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Effects of vibrotactile stimulation on the motor unit discharge properties

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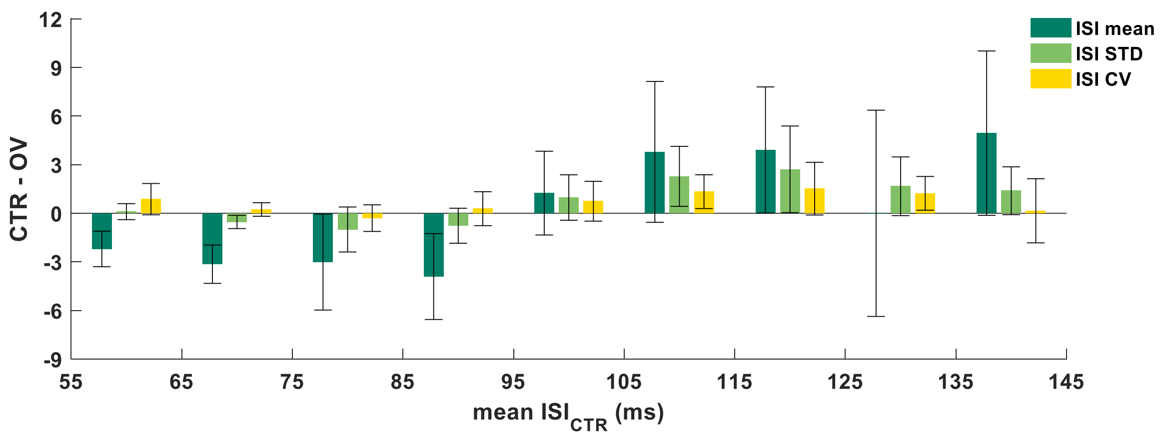
Background, Motivation and Objective. Previous studies have shown that an optimal vibrotactile stimulation can improve force control during isometric contractions. Experimental outcomes suggest that the improvement in force steadiness is followed by a decrease in both the mean discharge rate and the interspike interval (ISI) variability of a population of motor units (MU). However, these findings are controversial since MUs discharging at a low firing rate (high ISI) tend to have an increased ISI variability. One hypothesis is that vibrotactile stimulation recruits high-threshold MU, leading to a decrease in the mean discharge rate of the motor pool. Additionally, increased cutaneous afferent inflow to the spinal cord would increase the excitability of the motoneuron pool, thereby increasing the discharge rate and decreasing the ISI variability of the previously recruited MUs. In the present study, we aim at analysing the discharge properties of tracked MUs during isometric contractions with and without an optimal vibrotactile stimulation.

Methods. Ten healthy young adults (age: 27±3yrs) participated in this study. All procedures were approved by the Ethics Committee of the University of Campinas (CAAE 59961616.8.0000.5404). Participants performed visuomotor tasks that consisted of steady abduction contractions of the index finger at 2.5% and 5% of the maximal voluntary contraction (MVC). During the contractions, three intensities of vibrotactile stimuli at a frequency of 175 Hz were applied to the radial surface of the metacarpophalangeal joint. Additionally, a control condition without vibration (CTR) was evaluated. The vibration amplitude corresponding to the best force steadiness was considered as the optimal vibration (OV). Contractions lasted 45s, and each condition (force level and vibration intensity) was repeated three times. Trials were performed in a randomized order. The myoelectric activity of the FDI was recorded with a high-density surface electromyogram (EMG) grid with 64 electrodes, and the MU spike trains were extracted using an automatic decomposition algorithm. For the analysis, only MUs tracked in both CTR and OV conditions were considered. For these MUs, the following discharge properties were evaluated: i) mean ISI; ii) ISI standard deviation (STD), and iii) ISI coefficient of variation (CV). The effects of vibration and contraction intensity on the dependent variables were evaluated using a mixed ANOVA with a significance level of 5%. Also, the relative difference between CTR and OV conditions for all variables was analysed for different ranges of mean ISI calculated at CTR condition using Generalized Estimating Equation.

Results. Vibrotactile stimulation significantly decreased ISI CV (p=0.010) for the population of tracked MUs regardless of the contraction intensity (p=0.297). However, the relative difference between CTR and OV conditions for the ISI CV was not influenced by the mean ISI of the tracked MU in CTR condition (p=0.166, see the yellow bars in Figure 1). On the other hand, there were no significant effect of vibration for the mean ISI (p=0.116) and ISI STD (p=0.357) when the population of MUs is pooled. However, there were effect of OV on the ISI mean and ISI STD when the MUs were evaluated in different ranges of mean ISIs in CTR condition ($p<0.001$ for both variables, see dark and light green bars in Figure 1). However, in these cases, there was no significant effect of contraction intensity ($p=0.999$ and $p=0.670$ for ISI mean and ISI STD, respectively). In sum, OV increased mean ISI and ISI STD for MUs with lower mean ISIs (higher firing rate), while decreased these variables for MUs with higher mean ISI (lower firing rate).

Discussion and Conclusions. The present data partially refute the hypothesis that vibrotactile stimulation increases the excitability of the motoneuron pool, thereby increasing the discharge rate of the already recruited MUs and decreasing ISI CV. Here we showed that the effects of vibration on the mean ISI and ISI STD are influenced by the mean discharge rate (or mean ISI) of the MU in CTR condition. OV decreased the excitability of MUs with lower mean ISIs, while increased the excitability of MUs with higher mean ISIs. However, the relative difference in ISI CV (between CTR and OV conditions) was not influenced by the mean ISI of the MU in CTR condition. The later can be explained by the larger decrease in ISI STD as compared to the decreased mean ISI in MUs discharging at a lower firing rates so that the relative difference of the ISI CV was kept constant for the whole range of mean ISI evaluated. The most significant effect observed in MUs discharging at lower firing rates is likely due to the operation of the MUs close to their recruitment thresholds, where the synaptic noise largely influences the membrane potential fluctuations. On the other hand, for the MUs with lower mean ISIs (higher firing rates) the motor neurons discharge more regularly, and hence, the OV cannot influence ISI variability but can decrease the mean firing rate.

Figures 1. The relative difference between CTR and OV for the interspike interval (ISI) mean, STD and CV as a function of the mean ISI calculated in CTR condition. All data are presented as mean±95% confidence interval.



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Keywords. Vibration, motor unit, discharge properties, interspike interval variability, force control.