Potential impact of missing spikes on motor unit firing behaviors: A simulation study

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Summary

This simulation study sought to examine the impact of missing motor unit (MU) spikes on the statistical analysis of MU firing behaviors. A computational model of MU pool organization was used to determine spike trains for 120 MUs during an 8-s steady-state contraction at 100% neural drive. From the 120 MU spike trains, we randomly removed 1%, 5%, and 10% of the spikes over 100 iterations with each condition, and then calculated the mean firing rate during the middle 6-s contraction period. We found that missing spike rates of 1%, 5%, and 10% resulted in significant variations in MU firing rates of 0.3, 1.7, and 3.5 Hz, respectively. These results suggest that recordings with ≤10% of missing spikes may lead to misinterpretation of MU mechanics, especially for individuals with clinically relevant conditions.

Introduction

A fundamental issue in human neuromotor science is understanding how MU action potential trains (i.e., spikes) encode information regarding motor outputs. Although previous research has logically assumed this information is appropriately conveyed by the mean number of spikes fired during a specific time interval, this fundamental assumption requires revision. However, it is unknown if differences in spike number drive changes in MU firing behaviors. Accordingly, we sought to answer this question with the hypothesis that reductions in MU firing number lead to significant changes in its variability, which may lead to the misinterpretation of results. Additionally, we sought to determine if missing spikes were clinically more important than a shift in spike timing.

Methods

Using a computational model of MU pool organization developed for the first dorsal interosseous muscle [1], we determined spike trains for 120 MUs during a given ramp-up (i.e., linear increase from 0% to 100% neural drive in 5 s) and 8-s hold contraction protocol. From the 120 MU spike trains, we randomly removed the spikes at a missing rate of 1%, 5%, and 10%, and then calculated the mean firing rate for the middle 6-s contraction period. Additionally, we tested the impact of random shifts of the spike timing within ±4 ms at an error rate of 10% on the mean firing rate. Each condition was repeated 100 iterations, and the average values of the mean MU firing rates were compared with the mean MU firing rates from the original spike trains.

Results and Discussion

We when shifted the timing of spikes there were no significant difference (**Figure 1A**). However, when we randomly removed a certain percentage of spikes significant difference were found (**Figure 1B**). Specifically, using a 1% deficit in spikes resulted in a reduced mean firing rate of 0.3±0.2 Hz for MU1 and 0.1±0.1 Hz for MU120. Using a 5% deficit led to a decrease in the mean firing rate of 1.7±0.4 Hz for MU1 and 0.5±0.2 Hz for MU120. Using a 10% deficit resulted in a reduced mean firing rate of 3.5±0.5 Hz for MU1 and 1.1±0.3 Hz for MU120. Considering that a 3 Hz reduction in the mean MU firing rate could result in a 20% decrease in the muscle strength [2], changes in the mean firing rates due to missing spikes may lead to misinterpretation of MU mechanics, suggesting that decomposition accuracy and its validation are paramount.

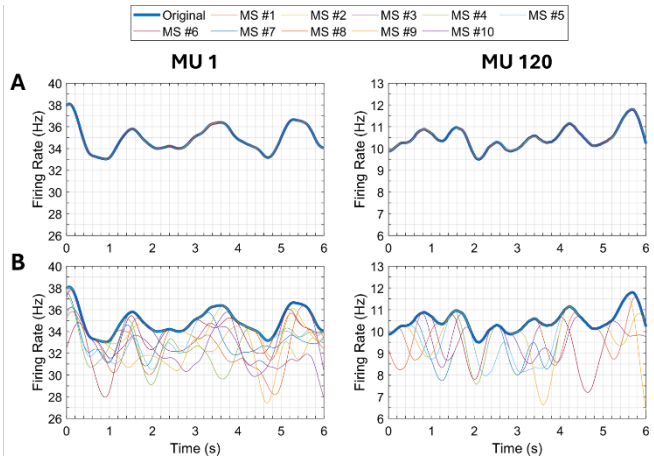

Figure 1: Examples of firing rate patterns from the original spike trains (A) and from the spike trains with a 5% random deficit (B).

Conclusions

In short, our findings suggest that missing spikes of ≤10% may lead to misinterpretation of clinically meaningful information. Notably, while our findings do not provide conclusive evidence due to this data being derived from a computer model, they do support the notion of including an index of estimated missing spikes during specified recording.

References

[1] Fuglevand A et al. (1993). *J Neurophysiol*, **70**: 2470-2488.
[2] Wages N et al. (2024). *Calcif Tissue Int*, **114**: 9-23.