

Response to Veerkamp et al.: Comments on Harkness-Armstrong et al. (2021)

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We would like to thank Veerkamp and colleagues for both their interest and their further exploration of the experimental data we reported in our recent publication in *Experimental Physiology* (Harkness-Armstrong et al., 2021). Idiopathic toe-walking (ITW) is an interesting, under-researched population, which poses a daily challenge for the clinicians who prescribe treatments. We therefore welcome the continued discussion on this topic.

In our study we found that both children with ITW and typically developing (TD) children operated at gastrocnemius fascicle lengths longer than their optimum, as measured by ultrasound, thus suggesting both groups utilise the descending limb of the moment-length relationship (Harkness-Armstrong et al., 2021; Figure 2). We hypothesised that this effect could be explained by the ~60% deficit in gastrocnemius lateralis muscle activation during the isometric maximum voluntary contractions in more dorsiflexed joint positions, which would have caused an underestimation of optimal fascicle length. Thanks to the neuromusculoskeletal model simulations of Veerkamp and colleagues, we can now accept this hypothesis. Consequently, these additional analyses further strengthen our original conclusion that children with ITW operate at joint angles and muscle fascicle lengths that correspond to where they are optimally strong, which may allow for the economical production of high contractile force, similarly to TD children and typically-developed adults (Fukunaga et al., 2001).

This has important implications when considering current clinical interventions for ITW. Current treatments that aim to lengthen the muscle, such as stretching or serial casting (Engström et al., 2013; Fox et al., 2006; Stricker & Angulo, 1998), may cause children with ITW to operate at longer fascicle lengths than optimal post-intervention. If true, this may explain the poor medium to long-term effectiveness of such treatments (Dietz & Khunsree, 2012; van Kuijk et al., 2014). Therefore, we suggest that treatments should aim to increase the length of the muscle-tendon unit, by increasing the length of the Achilles tendon, in an attempt to preserve the force-producing capabilities of the muscle. However, possible conservative treatments to lengthen the tendon in isolation without the need for invasive surgical procedures should be explored.

We agree that neuromusculoskeletal modelling can add value to experimental studies to answer questions that are not feasible *in vivo*. This exchange illustrates very well the complementary way that *in vivo* and *in silico* methods can, and probably should be used to overcome many of the limitations each approach faces. This is especially relevant in cases when atypical musculoskeletal anatomy and function may be present.

Declaration of Competing Interest

Thomas O'Brien and Kirsten Veerkamp have co-authored a recent paper unconnected to the subject of these letters. The letter by Veerkamp and colleagues, and this response, were prepared independently by each research team.

References

- Dietz, F., & Khunsree, S. (2012). Idiopathic toe walking: to treat or not to treat, that is the question. *The Iowa Orthopaedic Journal*, 32, 184.
- Engström, P., Bartonek, Å., Tedroff, K., Orefelt, C., Haglund-Åkerlind, Y., & Gutierrez-Farewik, E. M. (2013). Botulinum toxin A does not improve the results of cast treatment for idiopathic toe-walking: a randomized controlled trial. *JBJS*, 95(5), 400-407.
- Fox, A., Deakin, S., Pettigrew, G., & Paton, R. (2006). Serial casting in the treatment of idiopathic toe-walkers and review of the literature. *Acta Orthopaedica Belgica*, 72(6), 722.
- Fukunaga, T., Kubo, K., Kawakami, Y., Fukushima, S., Kanehisa, H., & Maganaris, C. N. (2001). In vivo behaviour of human muscle tendon during walking. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 268(1464), 229-233.
- Harkness-Armstrong, C., Maganaris, C., Walton, R., Wright, D. M., Bass, A., Baltzopoulos, V., & O'Brien, T. D. (2021). In vivo operating lengths of the gastrocnemius muscle during gait in children who idiopathically toe-walk. *Experimental Physiology*, 106(8), 1806-1813.
- Stricker, S. J., & Angulo, J. C. (1998). Idiopathic toe walking: a comparison of treatment methods. *Journal of Pediatric Orthopaedics*, 18(3), 289-293.
- van Kuijk, A. A., Kusters, R., Vugts, M., & Geurts, A. C. (2014). Treatment for idiopathic toe walking: a systematic review of the literature. *Journal of Rehabilitation Medicine*, 46(10), 945-957.