Mechanical and morphological properties of different muscle-tendon-units of the lower extremity and running mechanics: Effect of aging and physical activity

Karamanidis Kiros, Arampatzis Adamantios
Institute for Biomechanics and Orthopaedics, German Sport University Cologne, Germany

Introduction
Most studies analysing the motor control performance in relation to aging did not determine the muscle-tendon-unit (MTU) properties using the same subject groups. Furthermore, it remains unknown whether endurance running exercise influences the mechanical properties of different MTUs or the effectiveness of running. Therefore, the purpose of this study was to examine the effects of aging and endurance running exercise on the mechanical and morphological properties of different MTUs and their influence on running mechanics using the same subjects.

Methods
The investigation was conducted on 30 elderly (height: 175±6cm; body mass: 78±6kg) and 19 young adult males (height: 180±7cm; body mass: 76±7kg) divided into two subgroups according to their running activity: endurance-runners and non-active. To analyse the mechanical capacity of the triceps surae (TS) and quadriceps femoris (QF) MTUs all subjects performed isometric maximal voluntary (MVC) plantarflexion and knee extension contractions at 11 different MTU lengths on a Biodex dynamometer. The activation of the TS and QF during MVC was estimated by surface EMG (1080Hz). The architecture of the gastrocnemius medialis (GM) and the vastus lateralis (VL) and their distal aponeuroses were visualized by ultrasonography at rest and during MVC respectively. Ground reaction force (Kistler, 1080Hz) and kinematic data (Vicon, 120Hz) were recorded during running trials at 2.7m/s. To calculate the rate of force generation (FR) we divided the average vertical force per kg body weight divided by the ground contact time according to Kram and Taylor (1990). For the analysis of force generation per meter distance (FM) we divided FR by the running speed (Kram and Taylor 1990). The gear ratio of the TS and QF MTUs was calculated as the ratio (R/r) of the moment arm (R) of the GRF acting about the joint to the agonist tendon moment arm (r) (Carrier et al. 1994). All parameters were checked for differences between groups using a two-way (age x running activity) ANOVA.

Results
Elderly subjects had lower (p<0.05) max. isometric ankle and knee joint moments than the young adults. Furthermore, the young subjects had a stiffer QF tendon and aponeurosis than the elderly ones which was not noted at the TS. In contrast, the properties of both MTUs showed no differences between runners and the non-active group (p>0.05). No clear effects of age or running activity on the muscle architecture (fascicle length, ratio, pennation angle, thickness) were found. During running, elderly subjects selected a higher stride frequency, higher duty factor, lower flight time, lower step length, lower FR and FM and lower maximal moment and mechanical power at the ankle joint than the young adults (p<0.05). Age had an effect on the gear ratio at the ankle joint during the first 58% of the contact phase due to a lower moment arm of the GRF to the ankle joint (Fig. 1). Runners exhibited lower (p<0.05) step length and lower gear ratio at the knee joint due to a lower moment arm of the GRF to the knee joint during the first 42% of the contact phase than the non-active group (Fig. 1).

Discussion/Conclusion
Aging had a more pronounced effect on the properties of the analysed MTUs and on the running mechanics than endurance running exercise. Elderly subjects react to the reduced capacity of their MTUs by increasing the safety during running (higher duty factor, lower flight time) and with increased running effectiveness (lower gear ratio at the ankle joint, lower FR and FM) during contact phase. Although endurance running had no effect on the properties of the TS and QF MTUs, running exercise increases the mechanical advantage for the QF MTU (lower gear ratio). We supposed that the increase in running effectiveness in the elderly subjects happens due to perceptual motor recalibration and a feedforward adaptation of the motor task to reduce the disparity between MTUs capacity and running effort.

References