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Commentary

How to make the “jump” on understanding the importance of the intrinsic foot muscles for propulsion

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In this issue of the *Journal of Sport and Health Science*, Smith and colleagues[1] addressed a unique aspect of human locomotion; they evaluated the effects of the intrinsic foot musculature on the mechanical properties and energetic function of the human foot. By performing a controlled jumping experiment to mimic components of human locomotion, the researchers were able to assess the involvement of the intrinsic foot muscles by systematically impairing the activity of these muscles through a tibial nerve block and assessing differences in the mechanics and energetics of the foot. A primary outcome was the “gearing function” of the foot, which was defined as the ratio of the external moment arm (i.e., the distance of the ground reaction force centre of pressure to the ankle joint centre) and the internal moment arm of the triceps surae muscles (defined as the distance from the Achilles tendon to the ankle joint centre).[2] The key findings were that elimination of the active force produced by the intrinsic foot muscles via the nerve block induced a decrease in vertical jump height, a reduction in the external moment arm length, a lowered, internal ankle joint plantarflexion moment, and a change in gear ratio. The authors’ main conclusion is that the intrinsic foot muscles play a major role in optimizing ankle joint function, specifically the joint moment, during propulsion.

I commend the researchers for their thorough approach to understanding the function of the foot by performing a well-controlled experiment that could translate to understanding foot function during locomotion. This investigation may motivate a new line of research to further study and improve our fundamental understanding of the human foot during locomotor tasks. Even though I agree with the main conclusion of the study, it is important to point out some of the limitations that may guide future work in the field.

One limitation may be the use of the single-leg, static jumping task. This task is not trivial and it may take practice beyond familiarization trials to become proficient at maximizing jump height. Becoming proficient at this task may be even more difficult with the tibial nerve block. For this reason, the effects observed in the study may not only be due to the abolishment of the intrinsic foot muscles, but also due to the loss of sensory feedback,[3,4] which was not ruled out in the original study.[1]

An additional point to highlight is the method to determine the ankle internal moment arm. The internal moment arm was taken from reflective markers, which are prone to numerous errors, including skin movement artefacts[5,6] that would likely be augmented when placed over the posterior calf. These errors could influence the accuracy of the “true” ankle internal moment arm. Further to this point, if this estimate of internal moment arm affected the conditions differently (with or without nerve block), it could create differences in the findings and conclusions. I suspect that even if the internal moment arm was considered constant throughout the jump, or estimated with another method, such as musculoskeletal modelling software (e.g., Anybody, OpenSim),[7] it would not affect the overall conclusion of the manuscript. If this reflective marker method of estimating the internal moment arm is later validated and shows that moment arm estimates may be affected differently in the nerve block *vs.* non-nerve block conditions, the authors may have the ability to strengthen/alter their conclusion via re-analysis of the data.

Recognizing the authors highlight this potential limitation, the fact that there were no statistical differences in ankle joint power, no statistical differences in ankle joint velocity, yet significant differences in ankle joint moment point to a discrepancy between mechanical explanations of the data that are blurred by a reliance on statistical differences for strong conclusions. It appears that these findings, or lack thereof, are driven by the high standard deviation produced from the

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angular velocity measure. My main comment is that the authors might have had their "hands tied" to weigh their conclusion in favour of statistical and not mechanical reasoning and suggest that there were also ankle joint power differences in their study.[1]

My belief is that if I am to criticize certain findings, if possible, I should also provide suggestions to overcome limitations. To conclude whether the effects were driven primarily by the intrinsic foot muscles, additional methodological steps could have been completed. To rule out whether learning played a role in the tibial nerve block condition, the researchers could have had participants exposed to repeated nerve blocks and assessed if jump performance improved relative to the non-blocked condition over repeated exposures. Alternatively, participants could have performed repeated trials within the same, single nerve block session and, with adequate rest, determined if jump performance changes over time due to learning effects. Additionally, it would have been helpful to have the non-blocked condition to be performed once again after the effects of the tibial nerve block subsided to determine if the exposure to the tibial nerve block changes the biomechanics of the single-leg jump or have had the non-blocked and blocked conditions counterbalanced in the experiment—I suspect this was limited by the time course of nerve block recovery,[8] but nevertheless, would be helpful to further explore the mechanisms underpinning the authors main conclusions. Ruling out the sensory contributions may be more difficult, but there are some potential solutions. Topical anesthetic or cooling (e.g., application of ice for prolonged periods) of the plantar surface may be able to help exclude some sensory influences on the results, but this intervention would not be adequate to remove the contributions from muscle proprioception due to, for example, muscle spindle activity. A unique opportunity would be to recruit individuals with sensory peripheral neuropathy and perform a similar experiment with age-matched controls to determine if reductions in the main outcomes of this study are similar across participant groups or if there is an interaction effect between blocked *vs.* non-blocked and sensory peripheral neuropathy *vs.* no sensory peripheral neuropathy. I believe these additions may help explain further why the vertical jump height changed in the tibial nerve block condition and the associated foot-ankle measures (moment, gearing ratio, *etc.*).

The findings from this research[1] will lead to future research to help improve our understanding of the human foot during locomotion. The authors point to the effects of a carbon fiber plate and how increasing foot stiffness may influence foot function in terms of muscle function, joint work redistribution, gearing function, or estimated tendon damage during running.[9–15] If true that the intrinsic foot muscles change the gear ratio, it would be interesting to determine if the foot stiffness could be regained from an external source (orthotic, stiff insole/midsole) despite reduced function of the intrinsic foot muscles. From a running performance standpoint, this follow-up research could have applications to altering footwear based on foot muscle function or fatigue over the course of a run or from a clinical perspective, design footwear or neuroprosthetics to replace/augment intrinsic foot muscle function in individuals where this function is compromised (e.g., multiple sclerosis, stroke).[16,17] While the authors point to the need for intrinsic foot muscles to stiffen the foot and keep the external moment arm longer, the inverse could be true that activation of these muscle could change foot posture and may act to reduce the external moment arm, which may be desired for someone who seeks to reduce, for example, the Achilles tendon strain because of injury.

Concluding, the work by Smith et al.,[1] is remarkable and deserves high praise. I do not want the critiques of this commentary to overshadow this exceptional work and instead, utilize this fundamental research to expand on or open new lines of inquiring across multiple areas, including, but not limited to, basic biomechanics, applied running performance, and clinical biomechanics.

Competing interests

The author declares that he has no competing interests.

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