In Response

Thank you for allowing us to respond to the Letter to the Editor regarding our recently published study titled "Non-uniform changes in MRI measurements of the thigh muscles following two hamstring strengthening exercises" (27(3): 574–581, 2013). We would also like to thank the authors of the Letter to the Editor for their interest in this study and their commitment to scientific advancement. We feel that they raised some excellent points, which will stimulate ongoing discussions and research in the field of hamstring biomechanics and training. We will now respond to the authors' concerns.

The first of the authors' points of contention is our inference that sites of damage are reflective of sites of preferential activation. The authors correctly mention that transient increases in T2 are reflective of activation, are seen following all types of contractions (concentric, isometric, and eccentric), are primarily because of metabolic stress induced osmotic shifts, and are short-lived and dissipate within approximately 45 minutes after exercise. They also correctly mention that delayed increases in T2 are reflective of damage, are seen after eccentric exercise alone, are primarily because of damage-induced muscle oedema, and can persist for days or even weeks.

Based on this information, it is reasonable for the authors to conclude that the mechanisms causing transient T2 increases are different than the mechanisms causing delayed T2 increases and that the transient increases are more because of muscle activation, whereas the delayed increases are more because of strain-related muscle damage. We concede that we should have been more cautious in our vocabulary and elaborated on this topic.

However, when focusing on the exercises used in the study, Kubota et al (1,2) have found that the regions of muscles that show the highest transient T2 increases also show the highest delayed T2 increases during the eccentric prone leg curl. Specifically, the semitendinosus muscle (43.6%) showed a significantly higher change in the T2 value immediately after exercise than biceps femoris (short and long head) (9.3%) and semimembranosus (7%) (1). In the same way, the semitendinosus is the only muscle that is damaged up to 48 hour after the exercise execution (2). We are not aware of any published study showing transient and delayed T2 increases related to lunge exercise.

The second point that the authors raised was in regard to the classification of the forward lunge exercise as an eccentric hamstrings exercise. To the common observer, it would make sense that the hamstrings would not change their length much in a lunge because of the simultaneous lengthening at the hip and shortening at the knee during the eccentric phase and shortening at the hip and lengthening at the knee during the concentric phase. However, the study mentioned by the authors of "The Letter to the Editor" did indeed show that around 20% of the lunge exercise involved a lengthening component for the hamstrings (3). This could very well be sufficient to induce structural adaptations. Moreover, the methodology used to measure hamstrings musculotendinous length in the study mentioned by the authors of "The Letter of the Editor" has been called into question as it could very well underestimate length changes compared with other methods (4). This is especially important considering that, with the same methodology, the hamstrings have been shown to be at greater muscle lengths when contracted in the 90°/90° hip/knee position (bottom lunge position) compared with anatomical position (5).

It may therefore be overly simplistic to suggest that the length changes in the fibers are negligible. We feel that our study supports the notion that unique fascicle length changes occur in proximal and distal muscle regions of the hamstrings during the lunge exercise. The fascicle lengths of the biceps femoris long head have been shown to lengthen to a greater degree with sagittal plane hip motion compared with knee motion (5–7), and the fascicles of the biceps femoris long head indeed possess greater proximal lengths than distal lengths in vivo (8). Whether eccentric hip dominant hamstrings exercise induces these adaptations remains to be shown in the literature.

We have 2 more points of contention for the authors of "The Letter to the Editor." The authors mentioned that they would expect no damage in the biceps femoris from the lunge exercise because of the fact that they do not feel that it is an eccentric hamstrings exercise. We would like to point out that concentric exercise can indeed produce fiber damage and signal intensity changes (9); 1 study showed approximately half the fiber damage as eccentric exercise, and another study showed similar creatine kinase increases following work-matched concentric and eccentric exercises (10,11).

With regards to your statistical concerns, first there is no universally accepted approach for dealing with the problem of multiple comparisons. In fact, we could cite a multitude of researchers/studies that have not adjusted for multiple comparisons. One possibility involving the correction of the p value is with Bonferroni correction or the Benjamini-Hochberg procedure; however, some

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statisticians believe such corrections could lead to a high rate of false negatives (12).

Irrespective of the previous comment, we state that a more powerful analysis was developed to determine significant differences between sections. As it is described in the Methods section: "To account for the main effects a two factor (time × section), repeated measures ANOVA with post hoc contrasts was used." In addition to these results and for the peace of mind of the reader, we have calculated effect sizes (ES) to clarify some of the changes (13). The purpose of this analysis was to compare the magnitude of the change in signal intensity from pre to postexercise (lunge) at different muscle sections (from 5 to 11) of the biceps femoris (BIC). We found high to moderate effects proximally (in BIC5: ES = 0.76; and BIC6: ES = 0.54) compared with small and trivial effects distally (BIC9: ES = 0.12; BIC10: ES = 0.19; and BIC11: ES = 0.27).

Again, we thank the authors for their commitment to the scientific process. We feel that they have raised some great points, and we realize in retrospect that we should have elaborated on some of these topics.

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References

1. Kubota, J, Ono, T, Araki, M, Tawara, N, Torii, S, Okuwaki, T, and Fukubayashi, T. Relationship between the MRI and EMG measurements. *Int J Sports Med* 30: 533–537, 2009.
2. Kubota, J, Ono, T, Araki, M, Torii, S, Okuwaki, T, and Fukubayashi, T. Non-uniform changes in magnetic resonance measurements of the semitendinosus muscle following intensive eccentric exercise. *Eur J Appl Physiol* 101: 713–720, 2007.
3. Jönhagen, S, Halvorsen, K, and Benoit, D. Muscle activation and length changes during two lunge exercises: Implications for rehabilitation. *Scand J Med Sci Sports* 19: 561–568, 2009.
4. van der Krogt, MM, Doorenbosch, CA, and Harlaar, J. Validation of hamstrings musculoskeletal modeling by calculating peak hamstrings length at different hip angles. *J Biomech* 41: 1022–1028, 2008.
5. Hawkins, D and Hull, M. A method for determining lower extremity muscle tendon lengths during flexion/extension movements. *J Biomech* 23: 487–494, 1990.
6. Visser, J, Hoogkamer, J, Bobbert, M, and Huijing, P. Length and moment arm of human leg muscles as a function of knee and hip-joint angles. *Eur J Appl Physiol Occup Physiol* 61, 453–460, 1990.
7. Chleboun, GS, France, AR, Crill, MT, Braddock, HK, and Howell, JN. In vivo measurement of fascicle length and pennation angle of the human biceps femoris muscle. *Cells Tissues Organs* 169: 401–409, 2001.
8. Kellis, E, Galanis, N, Natsis, K, and Kapetanos, G. Muscle architecture variations along the human semitendinosus and biceps femoris (long head) length. *J Electromyogr Kinesiol* 20: 1237–1243, 2010.
9. Shellock, FG, Fukunaga, TF, Mink, JH, and Edgerton, VR. Acute effects of exercise on MR imaging of skeletal muscle: Concentric vs. eccentric actions. *AJR Am J Roentgenol* 156: 765–768, 1991.
10. Clarkson, PM, Byrnes, WC, McCormick, KM, Turcotte, LP, and White, JS. Muscle soreness and serum creatine kinase activity following isometric, eccentric, and concentric exercise. *Int J Sports Med* 7: 152–155, 1986.
11. Gibala, MJ, MacDougall, JD, Tarnopolsky, MA, Stauber, WT, and Elorriaga, A. Changes in human skeletal muscle ultrastructure and force production after acute resistance exercise. *J Appl Physiol* 78: 702–708, 1995.
12. Saville, DJ. Multiple comparison procedures: The practical solution. *Am Stat* 44: 174–180, 1990.
13. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, 1988. p. 567.