Contractile properties and behaviour of single motor units in elderly

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Introduction

Ageing is usually associated with decreased motor control, muscle force and slowing of contractile properties. In addition to changes in muscle architecture and tendon compliance (Narici et al, 2002), these alterations are related to adaptations in motor unit (MU) structure and function. Although a few studies have already investigated changes in MU recruitment, discharge frequency or contractile properties in aged population, most of them were performed in hand muscles (Roos et al, 1997). Since the age-related changes may vary specifically with the muscle group, it was interesting to examine these adaptations in a lower limb muscle. More precisely, we investigated single MUs in the tibialis anterior (TA). This muscle is involved in locomotion and stabilization of the body, two functions that are often altered in elderly adults.

Methods

Single motor units (MUs) were recorded from the TA of 6 young (2 males and 4 females, aged between 22 and 29 years) and from 6 elderly subjects (2 males and 4 females, aged between 71 and 83 years). All subjects were well accustomed to the experimental procedure. During the experiments, the subject sat on a chair with the right foot strapped to a footplate connected to a strain-gauge transducer (ankle and knee joints set at 90° and 110°, respectively). MU action potentials were recorded by highly selective wire electrodes (50 µm in diameter) inserted into the belly of the muscle. The mechanical responses of MUs were obtained by the "spike-triggered averaging" method (Milner-Brown et al, 1973). The method consists in extracting, by averaging, the mechanical contribution of a selected unit during a sustained contraction. Contractile properties and discharge rates were determined in 366 MUs in young and 101 MUs in elderly subjects. MU recruitment threshold (RT), defined as the level of torque at which the unit began to fire, and discharge frequency were determined during isometric ramp contractions. MU torque and RT were expressed as percentage of the subject's maximal voluntary contraction (MVC).

Results

In our elderly population, 70% of the MUs, compared with 40% in the young adults, were recruited below 20% of MVC. Therefore, a lower average value ($P<0.001$) for MUs RT was observed in the elderly group (15.1 ± 14.7 %MVC) compared with young subjects (26.8 ± 20.4 %MVC). The average MUs torque (expressed as %MVC) did not differ significantly between elderly (0.075 ± 0.073 %) and young (0.062 ± 0.053 %) subjects. However, when expressed relative to their recruitment threshold, MUs generated higher torque ($P<0.01$) in elderly compared with young subjects. Ageing was also associated with a slowing of MUs contractile properties, as evidenced by a prolonged average contraction time (40.8 ± 12.8 ms vs 64.4 ± 14.8 ms, $P<0.001$, in young and elderly subjects, respectively). In the two groups, a positive linear relationship was recorded between MU torque and RT ($r = 0.60$ and $r = 0.66$ in young and elderly subjects, respectively; $P<0.001$) and a negative one between MU time-to-peak and RT ($r = 0.20$ and $r = 0.45$ in young and elderly subjects, respectively; $P<0.001$). The discharge frequency at recruitment was similar in young (8.4 ± 3.0 Hz) and elderly subjects (8.4 ± 1.7 Hz). Although not statistically different from elderly subjects, young adults displayed a tendency to higher MU discharge frequencies at maximal or near maximal force.

Discussion/Conclusion

Our results indicate that ageing induces a slowing of MUs contractile properties, an observation in agreement with a study performed at the whole TA level (Baudry et al, 2005). In contrast to the reported increased MUs torque in hand muscles of elderly subjects (Galganski et al, 1993), the average torque (%MVC) is not significantly modified with ageing. This discrepancy may be explained by the greater proportion of MUs with low RT in our elderly population. The positive linear relationship between MUs torque and their RT, classically observed in young subjects and known as the "size principle" (Milner-Brown et al, 1973), is preserved in elderly subjects. Similarly, the negative linear relationship between MUs contraction time and RT persists in elderly, which indicates that slow MUs are recruited before fast MUs during graded contractions. In addition, when expressed relative to their RT, MUs generate higher torque in elderly compared with young subjects. This observation supports the viewpoint of an increased MUs size with ageing. Such adaptation is due to the reinnervation of some denervated muscle fibres by the surviving MUs, following the progressive death of motor neurones (Roos et al, 1997). Despite the substantial changes in the contractile properties of TA MUs with ageing, their discharge frequencies do not appear to differ significantly from young adult.

References

Baudry S et al (2005). J Appl Physiol 98: 1243-1250
Galganski ME et al (1993). J Neurophysiol 69: 2108-2115
Milner-Brown HS et al (1973). J Physiol 228: 285-306
Narici MV et al (2002). J Gravit Physiol 9: 137-138
Roos MR et al (1997). Muscle Nerve 20: 679-690

This project was supported by the European Commission (contract # QLRT-2001-00323)