Power exertion of gastrocnemius fascicle and tendon in running at different speeds: a pilot study

Toshihide Fujimori[1,2], Tempei Tominaga[1], Takeshi Edagawa[1], Yoshiki Tasaki[1], Natsuki Sado[3,4]
[1]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan
[2] Research Fellow of the Japan Society for the Promotion of Science, Tokyo, Japan
[3] Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan
[4] Advanced Research Initiative for Human High Performance, University of Tsukuba, Tsukuba, Japan
Email: sado.natsuki.gm@u.tsukuba.ac.jp

Summary

Ankle plantar flexors are the largest power generators during running. Ankle power increases from jogging (≤3 m/s) to sprinting (≥8 m/s). However, little is known regarding how large power exertion is achieved by fascicle and tendon within the muscle-tendon unit (MTU) during sprinting. We analysed gastrocnemius MTU dynamics during running at different speeds [JOG: 3 m/s, INT: 5 m/s and SPRINT: 8 m/s] of three males using an ultrasound apparatus, a motion capture system and force platforms. Tendon power increased in the order of JOG (953±457 W), INT (1775±648 W) and SPRINT (2445±1044 W). Fascicle power increased from JOG (339±49 W) to INT (452±253 W) but seemed similar between INT and SPRINT (443±197 W). These results suggest that fascicle power exertion in running can reach its limit at 5 m/s, and that the increase in MTU power at high-speed range (>5m/s) was mainly achieved by tendon.

Introduction

Ankle plantar flexors are the largest power generators during the stance phase in the running. Ankle joint power increases from jogging (≤3 m/s) to sprinting (≥8 m/s) [1]. However, little is known regarding how large power exertion is achieved by fascicle and tendon within the muscle-tendon unit (MTU) during sprinting. In the soleus, a study, combining ultrasound analysis and Hill-type modelling, predicted that maximum fascicle power exertion may continuously increase toward sprinting through the increase in muscle activation [2]. Gastrocnemius and soleus are typical synergists of ankle plantar flexion, but they exhibit different fascicle dynamics during running [3]. We analysed gastrocnemius fascicle and tendon power exertion from jogging to sprinting *in vivo*.

Methods

Three adult males performed overground running at different speeds (JOG: 3 m/s, INT: 5 m/s and SPRINT: 8 m/s). Joint kinematics and ground reaction force were respectively recorded by the motion capture system (250 Hz) and force platforms (1000 Hz). Gastrocnemius B-mode images were recorded at 152 Hz by the ultrasound apparatus, synchronised with the motion capture. MTU length was calculated from joint angles. Fascicle length was calculated from ultrasound images. Tendon length was calculated by subtracting the effective fascicle length from MTU length. MTU force was calculated by dividing the ankle joint torque by the Achilles tendon moment arm. We calculated the whole MTU power, fascicle power and tendon power.

Results and Discussion

The whole MTU peak positive power exertion was larger with the increase in speed (JOG: 1143±376 W, INT: 1954±603 W and SPRINT: 2671±967 W). Within MTU, the fascicle showed power generation throughout the stance phase, while the tendon showed a pattern of absorption followed by generation (Figure 1A). Peak positive fascicle power increased from JOG (339±49 W) to INT (452±253 W), but seemed similar between INT and SPRINT (443±197 W) (Figure 1B), suggesting that gastrocnemius fascicle power can reach its limit at 5 m/s. This result for gastrocnemius fascicle power using the inverse dynamics method differed from that for soleus fascicles using the Hill-type modelling [2]. Peak positive tendon power increased in the order of JOG (953±457 W), INT (1775±648 W) and SPRINT (2445±1044 W). We suggest that an increase in tendon power mainly causes the increase in whole MTU power at high-speed range (>5m/s).

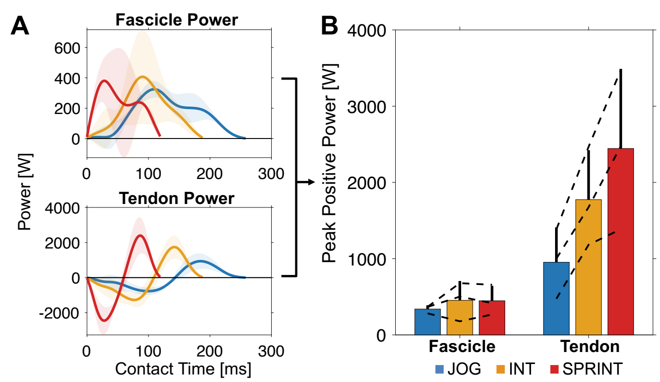

Figure 1: **A**: Time series changes of gastrocnemius fascicle power and tendon power during the stance phase. **B**: Peak positive power of gastrocnemius fascicle and tendon.

Conclusions

We suggest that gastrocnemius fascicle power can reach its limit at 5 m/s. MTU power increase at low-speed range (<5m/s) was achieved both of fascicle and tendon, whereas high-speed range (>5m/s) was mainly achieved by tendon.

Acknowledgements

This work was supported by Yamaha Motor Foundation for Sports and Grant-in-Aid for JSPS Research Fellow 24KJ0479.

References

[1] Schach et al. (2011). *Med Sci Sports Exerc*: 43 (7)
[2] Bohm et al. (2023). *J Exp Biol*: 226 (22).
[3] Lai et al. (2018). *Scand J Med Sci Sports*: 28 (7).