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Relationship between Athletic Performance and Visco-elasticity of the Plantar Flexor Muscles Revealed by the Vibration Method in Long-Distance Runners

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INTRODUCTION:
During the contact phase of running, the visco-elastic properties of the muscle-tendon complex (MTC) play a crucial role in functional muscle-tendon interaction and the recycling of elastic energy (1). In human experiments using B mode ultrasound, long distance runners have lower tendon stiffness (2) and higher muscle stiffness (3) in the plantar flexor muscles, which are associated with faster 5000 m times. However, viscosity, which has been the focus of attention in running shoes development in recent years, and viscoelasticity due to the exertion of multi-step forces have not been measured. The purpose of this study was to measure these values using the vibration method and to examine the relationship between these values and athletic performance.
METHODS:
Twenty male athletes in long-distance of track and field participated. Athletic performance was calculated by converting the best 5000m season record (15 minutes 16.35 ± 50.45 seconds) in 2020 and 2021 into the IAAF Score (768.30 ± 147.75). We used the vibration method similar to (4). This method involved hitting a weight placed on the knee with a hammer, vibrating the triceps surae muscle, and inducing a damped oscillation. By combining the equation of motion of the mass-spring model and the waveform of the force, we calculated the elastic coefficient of MTC, and the viscosity coefficient from the vibration frequency and the amplitude reduction. We estimated each coefficient by regression for every 100N up to 800N. Then, the elasticity of MTC was separated into muscle and tendon components, based on the assumption that they are arranged in series.
RESULTS:
IAAF Score and the elastic coefficient of the muscle-tendon complex were significantly positively correlated under various force conditions (e.g. 800N: $r=0.72$, $p<0.01$). The coefficient of determination increased as the Achilles tendon tension rose (e.g. 100N: $r^2 = 0.22$, 800N: $r^2 = 0.52$). The separation of elasticity in muscle and tendon revealed a significant positive correlation ($r=0.47$, $p<0.05$) between IAAF Score and the muscle elastic coefficient, but not between IAAF Score and the tendon elastic modulus. IAAF Score and the viscosity coefficient were not significantly correlated.
CONCLUSION:
IAAF Score and the elastic coefficient of both muscle-tendon complex and muscle were significantly positively correlated. Higher muscle-tendon elasticity allows more elastic energy to be stored with smaller displacements during the stretch shortening cycle motion that occurs during ground contact. High elasticity also shortens the ground contact time (5). These effects are thought to enable energy-efficient movements with less vertical movement of the center of gravity and increased pitch.
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