Control in Motor Units of Lower Extremity Muscles in the Swing Phase during Fast, Free and Slow Walking

A. Kobe, M. Yamaguchi, N. Ikeda and M. Hamada

Department of Rehabilitation Medicine
Kanazawa Medical University, Uchinada, Kachoku, Ishikawa, Japan

Summary

The purpose of this study was to clarify the control over recruitment and firing rate of motor units in the lower extremity muscles during the swing phase during fast, free and slow walking in normal adults.

We hypothesized that the medial hamstrings during the swing phase would be selectively controlled to recruit the larger motor units in fast-twitch muscle fibers with increasing walking speeds. Contrary to our expectations, the vastus lateralis was selectively controlled to recruit the smaller motor units in slow-twitch muscle fibers with increasing walking speeds.

The different motor controls for each muscle were precisely performed in the swing phase during changes in walking speed.

Introduction

We investigated changes in median power frequency (MdPF), integrated electromyography (IEMG), and the ratio for IEMG between the partial frequency zone and whole zone in the right lower extremity muscles during the swing phase at fast, free and slow walking speeds in normal adults. We also examined the control over recruitment and firing rate of motor units in these muscles during the swing phase.

Methods

Ten healthy volunteers without signs of neuromuscular disorders (4...
men and 6 women), ranging in age from 22 to 38 (mean 30) years participated in the study.

Using a digital metronome, the subjects were requested to walk on a level surface for a distance of fifteen meters at three different walking speeds: fast (1.69 m/s), free (1.2 m/s), and slow (0.69 m/s).

The muscles selected for this study were the right vastus lateralis (VL) and medial hamstrings (MH). A pair of Ag-AgCl surface electrodes, one-centimeter in diameter (Nihon Koden, co. Japan) in a bipolar lead system were placed over the central belly of each muscle. They were placed parallel to the muscle fibers two centimeters apart and secured to the skin by a piece of tape. Analog signals from the electrodes were converted to digital signals and stored in a PC card by means of an 8-channel PC card recorder (Teac DR-C2: Teac, co. Japan). Signals taken at a sampling time of 0.2 ms were analyzed using a new method in a computer program called “MemCalc”

MemCalc, developed by Ohtomo (Faculty of engineering, Hokkaido University, Japan), is a linearized version of the nonlinear least squares method for fitting analysis in the time domain, combined with the maximum entropy method for spectral analysis in the frequency domain. This method overcomes the disadvantage associated with conventional spectral analysis and the difficulties in using nonlinear least squares fitting.

The mean MdPFs and IEMG values and the ratio for IEMG value between the partial frequency zone and the whole zone of the VL and MH were compared between the early stance phase and swing phase in each identical walking speed.

The following five frequency zones, obtained using band-pass filtering, were analyzed for the determination of MdPF in each zone: 20 to 1000, 20 to 40, 40 to 70, 70 to 200, and 200 to 1000 Hz, respectively, suggested by Nagata.

The data were statistically analyzed by analysis of variance and t-test and the level of significance was set at 0.05.

**Results**

Within the zone of whole frequency from 20 to 1000 Hz, the mean IEMG values of VL and MH during the swing phase were significantly greater with increasing walking speeds (fig. 1). In the high frequency zone from 200 to 1000 Hz, the mean rate of MH during the swing phase tended to increase with increased walking speed (fig. 2). On the other hand, the mean rate of VL in the above high frequency zone, decreased significantly with increasing walking speeds (fig. 3). In the whole frequency zone, the mean MdPFs of VL during the swing phase during fast
Fig. 1. Comparison of the mean 1 EMG value (20-1000Hz) \*; P<0.05

Fig. 1. Comparison of the mean 1 EMG value (20-1000Hz) \*; P<0.05 and free walking were significantly smaller than those during slow walking (fig. 4). But, no significant differences in MdPF of MH were observed among the three walking speeds.

**Discussion**

We concluded that the MH for the swing phase was selectively controlled to recruit the larger motor units in fast-twitch muscle fibers with
increased walking speed, given that in the high frequency zone, the rates of IEMG values of that muscle during the swing phase was significantly greater with increasing walking speed. In contrast, the VL was selectively controlled to recruit the smaller motor units in slow-twitch muscle fibers with increasing walking speed, given that in the high frequency zone the rate of IEMG value of the VL during the swing phase de-
creased, while in the low frequency zone, that for the swing phase tended to increase with increasing walking speeds.

**Conclusions**

In conclusion the different motor controls for each muscle were precisely performed during the swing phase during changes in walking speed.

**References**
