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## Last Word on Point:Counterpoint: Artificial limbs do/do not make artificially fast running speeds possible

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TO THE EDITOR: We thank the authors of the comments for their time and ideas. Drs. Buckley and Cavagna (see Ref. 3) raise important points regarding how leg spring stiffness affects running speed. It is well established that biological leg stiffness remains nearly constant across slow to moderate running speeds, but a recent review suggests that biological leg stiffness increases at speeds faster than  $\sim 6$  m/s (2). As Dr. Buckley points out, it is not possible to dynamically modulate the stiffness of existing prostheses. Since force is intrinsically dependent on stiffness, an inability to increase stiffness likely prevents athletes using prostheses (unilateral or bilateral) from exerting greater forces as they approach their maximum speeds. Further research is required to determine how leg stiffness limits force production. We differ with Dr. Buckley who equates contact time and the resonant half period. We, like Dr. Cavagna, feel that the resonant half period of the spring-mass system is better modeled as only the time when the vertical ground reaction force exceeds body weight.

Although we agree with Cavagna that an ideal passive, elastic running prosthesis could make running more efficient, efficiency is unimportant for sprint running performance. Furthermore, no study has demonstrated that the use of running-specific prosthetic legs results in a lower metabolic cost of running.

We concur with Dr. Adamczyk (see Ref. 3) that horizontal ground reaction forces deserve further investigation. It is commonly observed that sprinters using prosthetic legs have poor acceleration compared with athletes with biological legs. Botwell et al. (1) described a novel speed-servo treadmill and showed that when sprinters do not need to overcome air resistance or inertial forces during horizontal acceleration, they can reach top speeds nearly 12% faster. A speed-servo treadmill could help us to measure and understand any disadvantage that sprinters with prosthetic legs have during acceleration. Although Zelik (see Ref. 3) considers the term “net advantage” to be unscientific, we feel the probable disadvantage that

sprinters with prosthetic legs have during acceleration deserves quantification.

We accept Morin’s as well as Weyand and Bundle’s (see Ref. 3) criticism of the low video frame rate used in Grabowski et al. (4), but note that Weyand et al. (6) used the same technique in their research. Unfortunately, Grabowski et al. comprise the only leg swing time data available for runners using prostheses during maximal speed overground sprinting. The leg swing time data reported by Mann (5) for US Olympic Trials athletes appear to be for only one stride per subject; however, the methods are not provided in the self-published monograph. We look forward to a comprehensive study of leg swing time using high-speed video analysis of multiple strides for the highest caliber Paralympic and Olympic sprinters during overground sprinting.

Although this piece is entitled “last words,” this Point:Counterpoint is only a preamble to the exciting future of the science and engineering of running prostheses.

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