Functional Role of Endomysium in Skeletal Muscle Fiber Bundle Mechanics

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Summary

Forces produced within muscle fibers are transmitted not only through myotendinous connections but also laterally across muscle fibers via the extracellular matrix (ECM) and other connective tissues, including the endomysium, perimysium, and epimysium. This study investigates the impact of endomysium integrity on force production and sarcomere organization in muscle fiber bundles. Disrupting endomysial connections between two fibers in a bundle significantly reduced passive and active stress, shifted optimal fiber length, and increased sarcomere length heterogeneity. These findings indicate that endomysium plays a crucial role in determining sarcomere behavior and facilitating mechanical interactions between fibers within the bundle.

Introduction

Force transmission between muscles through epimysium has been studied well [e.g., 1,2]. Earlier [3] and recent [4] findings showed the importance of endomysium in both passive and active force production and transmission. This study aimed to investigate how the integrity of endomysial connections between fibers within a bundle influences fiber mechanics and sarcomere-level behavior.

Methods

Extensor digitorum longus muscles from two male Wistar rats (7 months old, 558 ± 31 g) were dissected into fiber bundles, skinned, and stored at –30 °C. On the day of the experiment, bundles of 5 fibers ($n = 8$) were isolated and tested under two conditions: (I) with intact endomysium and (II) after blunt dissection of the endomysial connection between two fibers. Passive and active stresses were measured across fiber lengths ranging from 0.7 to 1.3 of the optimal length (L_{opt}) and were normalized to the maximum stress at L_{opt} in condition (I). The passive and active stress-length relationships were described using an exponential function and a fourth-order polynomial ($R^2 \geq 0.90$), respectively. Differences in force and sarcomere length between conditions were analyzed using repeated-measures ANOVA.

Results and Discussion

Dissecting the endomysial connection between two fibers at the periphery of the bundle significantly reduced passive stress by 28.4% (47.3% normalized) ($p < 0.001$, Figure 1), confirming the endomysium’s role as a key load-bearing structure.

In the active state, disrupting the endomysial connection led to a 15.6% decrease in active fiber stress (16.9% normalized) ($p < 0.001$, Figure 1). Additionally, optimal fiber length increased by 8.7% ± 4.9% ($p = 0.010$). After dissection, sarcomere length heterogeneity was observed at fiber lengths slightly shorter and longer than optimal length. These results suggest that reducing endomysial connections made fibers more mechanically independent, disrupted lateral force transmission, and led to localized differences in sarcomere strain. As a result, some sarcomeres operated at shorter lengths, shifting optimal fiber length to longer lengths and contributing to an overall drop in force production. These findings align with previous reports on sarcomere length heterogeneity [5, 6], further emphasizing the critical role of endomysial integrity in fiber bundle mechanics.

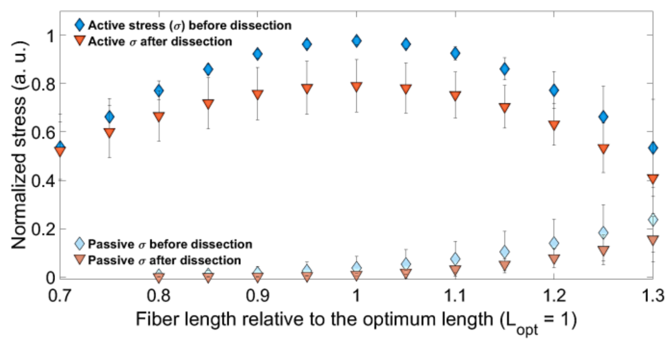

Figure 1: Normalized active and passive stress-length characteristics. Data is shown as mean ± standard deviation.

Conclusions

Our findings highlight the critical role of endomysial continuity in both passive and active mechanical behavior of muscle fiber bundles. These results suggest that mechanical interactions between fibers via the endomysium are essential for maintaining sarcomere organization and optimizing force transmission. The loss of continuity following dissection underscores the importance of ECM integrity in muscle function, adaptation, injury, and rehabilitation.

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