BIOMECHANICAL CONSEQUENCES OF RUNNING WITH DEEP CORE MUSCLE WEAKNESS

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INTRODUCTION

In recent years core stability has become a popular topic among sports medicine clinicians, physically active people in general, and especially runners. Its popularity is stimulated largely due to the theory that insufficient core stability during physical activity may lead to movements that are less efficient and ultimately lead to injury [1].

The deep core muscles (quadratus lumborum (QL), psoas major (PS), multifidus (MF), and the deep fascicles of the erector spinae (deep ES)) are believed to be vital to postural control and stabilization of the lumbar spine [2]. One mechanism by which core musculature contributes to stability of the lumbopelvic-hip complex is through axial compressive spinal loads [3]. Inadequate compressive spinal loads may not stabilize the spine sufficiently, but excessive loads have been associated with low back pain (LBP), so a balance between these extremes is necessary to minimize injury.

The role of the deep core muscles during everyday tasks and especially during running is not well understood. The purpose of this study was to use simulations to identify compensation strategies for weakness of the deep core musculature and changes in spinal compressive loads during running.

METHODS

Three subjects (2 female, height = 1.71 ± 0.03 m, mass = 63.16 ± 4.73 kg) from a healthy population provided informed consent participated in a previously published IRB-approved study [4]. We collected marker trajectory and ground reaction force data during continuous overground running at a self-selected comfortable speed in our motion analysis laboratory. Multiple subject-specific kinematically-driven simulations were generated for each subject using OpenSim. A full-body generic musculoskeletal model we developed from three previously built OpenSim models was scaled to match each subject’s anthropometry. This model is comprised of 21 segments, 30 degrees-of-freedom, and 324 musculotendon actuators. The trunk contains the 8 major muscle groups of the lumbar spine (rectus abdominis (RA) external and internal obliques (EO and IO), latissimus dorsi (LD), erector spinae (ES)) which is comprised of the superficial (sf) and deep longissimus thoracis (LT) and iliocostalis lumborum (IL), QL, MF, and PS), each of which is modeled as multiple fascicles. The spine consists of the sacrum, five lumbar vertebrae, and lumped thoracic and cervical vertebrae. After solving for the model’s joint angles and moments that best matched the experimental marker data, static optimization (SO) was performed to resolve the net joint moments into individual muscle forces at each time instant. Lastly, a joint reaction analysis was performed to calculate internal joint loads acting on each of the lumbar vertebrae.

A baseline simulation of running was created for each subject. Additional simulations were then created for each subject at progressively higher levels of deep core muscle weakness. The QL, MF, PS, and deep ES were weakened individually and simultaneously from 20-100% weakness in increments of 20%. Trunk muscle force production and axial compressive loads on the lumbar vertebrae were recorded at each level of muscle weakness. When individual muscles were weakened, compensating muscle forces were recorded at the point of the weakened muscle’s baseline peak force production. When the four deep core muscles were weakened simultaneously, peak muscle force was reported for compensating muscles.

RESULTS AND DISCUSSION

Compensations for individual and total deep core muscle weakness are shown in Table 1. Based on...
the level of required compensations, these results suggest the deep ES may be most crucial to maintain running kinematics, followed by the Psoas, MF, and QL, respectively. Of the weakened deep core muscles, the deep ES produced the highest muscle forces during running and therefore, the largest compensations were necessary, while the contrary was true with the QL. When all deep core muscles were weak, muscles that compensated were those that also attached to the lumbar vertebrae.

For individual muscle weakness, axial spinal loading was most affected when the deep ES was weakened. Axial compressive loads on all lumbar vertebrae decreased when the QL and PS were each individually weakened. In all other cases loading on the higher lumbar vertebrae increased and loading on the lower lumbar vertebrae decreased with muscle weakness. Increased axial spinal loads could be detrimental since elevated loads are believed to be associated with LBP, while decreased loads similarly may also signify a loss of spinal stability. Changes observed in these loads with our simulations suggest that all deep core muscles contribute to maintaining stability of the spine, and the MF and deep ES fascicles may be most influential in minimizing elevation of normal (baseline) axial compressive loads.

One limitation of this study is that running kinematics were forced to stay the same after the muscle weakness was implemented. It is likely some people may choose to alter kinematics rather than muscle forces in order to compensate for muscle weakness. Also, the deep core muscles could successfully be weakened 100% individually and together in the model. This may have occurred because the model has an abundant number of trunk muscle fascicles that are able to compensate and SO is a robust, frame-by-frame solver. It is unknown if this phenomenon is entirely realistic clinically, however these simulations will still provide valuable insight into compensations and consequences of core muscle weakness.

REFERENCES

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Table 1. Primary compensators and altered spinal loading that result when the specified muscles are weakened 100%. Color coding indicates the level of % increase in compensating muscle forces. blue=0-9.9%, orange=10-24.9%, red=25-49.9%, dark red=50+%.