Evaluation of a Personalized Assessment and Exercise Prescription Concept to Reduce Muscle-Tendon Imbalances

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Summary

This study evaluates a personalized assessment and exercise concept that uses tendon strain during maximum contractions to identify imbalances between muscle strength and tendon stiffness, prescribe loading modalities depending on the respective deficits and personalize load intensities to confine tendon strain during exercises to an effective range for adaptation. In a large group of athletes, it was shown that the concept successfully reduced muscle-tendon imbalances and enabled the mitigation of deficits in muscle strength or tendon stiffness on an individual basis.

Introduction

Imbalances of muscle strength (*MS*) and normalized tendon stiffness (k_n; i.e. stiffness under consideration of tendon resting length) can increase the operating strain and resultant mechanical demand on tendons. It was recently shown that tendon strains during maximum fixed-end contractions $\varepsilon_{max} \geq 9$ % indicate a higher risk of injury in athletes [1]. Therefore, the identification of musculotendinous imbalances and respective individual adjustments of training may contribute to tendon injury prevention [2]. The aim of the study was to identify muscle-tendon imbalances in athletes and promote a more balanced adaptation of muscle and tendon by means of a novel personalized assessment and exercise concept.

Methods

A total of 85 adolescent and adult ball game athletes were assigned to a control and intervention group. We assessed knee extensor *MS*, patellar tendon k_n and ε_{max} at four measurement time points over a competitive season. Muscle-tendon imbalances were identified based on the individual ε_{max} [2]. High strains ($\varepsilon_{max} \geq 9\%$) were interpreted as deficit in k_n and the respective athletes in the intervention group performed exercises (3x/week) with a personalized load to reach ~5.5% tendon strain, which is known to effectively promote tendon adaptation and corresponds to rather low muscle loading in these individuals. In the case of a balanced relationship between *MS* and k_n (i.e. $4.5 \leq \varepsilon_{max} < 9\%$), the load on the muscle to achieve the effective range of tendon loading would increase and the prescribed training load was expected to provide a similar stimulus to both muscle and tendon. Finally, low strains ($\varepsilon_{max} < 4.5\%$) were interpreted as deficit in *MS*, and athletes trained with moderate loads to failure (corresponding to low tendon strains) to mainly promote *MS* via metabolic stress.

Results and Discussion

The personalized intervention significantly reduced the fluctuations of ε_{max} over the four measurements compared to the control group ($p = 0.016$), which indicates a more balanced adaptation of muscle and tendon and led to a clear reduction in the proportion of athletes with $\varepsilon_{max} \geq 9\%$. In the control group, athletes with balanced *MS* and k_n at baseline demonstrated a significant increase in the force applied to the tendon (TF_{max}; $p = 0.04$) at the end of the season and, since k_n remained similar, a significant increase in ε_{max} ($p = 0.03$; Figure 1A). In athletes of the control group presenting a deficit in k_n (Figure 1B), TF_{max}, k_n as well as the resultant ε_{max} did not change significantly over the period of observation ($p > 0.05$), indicating persistent imbalances. In the intervention group, athletes with balanced muscle strength and tendon stiffness demonstrated a significant increase in both TF_{max} ($p = 0.018$) and the force for a given level of strain ($p < 0.05$), thus ε_{max} remained within the target range (Figure 1C). Athletes with marked deficits in k_n at baseline (Figure 1D) demonstrated a clear increase in slope of the force-strain relationship ($p < 0.05$) and no significant increase in TF_{max}, which significantly reduced ε_{max} ($p < 0.001$) to the proposed target range corresponding to balanced *MS* and k_n.

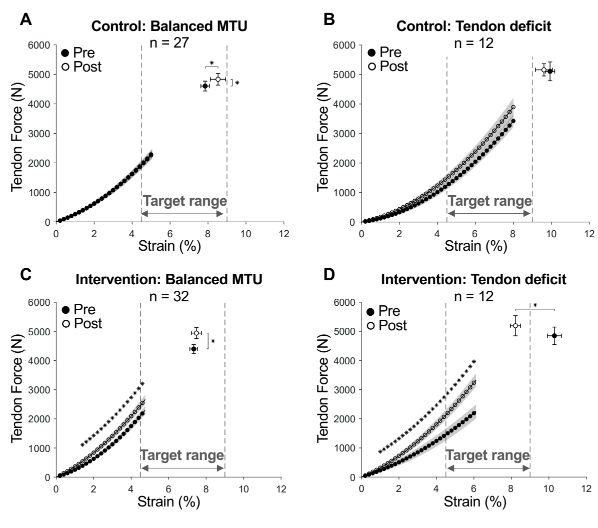

Figure 1: Patellar tendon force-strain relationship (mean ± SE) before and after the intervention period (24 to 36 weeks) in the control and intervention group. See text for further explanations.

Conclusions

The proposed concept enables the identification, mitigation and prevention of muscle-tendon imbalances. It provides new opportunities to prevent overuse injury in athletes and personalize exercise during rehabilitation.

References

[1] Mersmann F et al. (2023). *Sports Med. - Open*, **9**: 83.
[2] Arampatzis A et al. (2020) *Front. Physiol.* **11**: 7