The Differential Effects of Mental Fatigue on Inter-Joint Coordination in Young and Older Adults

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Summary

The study investigated how mental fatigue affects inter-joint coordination during walking in young and older adults. Employing EEG and gait kinematic analysis, this study revealed that mental fatigue, induced by a computerized cognitive task, leads to altered inter-joint coordination variability, with different impacts observed between age groups. Results indicated significant changes in coordination patterns, particularly during the stance phase in young adults, and varying effects across ages. This suggests that mental fatigue could influence motor control differently depending on age.

Introduction

Mental fatigue is a psychobiological state caused by prolonged periods of demanding cognitive activity, and it likely involves changes in brain activity involving the anterior cingulate cortex, a brain area at the interface between cognition, emotion, and motor control. Observations indicated that this condition impacts several gait dynamics in young and elderly adults, exemplified by augmented step length variability [1]. Despite these findings, the ramifications of mental fatigue on the inter-joint coordination of the lower limbs remain inadequately elucidated.

Methods

Four healthy young adults (2M/2F, 23±2.2yrs) and four healthy old adults (2M/2F, 64±5.8yrs) were recruited. A mental fatiguing protocol was applied, and EEG signals were

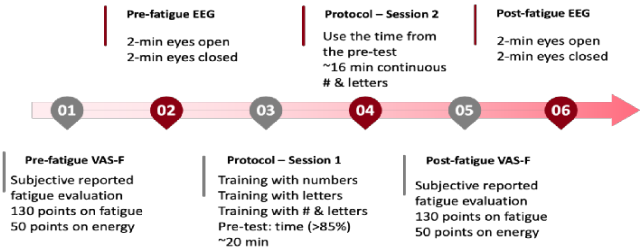
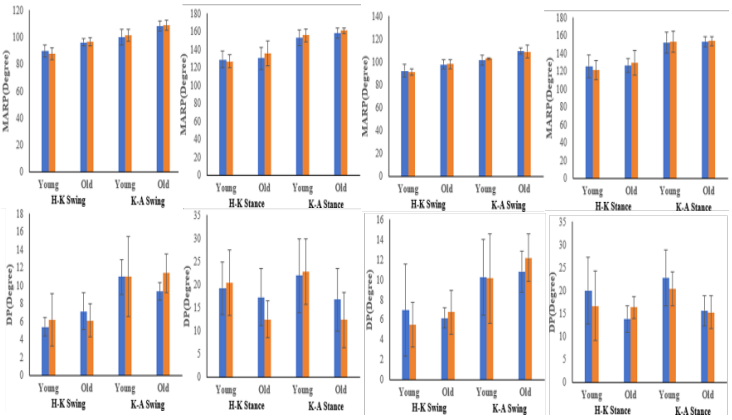


Figure 1: Mental fatigue protocol

monitored to assess mental fatigue (Fig.1). A twelve-camera motion analysis system (Qualisys AB, Sweden) was used to collect 3D-kinematic data of preferred and fast speed walking before and after fatigue. Sagittal plane joint angles and velocities of the hip, knee, and ankle of the right leg were calculated using Visual3D (C-Motion, Inc., MD), and all kinematic data were interpolated to 100% of the stance phase and swing phase. Continuous relative phase (CRP) was used to investigate the inter-joint coordination pattern and variability in this study. Joint angles (θ) and angular velocity (ω) data were normalized to [-1,1] to mitigate differences in amplitude and frequency [2]. Phase angles (φ) of each joint were calculated as $\varphi = \tan^{-1}(\omega/\theta)$ for each data point ($\varphi \in (-\pi, \pi)$), and the CRP was then obtained by subtracting the phase angles of the distal joint from that of the proximal joint (e.g., $\varphi_{hip} - \varphi_{knee}$) [3]. Three metrics, mean absolute relative phase (MARP), deviation phase (DP), and cross-correlation, were employed to indicate the CRP variability. EEG data were processed with a 2nd order Butterworth band-pass filter and analyzed using the FFT to examine the frequency domain in the Theta and Alpha bands. The two-way repeated measures ANOVA examined the effects of mental fatigue and age.

Results and Discussion

The frequency of the α-band decreased, and the θ-band increased at the end of the fatiguing protocol, respectively. For the hip-knee CRP pattern (Fig.2), the swing phase MARP exhibited significant differences within the age groups in both walking conditions ($p = .001$), and the stance DP between pre- and post-fatigue was statistically different only in the young group under fast walking ($p = .008$). Opposite trends in stance MARP and DP before and after fatigue can be observed in young and old groups under both walking conditions. For the knee-ankle CRP pattern (Fig.2), the stance DP and swing MARP significantly differed within age groups in both walking conditions. No difference was found within age or fatigue groups in the cross-correlation coefficient. No interaction effect was seen.



A) Preferred speed walking B) Fast speed walking

Figure 2: CRP variabilities (Bule: pre-fatigue; Orange: post-fatigue)

Conclusions

There were significant differences in the coordination variability during walking between different ages. In addition, mental fatigue may have opposite effects on coordination variability, especially standing phases, in different age groups.

References

[1] Boksem & Tops (2008), *Brain Res Rev* **59** (1).
[2] Chiu & Chou (2012), *J Biomech* **45** (2).
[3] Chiu, et al. (2010), *Gait & Posture* **32** (4).