keywords

Variability • Coordination • Vector coding

G. A. G. De Villa (✉) · F. B. Rodrigues · M. F. Vieira
Bioengineering and Biomechanics Laboratory, Federal University of Goiás, Avenue Esperança, 74690-900 Goiânia, Brazil

F. B. Rodrigues
State University of Goiás, Goiânia, Brazil

A. Abbasi
Department of Biomechanics and Sports Injuries, Faculty of Physical Education and Sports Sciences, Kharazmi University, Tehran, Iran

A. O. Andrade
Center of Innovation and Technology Assessment in Health, Federal University of Uberlândia, Uberlândia, Brazil

T. F. Bastos-Filho et al. (eds.), *XXVII Brazilian Congress on Biomedical Engineering*,
IFMBE Proceedings 83, https://doi.org/10.1007/978-3-030-70601-2_54

1 Introduction

The practice of physical activities in adolescents is related to greater social interaction, less risk of diseases with aging, better musculoskeletal development among other benefits [1, 2]. However, how exercise affects segmental thigh-leg coordination in young people remains unclear.

Walking is a cyclical movement that is repeated in several and different patterns for each individual, in which coordination between different segments is of importance. Recent literature estimates that five [3], ten [4] to fifteen gait cycles [5] are the minimum number of gait cycles needed to calculate a reliable coordinative variability. However, it is commonly agreed that less than five cycles are a small number and the reported values cannot be representative of the true variability of an individual or group. For more reliable results, this work used the entire time series collected, a total of 25 gait cycles for everyone.

According to studies the ideal analysis is in the sagittal plane, because this is the most demanding plane presenting expressive extension and flexion excursions in the joint that connects the lower limb segments, analysis of sagittal plane can clearly show the phase and anti-phase relationships between segments [6–8].

The aim of this study was to estimate the coordination and coordination variability between the Thigh-Leg segments of two groups of young people (sedentary and active), while walking on a treadmill at different speeds, using the previously reported modified Vector Coding (VC) technique [7]. As the practice of physical actives can contribute to a lower risk of injuries, we hypothesized that (1) young active have greater coordinative variability compared to the other group, (2) and the instants of support would be of greater concern, with smaller values for sedentary group.

2 Materials and Methods

2.1 Subjects

Thirty young adults, 15 sedentary and 15 actives participated in the study. Young adults were classified as active if they practice physical activity at least three times a week, one hour a day.

2.2 Protocol

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). A 3D capture system containing 10 infrared cameras operating at 100 Hz was used. Data were filtered using a low pass, zero- lag, fourth order, Butterworth filter with a cut-off frequency of 8 Hz. Kinematic data were exported as text file and ana- lyzed with a custom MatLab code (R2018a, MathWorks, Na- tick, MA).

The preferred walking speed (PWS) on the treadmill was determined according to a previously reported protocol [9]. A four-minute walk on the treadmill was allowed for familiarization and immediately followed by a two-minute rest. After the rest period participants performed three walks of 1 min each, in the PWS, 120% of the PWS and 80% of the PWS, in randomized order.

As already stated above the Thigh-Leg segment was analyzed for 25 strides, normalized to 100 points each, for each one-minute walking period. The segmental angles were calculated in relation to the global coordinate system of the la- boratory. Then the coupling angles were calculated using the previously reported modified Vector Coding technique [7], in four phases of the gait cycle: first double support, single support, second double support and swing phase. 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.

2.3 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 effect of interaction 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 $\alpha < 0.05$.

Figure 1 show a typical example of the coupling angle (γ_{mean}) and coupling angle variability (CAV) for the Thigh-Leg segment, for the two conditions that showed differences.

3 Results

The segments Thigh-Leg had rotation in the same direction, being, therefore, in-phase. The statistical results for each phase are shown in the Table 1.

Regarding Table 1, comparing the two groups, there were no significant differences for Groups or for Groups versus Speeds. However, there were differences between 120% of PWS and 80% of PWS ($p = 0.0016$) for speed (bold in table), with greater variability to 120% of PWS.

Even though it is not the focus of the article, in Fig. 1, the values of the coordination of this segment are represented, which is being analysed as a way of seeing how its variability behaves in relation to its coordination.

4 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 Thigh-Leg coordination during walking. The first two hypotheses were discarded the results only support the second hypothesis: significant differences were found in the single support phase and were sensitive to the speed.

With respect to speed, similar results were previously reported for young and older adults [10, 11], besides people tend to have more difficulties walking at a lower speed than at a higher speeds in relation to PWS itself [12]. Furthermore, all differences were observed in stance phase. This suggests that Thigh-Leg segments coordination occurs during foot contact and subsequent body weight loading on unilateral lower limb. This may lead to different patterns of overuse in stance phase at different walking speeds, as it has been reported that altered segment coordination is indicative or marker of overuse injury [13], through the shift of stress to tissues not adapted for repetitive loading [3]. The different segment coordination between walking speeds can be a result of a change in amplitude or relative timing of adjacent segment.

5 Conclusions

There was no significant main effect of activity, and no significant interaction effect between groups and speeds. However, significant main effect of speed was observed

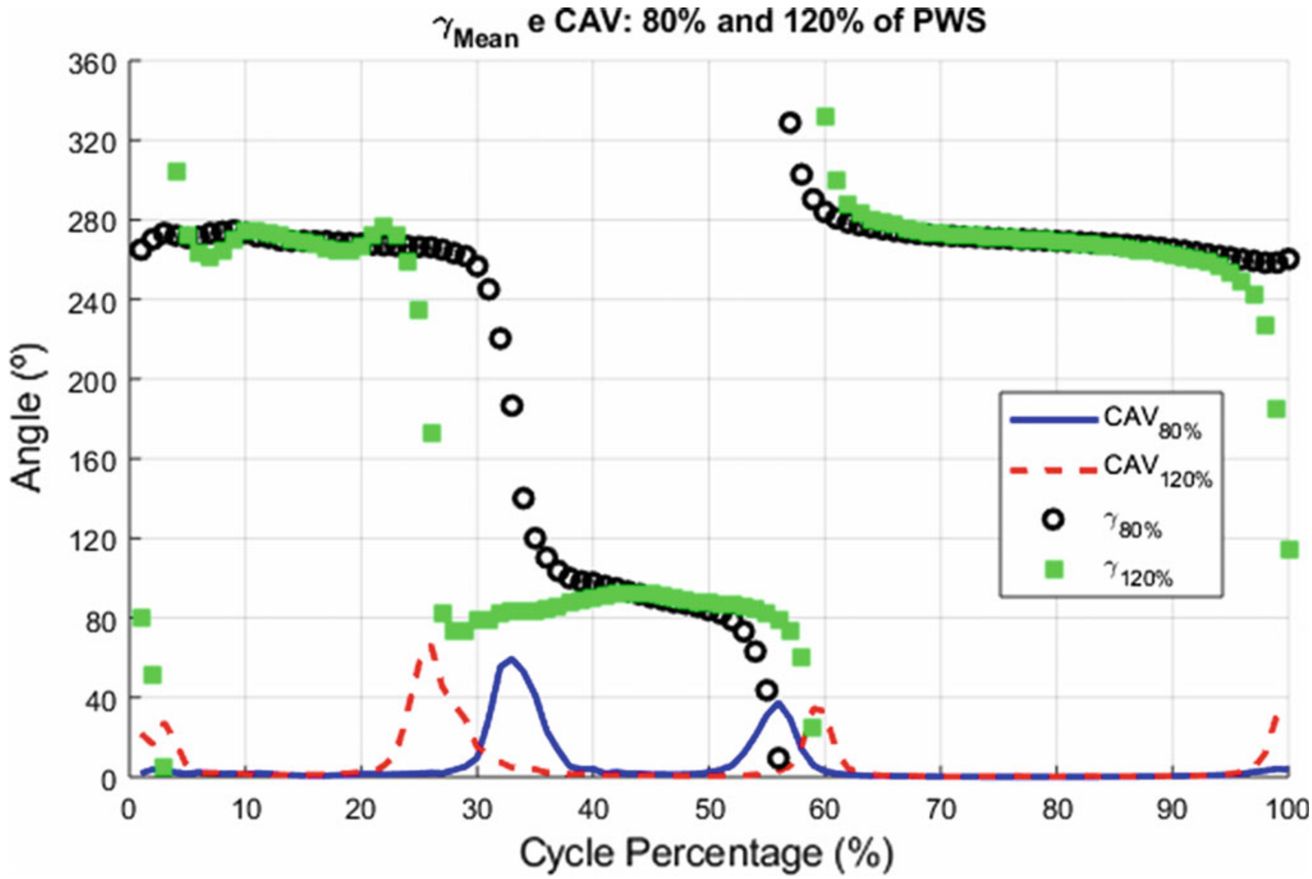

Fig. 1 Coupling angle variability (CAV) and coupling angle (γ_{mean}) for the Thigh-Leg segments at 120 and 80% of preferred walking speed (PWS)

Table 1 Coordination variability of thigh-Leg pair

Effect	Phases of gait	F	p	η^2
	FDS	0.174	0.480	0.033
Group	SS	1.498	0.241	0.097
	SDS	0.303	0.303	0.002
	SG	0.359	0.559	0.025
	FDS	0.945	0.373	0.063
Speed	SS	2.994	**0.046**	0.176
	SDS	1.722	0.203	0.110
	SG	1.180	0.299	0.078
	FDS	0.003	0.979	0.000
Group x Speed	SS	0.800	0.431	0.054
	SDS	1.728	0.200	0.110
	SG	0.398	0.538	0.028

Analysis of Repeated Measures (ANOVA). FDS = First Double Support; SS = Single Support; SDS = Second Double Support; SG = Swing

during single support phase. These preliminary results suggest that Thigh and Leg coordination variability during single support phase are speed dependent showing that, although these segments are in phase irrespective to walking speed, their coordination variability differs. Changes in walking speed produce changes in motion amplitude or relative tim- ing of the analyzed segments that, in turn, alter the coordination variability during single support phase. However, this result was not sensitive to the level of activity, probably because the balance control during single support phase, where human body behaves as an inverted pendulum, is not affected by level of activity [14]. Future studies can investigate more closely this link between the level of physical activities and speed for this segment, in order to develop practices of physical exercises that add more to the health of young people as well as improving the quality of gait.

Acknowledgements 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), the Foundation for Research Support of State of Goiás (FAPEG) and the Foundation for Research Support of State of Minas Gerais (FAPEMIG). A. O. Andrade and M. F. Vieira are CNPq fellows, Brazil (304818/2018-6 and 306205/2017-3, respectively).

Conflict of Interest
The authors declare that they have no conflict of interest.

References

1. Aaron DJ, Dearwater SR et al (1995) Physical activity and the initiation of high-risk health behaviors in adolescents. Med Sci Sport Exerc 27:1639–1645. https://doi.org/10.1249/00005768-199512000-00010
2. Fairclough S (2004) Physical education makes you fit and healthy. physical education's contribution to young people's physical activity levels. Health Educ Res 20:14–23. https://doi.org/10.1093/her/cyg101
3. Hafer JF, Silvernail JF et al (2016) Changes in coordination and its variability with an increase in running cadence. J Sports Sci 34:1388–1395. https://doi.org/10.1080/02640414.2015.1112021
4. Miller RH, Chang RB et al (2010) Variability in kinematic coupling assessed by vector coding and continuous relative phase. J Biomech 43:2554–2560. https://doi.org/10.1016/j.jbiomech.2010.05.014
5. Heiderscheit BC, Hamill J, Van Emmerik RE (2002) Variability of stride characteristics and joint coordination among individuals with unilateral patellofemoral pain. J Appl Biomech 18:110–121
6. Chang R, Van Emmerik R, Hamill J (2008) Quantifying rearfoot–forefoot coordination in human walking. J Biomech 41:3101–3105. https://doi.org/10.1016/j.jbiomech.07.024
7. Needham R, Roozbeh NNC (2014) Quantifying lumbar-pelvis coordination during gait using a modified vector coding technique. J Biomech 47:1020–1026. https://doi.org/10.1016/j.jbiomech.2013.12.032
8. Harrison K, Kwon YU et al (2019) Inter-joint coordination patterns differ between younger and older runners. Hum Mov Sci 64:164–170. https://doi.org/10.1016/j.humov.2019.01.014
9. Dingwell JB, Marin LC (2006) Kinematic variability and local dynamic stability of upper body motions when walking at different speeds. J Biomech 39:444–452. https://doi.org/10.1016/j.jbiomech.2004.12.014
10. Ghanavati T, Salavati M et al (2014) Intra-limb coordination while walking is affected by cognitive load and walking speed. J Biomech 47:2300–2305. https://doi.org/10.1016/j.jbiomech.2014.04.038
11. Chiu S-L, Chou L-S (2012) Effect of walking speed on inter-joint coordination differs between young and elderly adults. J Biomech 45:275–280. https://doi.org/10.1016/j.jbiomech.2011.10.028
12. Silvernail JF, Bradley S, Wiegand K (2018) Differences in the coordination of gait based on body mass index in sedentary young adults. Osteoarthr Cartil 26:S382. https://doi.org/10.1016/j.joca.2018.02.747
13. DeLeo AT, Dierks TA, Ferber R, Davis IS (2004) Lower extremity joint coupling during running: a current update. Clin Biomech 19:983–991. https://doi.org/10.1016/j.clinbiomech.2004.07.005
14. Winter DA, Prince F, Patla A (1997) Validity of the inverted pendulum model of balance in quiet standing. Gait Posture 5:153–154. https://doi.org/10.1016/S0966-6362(97)83376-0