11º CONGRESSO NACIONAL DE BIOMECÂNICA
A. P. G. Castro, C. Pina, P. R. Fernandes, C. Santos, J. Folgado & A. Amaro (Eds)
Sesimbra, Portugal, 21-22 de Fevereiro, 2025

EFFECT OF COGNITIVE TASKS DIFFICULTY ON POSTURAL CONTROL DURING DUAL TASKS – LINEAR AND NONLINEAR ANALYSIS

Marina Saraiva [1,2], João P. Vilas-Boas [3], Orlando Fernandes [4] e Maria António Castro [2,5]

[1] *Dr. Lopes Dias Health School, Sector of Physiotherapy, Polytechnic Institute of Castelo Branco, Portugal*

[2] *Department of Mechanical Engineering, University of Coimbra, CEMMPRE, Coimbra, Portugal*

[3] *LABIOMEP-UP, Faculty of Sports and CIFI2D, University of Porto, Portugal*

[4] *Comprehensive Health Research Center (CHRC), University of Évora, Portugal*

[5] *School of Health Sciences, Sector of Physiotherapy, Polytechnic Institute of Leiria, Portugal*

marina.saraiva@outlook.com; jpvb@fade.up.pt; orlandoj@uevora.pt; maria.castro@ipleiria.pt

KEYWORDS: center of pressure; approximate entropy, dual-task, difficulty task.

1 INTRODUCTION

Most studies use linear measures of center of pressure (CoP) to quantify postural control [1], but given its complexity, nonlinear analysis of CoP is of increasing interest in the field. Approximate entropy (ApEn) is one example of a nonlinear CoP analysis measure. ApEn is a system complexity and regularity measure that quantifies the randomness in a time series in various situations [2]. It is a valuable measure of postural control complexity used to describe postural control changes [3]. This study aimed to analyze the effect of two cognitive tasks with different difficulty levels in postural control complexity on the static standing posture in young adults.

2 METHODOLOGY

According to eligibility criteria, thirty-six healthy young adults (age=23.08±3.92 years) were recruited and signed informed consent to participate in this study. The Ethics Committee of the Polytechnic Institute of Coimbra approved the study. Young adults performed three tasks, each one during 60s, with 45s rest period between tasks: a single task (ST: keeping a quiet standing posture); an easy cognitive dual-task (easy cogn-DT: maintaining a quiet standing posture while performing adding and subtracting calculations with one digit or memorizing the color of the figure displayed on the smartphone screen), and a difficult cognitive dual-task (difficult cogn-DT: maintaining a quiet standing posture while performing adding and subtracting calculations with one or two digits or memorizing figure's color, number, and the image displayed on the smartphone screen). The center-of-pressure time series displacements (ApEn) for the anterior-posterior (ApEn-AP) and medial-lateral (ApEn-ML) components of CoP and the excursion of the CoP in medial-lateral (CoP-ML) and anterior-posterior (CoP-AP) directions were collected from a Bertec® force plate (model FP4060-07-1000; Bertec Corporation, Columbus, OH, USA). The CoP-ML and CoP-AP data were filtered using a 50 Hz low-pass filter, a 7th order Butterworth, and they were processed after the assessment with a Matlab routine (version R2020b, The Mathworks, Inc., USA). The algorithm for calculating ApEn begins with the time series data of length N with an embedding dimension, m (pattern length), and a lag. The time series of length N is divided into short vectors of length [3]. The ApEn algorithm was calculated by applying the following Equation (1):

$$\phi_m = (N - m + 1)^{-1} \sum_{i=1}^{N-m+1} \log (N_i) \qquad (1)$$

2.1 STATISTICAL ANALYSIS

The normality of the distribution of the CoP data was tested with the Shapiro-Wilk test. The Friedman test was used to compare the differences between the ST, easy cogn-DT, and difficult cogn-DT for each linear and nonlinear parameter, with *post hoc* Bonferroni correction to evaluate pairwise comparisons. The CoP data are represented in median values and interquartile range (IQR). The statistical analysis was performed using IBM-SPSS 25.0 software. The significance level was set at $p<0.05$.

3 RESULTS

The comparison of the excursion of CoP and ApEn in AP and ML directions (linear and nonlinear analysis of CoP) between the different tasks is represented in Table 1.

Tabela 1 - Comparisons of displacements of the center of pressure and CoP time series displacements in anterior-posterior and medial-lateral directions among single task and easy and difficult cognitive dual tasks, median (IQR).

		Single Task	Easy Cognitive Dual-Task	Difficult Cognitive Dual-Task	*p*-value[1]
Linear measures	**CoP-AP (mm/s)**	1837.57 (1650.85–2156.71)	1947.95 (1749.31–2274.04)	1965.44 (1790.44–2362.37)	<0.001*
	CoP-ML (mm/s)	1224.69 (1076.46–1404.73)	1262.54 (1120.56–1529.01)	1285.30 (1187.67–1512.78)	<0.001*
Nonlinear measures	**ApEn-AP**	1.04 (0.91–1.24)	1.02 (0.71–1.24)	0.90 (0.67–1.14)	0.032*
	ApEn-ML	1.18 (0.92–1.52)	1.02 (0.73–1.30)	1.02 (0.66–1.28)	0.001*

CoP-AP and CoP-ML, displacements of the center of pressure in anterior-posterior and medial-lateral direction, respectively; ApEn-AP, Approximate entropy for anterior-posterior components of the CoP coordinate time series; ApEn-ML, Approximate entropy for medial-lateral components of the CoP coordinate time series. [1]Friedman test (differences between the three tasks); * $p < 0.05$.

Linear analysis showed an increase in displacements of the CoP in the AP and ML direction from ST to easy cogn-DT to difficult cogn-DT. CoP nonlinear analysis showed a decrease in the ApEn-AP and ApEn-ML time series values from the ST to both cognitive dual-tasks with different challenging levels ($p<0.05$). The *post hoc* analysis showed differences between ST and easy cogn-DT and between ST and difficult cogn-DT ($p<0.05$) in CoP linear analysis. In nonlinear analysis, there were found differences between ST and easy cogn-DT in ApEn-ML and between ST and difficult cogn-DT in ApEn-AP and ML ($p<0.05$). However, no differences were found between cognitive dual-task with different difficulty levels in both CoP analyses ($p>0.05$).

4 DISCUSSION/CONCLUSION

In this study, we used a nonlinear analysis to understand how complex postural control is when performing DT with different levels of cognitive difficulty. Both linear and nonlinear analyses showed that postural control was worse during the cognitive DT compared to the single task. In conclusion, performing any cognitive task while standing, regardless of its difficulty, led a decrease in postural stability during DT conditions. However, difficult cogn-DT presented less complexity and more regularity in body sway than easy cogn-DT when compared to the ST.

REFERENCES

[1] B. Chen, P. Liu, F. Xiao, Z. Liu, Y. Wang, "Review of the upright balance assessment based on the force plate." Int. J. Environ. Res. Public Health, 18, 2696, 2021.

[2] S.M. Pincus, "Approximate entropy as a measure of system complexity." Proc. Natl. Acad. Sci. USA, 88, 2297–2301, 1991.

[3] N. Stergiou, Nonlinear Analysis for Human Movement Variability; CRC Press: Boca Raton, FL, United States, 2016.