MUSCLE-TENDON ADAPTATION MONITORING IN ELITE ATHLETES: PRELIMINARY RESULTS FROM A LONGITUDINAL INVESTIGATION

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In this study, we analysed the triceps surae (TS) muscle-tendon unit (MTU) mechanical properties (muscle strength and tendon stiffness) in elite jumping event athletes (long jump, triple jump, high jump, pole vault) and monitored the training-induced alterations in these properties over one year in nine elite jumpers, in order to detect potential changes in the uniformity of adaptation within the TS MTU. The findings indicate to a higher TS muscle strength and Achilles tendon stiffness in the take-off leg in comparison to the swing leg. The longitudinal monitoring revealed a concordant muscle and tendon adaptation in the TS MTU in both legs in the selected athletes.

KEY WORDS: muscle strength, tendon stiffness, training adaptation, jumpers

INTRODUCTION: Human muscle-tendon units (MTUs) are mechanosensitive and are able to respond to repetitive mechanical loading by changing their biomechanical properties (Arampatzis et al., 2007; Kubo et al., 2001). However, differences in the time course of muscle and tendon adaptation to mechanical loading (Mersmann et al., 2016) and unequal mechanical loading patterns (Couppé et al., 2008) may affect the intra- and inter-limb uniformity of the MTU, potentially leading to tendon injuries. In the current study, we analysed the triceps surae (TS) MTU mechanical properties (muscle strength and tendon stiffness) of both legs in young adult elite jumpers and monitored the training-induced alterations in these properties over one training year, in order to detect potential changes in the uniformity of adaptation within the TS MTU.

METHODS: The current preliminary analysis is part of an ongoing nationwide study on the TS MTU adaptation of elite international and national level jumping event (long jump, triple jump, high jump, pole vault) track and field athletes (currently over 30 athletes; mean age 23±4 y) from the German national team. The study was approved by the responsible ethics committee of the German Sport University Cologne and a written informed consent was obtained from all participants. In all athletes the maximum ankle plantarflexion moment and Achilles tendon (AT) stiffness are assessed regularly (every 2 – 4 weeks) by using a mobile device (integrated dynamometry and ultrasonography; TEMULAB®, Protendon, Aachen, Germany; see Fig. 1) at their respective Olympic training centres or at the national team training camps during the preparation and competition periods over one whole season (winter and summer). The exact measurement setup is explained in more detail in our previous study (Ackermans et al., 2016). Up to this point nine of the participants (23±3 y) have been measured regularly over a time period of 1 year. A one-way analysis of variance (ANOVA) with the leg (take-off vs swing leg) as a factor and Bonferroni post hoc test was used in order to examine potential intra-individual differences between legs in TS muscle strength and AT stiffness. In order to investigate possible intra-individual differences in muscle and tendon adaptive changes within one year, the coefficients of variation (CV) for TS muscle strength and tendon stiffness were calculated over all analysed measurements (on average 16 measurements for all nine participants).

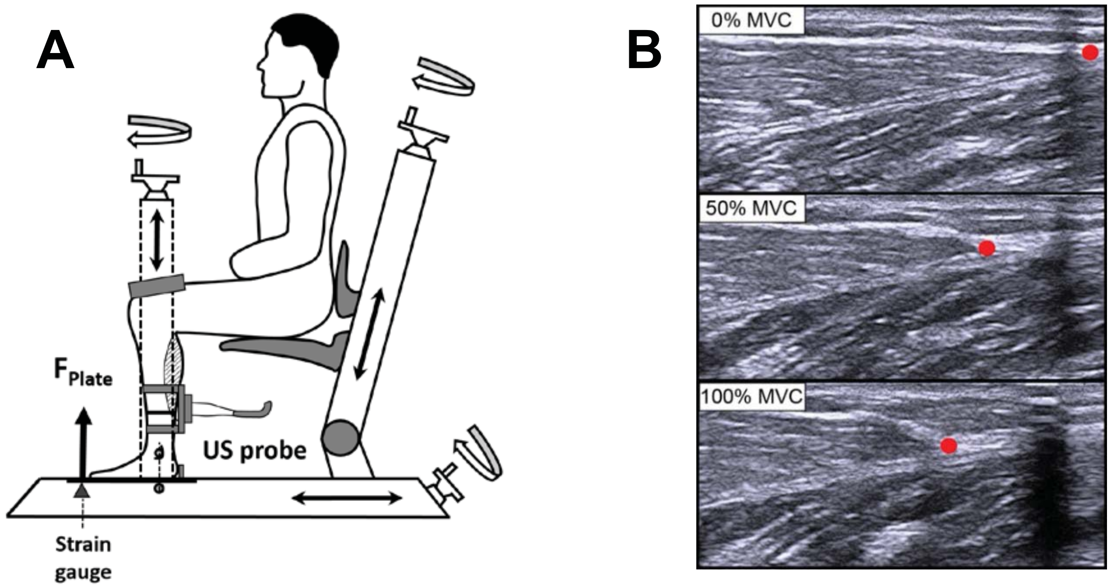

Figure 1. A: The used mobile device (TEMULAB®, Protendon, Aachen, Germany) to assess ankle plantarflexion moment and Achilles tendon stiffness in the participants (see also Ackermans et al., 2016). B: Ultrasound image sequence (at 0%, 50% and 100% of MVC) during a maximal ankle plantarflexion moment (red dot represents the tracked myotendinous junction).

RESULTS: The use of a one-way ANOVA revealed a significant leg effect, showing significantly ($p<0.05$) higher TS muscle strength (371 ± 58 Nm vs. 348 ± 44 Nm) and also AT stiffness (874 ± 113 Nmm^{-1} vs. 812 ± 110 Nmm^{-1}) for the take-off leg in comparison to the swing leg. The longitudinal monitoring of the nine healthy young adult elite athletes revealed similar patterns in the relative changes of TS muscle strength and tendon stiffness for both, take-off leg (CVs of 9.1 ± 2.3 % and 13.8 ± 6.1 % respectively) and swing leg (CVs of 8.6 ± 1.7 % and 12.0 ± 3.5 % respectively). Nevertheless, two of the analysed participants showed remarkably higher CV values for tendon stiffness in comparison to muscle strength in both legs.

DISCUSSION: The findings of the current study indicate limb-specific differences of both TS muscle strength the AT stiffness due to training in elite jumpers, with higher values for the take-off leg in comparison to the swing leg, which may be related to a possibly higher training load of the take-off leg. This finding is in accordance with an earlier study with collegiate-level jumping athletes showing higher AT stiffness and Young's modulus in the take-off leg (Bayliss et al., 2016). However, when the relative differences between the take-off and swing legs in the TS muscle strength are similar (7% in elite vs. 9% in collegiate-level jumping athletes), the dissimilarities in AT stiffness between the legs seem to be lower in the elite athletes than in the collegiate-level jumping athletes (8% vs. 18% respectively). When considering the uniformity of muscle and tendon adaptation, the longitudinal monitoring of the nine analysed elite jumpers revealed a relatively concordant muscle and tendon adaptation within the TS MTU over a course of one year of athletics training, and this independent from the leg (see individual data from of the athlete in Fig. 2).

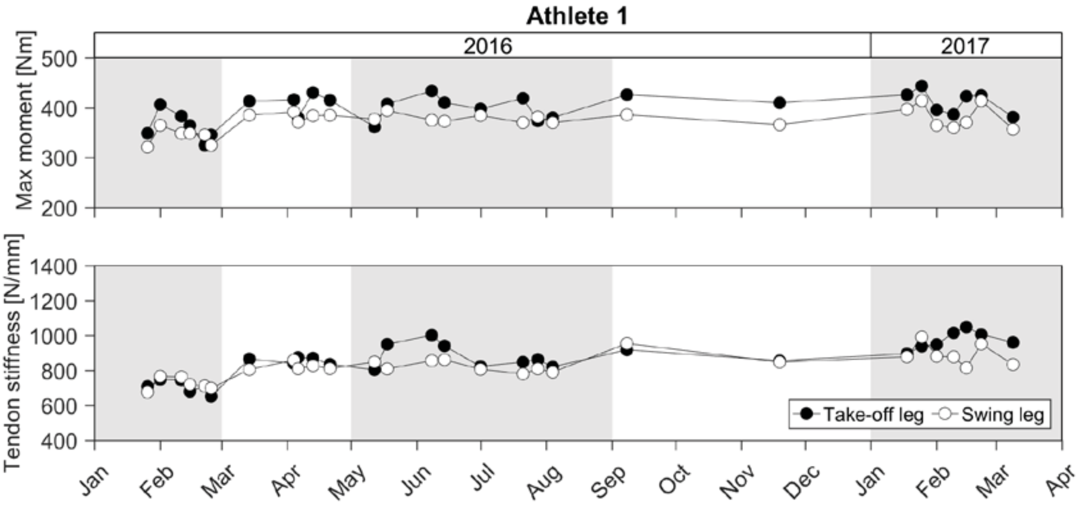

Figure 2. Individual time-course over one year in the maximal plantarflexion moment and Achilles tendon stiffness of Athlete 1 (dark rounds, take-off leg; white rounds, swing leg; grey background, competition period; white background, preparation period).

CONCLUSION: The TS MTU capacities of the take-off leg in elite jumpers seem to be greater (higher TS muscle strength and AT stiffness) than in the swing leg, which indicates a higher demand on the take-off leg due to the training schedule. Further, the identified similar patterns in the relative changes of muscle and tendon adaptation suggest that athletics training and competition load in this group of athletes did not lead to a non-uniform adaptation within the muscle-tendon unit. However, an individual approach in training planning and regular monitoring in elite athletes it is suggested for a concordant adaptation between muscle and tendon.

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