



## Letter to the Editor

## Reply to “MUNIX value dependence on surface electromyogram properties”



We thank Dr Miralles (Miralles, 2019) for his interest in our study (Bostock et al., 2019) on the relationship between motor unit number index (MUNIX) (Nandedkar et al., 2010) and compound muscle action potential (CMAP) amplitude, which used data from our previous study (Jacobsen et al., 2017) and a theoretical analysis. Miralles comments critically on two of our three lines of reasoning. In the first, as correctly reported by Miralles (2019), we showed how MUNIX can be expressed in terms of the CMAP and  $G_{SIP(20\mu V)}$ , the form factor ( $G$ ) of the surface interference pattern (SIP) of the electromyogram, when the SIP has a mean rectified value of 20  $\mu V$ . We then showed, as again accepted by Miralles, that  $G_{SIP(20\mu V)}$  for healthy controls is always close to the value of 1.42 (Fig. 2C in Bostock et al., 2019), so that MUNIX is almost entirely dependent on the CMAP.  $G_{SIP(20\mu V)}$  is also similar in many patients with amyotrophic lateral sclerosis (ALS) (Fig. 2D). It only increases above that value when motor unit potentials are so large that they can generate the mean rectified value of 20  $\mu V$  with little overlap, and we have no disagreement with Miralles that in these cases the SIPs do convey information about motor unit size. We never claimed, as Miralles mistakenly reports, that MUNIX provides no more information than the CMAP in ALS patients, only that it provides no more information in healthy subjects and little more information in ALS.

The question of how accurately and how sensitively MUNIX can detect changes in motor unit size is most clearly answered by our second line of reasoning. Again, there seems to be no disagreement about the data. Dr Miralles accepts our finding that if all motor unit sizes in the SIPs are doubled, for the same CMAP amplitude, MUNIX is almost unchanged (except for a few ALS patients, see Fig. 4B in Bostock et al., 2019). We are puzzled that he does not appear to appreciate that this reveals a fundamental flaw in the method, since if the units were doubled in size, this would mean that only half the number would be required to sum to make the CMAP, and MUNIX should be halved. References to mathematical models and the value of  $\beta$  cannot obscure this simple fact.

In conclusion, we did not intend to accuse MUNIX of never providing more information about motor unit numbers than CMAP amplitudes. Our aim was to draw the attention of MUNIX users to the close relationship between the two, which is only altered when there is sufficient collateral reinnervation that a mean rectified SIP value of 20  $\mu V$  is achieved with limited overlap of motor

unit potentials. This close relationship explains why, in our study comparing MUNIX with two different motor number estimation (MUNE) methods, MUNIX was no better than CMAP amplitude at distinguishing ALS patients from healthy controls, whereas the two MUNE methods were significantly better (Jacobsen et al., 2017). It is important that MUNIX users be aware that when motor units overlap extensively, information about motor unit size is completely lost, since the SIP form factor becomes constant.

## Declaration of Competing Interest

None of the authors have potential conflicts of interest to be disclosed.

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