Changes in muscle activity with gait and balance impairment in elderly with cerebral small-vessel disease

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Summary

This study aims to explore unreported lower limb muscle activity changes related to gait and balance in patients with cerebral small-vessel disease (CSVD). We found gait disturbance and balance issues exhibited in CSVD patients, which were consistent with previously reported. Subsequent studies of the characterization of lower extremity muscle activity showed that higher TA (Tibialis Anterior) and GL (Gastrocnemius Lateralis) activity, lower TA muscle contraction-diastole coordination, and higher RF (Rectus Femoris)-BF (Biceps Femoris) coactivation appeared in the CSVD group in natural walking condition. In dual-task condition, the activity of RF, the systolic-diastolic coordination of RF and BF, and the coactivation of TA-GL showed a significant decrease in the CSVD group. These results indicated that training maneuvers targeting these four muscles could be added to promote coordination of muscle activity.

Introduction

CSVD is a common cerebrovascular disease in the elderly, and is a major cause of stroke and dementia. Impaired gait and balance are typical motor function manifestation in CSVD [1]. Mechanically, gait and balance result from the coordinated action of the muscular and skeletal systems. Currently, aerobic exercise training is an effective rehabilitation approach for CSVD. However, existing studies have not reported the lower-extremity muscle activity characteristics in CSVD, which has hindered the development of more precise and targeted athletic training therapies. In our study, we investigated the characteristics of lower limb muscle activity in patients with CSVD and provide a reference for clinical rehabilitation training.

Methods

Sixteen CSVD and fifteen healthy subjects were recruited for this study (Ethical approval No. SHSY-IEC-4.0/19-97/01) and there were no significant differences between the two populations in terms of gender, age, weight, height. A total of two experimental paradigms of single-task natural walking and dual-task walking were set up. The gait, balance and lower limb muscle sEMG signals of the subjects during walking were synchronously collected by using the 3D motion capture system and the sEMG sensor. Analysis of gait spatiotemporal parameters and acceleration data to examine subjects' gait and balance. Muscle sEMG parameters: 1. Peak amplitude (defined as the maximum of the envelope sEMG signal) and RMS of sEMG signal were calculated for the four different sub-phases of gait cycle, including the loading response, single stance, preswing and swing phase. Time to peak (time when this peak occurred in sEMG activity in the whole gait cycle) was computed based on occurrence of peak from the HS, The Root Mean Square (RMS) of sEMG was used to quantify the degree of muscle activity in the lower limbs during different gait phases. The Modulation index (MI) of sEMG was used to assess the coordination of muscle self-activity during each gait phase. The coactivation index (CI) of sEMG was used to assess the degree of active-antagonist muscle co-contraction in each gait phase; For statistical analysis, normality was tested using Shapiro-Wilk test, t-test was used for independent samples and mixed ANOVA was used for paired samples.

Results and Discussion

1. Gait and balance characteristics: During single-task natural walking, the step speed and step length was significantly lower in the CSVD group than in the HC group ($p<0.05$), whereas step time and double support time were significantly higher in the CSVD group ($p<0.05$). During dual-task walking, the CSVD group had a greater step width ($p<0.05$). In terms of balance function, the root mean square (RMS) of acceleration in all directions was significantly higher in the CSVD group than in the HC group during single-task natural walking ($p<0.05$). The RMS of acceleration in anterior-posterior and medial-lateral directions and the variability of acceleration in the vertical direction were significantly higher during dual-task walking ($p<0.05$); The RMS acceleration in medial-lateral direction was significantly higher in the CSVD group than in the HC group during closed-eye and tandem standing conditions ($p<0.05$)

2. Muscle activities of lower limb: During natural walking, the activity of the TA during the pre-swing phase and of the GL during the loading response phase were higher in the CSVD than in the HC group ($p < 0.05$). The modulation of the TA during the swing phase was significantly lower in the CSVD group compared to the HC group ($p < 0.05$). The coactivation of RF-BF during the single stance phase was significantly higher in the CSVD group ($p < 0.05$). During dual-task walking, the RF activity and modulation during the single stance phase were decreased in the CSVD group than in the HC group, as well as BF modulation ($p < 0.05$). Additionally, the coactivation of TA-GL during the swing phase was significantly reduced ($p < 0.05$).

3. Discussion: CSVD patients have gait and balance issues. A further study found abnormal activity in four lower - limb muscles (TA, GL, RF, BF). This suggests that targeted training for these muscles could be an effective therapy for CSVD patients.

Conclusions

Our study shows that the muscle activity characteristics of TA, GL, RF and BF in CSVD patients are different. Existing aerobic rehabilitation training fails to target these four muscles. Thus, anaerobic training can be strategically incorporated to boost the activity of these muscles, aiming to restore gait and balance dysfunctions.

References

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