MUSCULAR CONTRIBUTIONS TO VERTEBRAL JOINT ROTATIONAL STIFFNESS DURING THE STANDARD PUSHUP

Samuel J. Howarth, Tyson A.C. Beach, Jack P. Callaghan

Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada
E-mail: sjhowart@uwaterloo.ca

INTRODUCTION

Recent trends are promoting the use of pushups as an exercise to challenge the core trunk musculature. Evidence from Freeman et al (2006) supports this idea provided that one aims to maintain a neutral spine posture while performing the exercise.

The purpose of this study was to quantify the relative contributions of each muscle group surrounding the spine to vertebral joint rotational stiffness (VJRS) during the pushup exercise using an approach developed by Potvin and Brown (2005). It was hypothesized that the abdominal musculature would contribute more to VJRS than the posterior musculature of the lumbar spine during a standard pushup.

METHODS

Eleven males (age: 27.4 ± 2.8 years, height: 1.83 ± 0.06 m, weight: 89.4 ± 11.0 kg) volunteered to participate in the study. All participants signed an informed consent document that had been approved by the University of Waterloo's Office of Research Ethics.

All participants performed a series of 8 pushups at a cadence of one full pushup (down and up cycle) every 2 seconds.

Electromyographic (EMG) recordings were obtained bilaterally from: erector spinae at the level of the T9, L3 and L5; rectus abdominis; external abdominal obliques; internal abdominal obliques; and latissimus dorsi (Cholewicki and McGill 1996). Upper body kinematics were recorded with four position sensors (Optotrak Certus System, NDI, Waterloo, ON, Canada) and hand loads were recorded with two tri-axial force transducers (MC3A-X-500, AMTI, Watertown, MA, USA). The EMG and force transducer data were sampled at a rate of 2048 Hz while the joint kinematics were obtained at a rate of 64 Hz.

EMG signals of the aforementioned muscles collected during the pushup were full wave rectified, lowpass filtered with a 2nd order Butterworth digital filter with a cutoff frequency of 2.5 Hz, and normalized as a percentage of previously recorded maximal voluntary isometric contractions. Individual fascicle force and stiffness for a set of 118 muscle fascicles surrounding the lumbar spine were determined from a Distribution Moment model that used the normalized EMG signals as its inputs. Individual fascicle force and stiffness were multiplied by a participant-specific adjustment that accounted for differences in maximum muscle stress and muscle physiological cross sectional area. Muscular contributions to VJRS were determined using a combination of the adjusted fascicle force, stiffness and geometry (Potvin & Brown, 2005). The proportion of total VJRS for each muscle group was obtained using the methods described by Brown & Potvin (2007).

Differences between the relative contributions of individual muscle groups to VJRS were analyzed using a single factor analysis of variance and Tukey's *post hoc* analyses. The level of statistical significance was set at $p = 0.05$ for rejecting the null hypothesis in all analyses.

RESULTS AND DISCUSSION

The VJRS contributions are dominated by the abdominal musculature. In particular, rectus abdominis contributed the most to VJRS about the flexion/extension axis at each lumbar vertebral joint while external oblique and internal oblique contributed the most to VJRS about the lateral bend and axial twist axes respectively at all lumbar vertebral joints with the exception of L5-S1 (Figure 1).

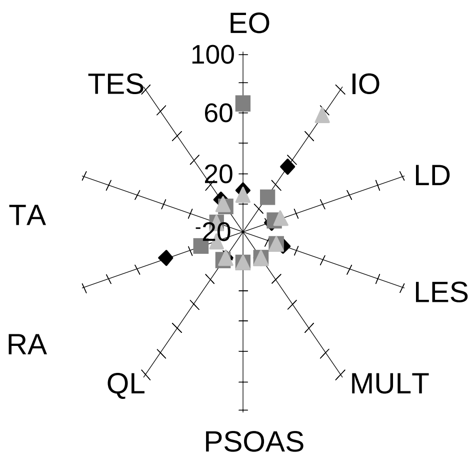

Figure 1: Proportion of VJRS for each muscle group about the flexion/extension (♦), lateral bend (■) and axial twist (▲) axes.

At L5-S1, external oblique and internal oblique contributed the most to VJRS about the axial twist and lateral bend axes respectively.

Due to the novelty of the stiffness analysis, there is no data for direct comparison of muscle contributions to VJRS during other exercises. However, the motor patterns described by Beach et al (submitted), and the neutral lumbar spine posture is similar to the motor patterns and spine posture of other abdominal training exercises (Kavcic et al, 2004), suggesting that VJRS contributions of the abdominal muscles in this study would be consistent with the VJRS outputs for other abdominal exercises. Analysis of EMG magnitudes during exercises does not include muscle morphology which is included in analyses of VJRS. Thus, VJRS can provide direct insight into the muscular stiffening mechanism during exercises.

SUMMARY/CONCLUSIONS

The pushup can be considered a challenge to the abdominal musculature. The orientation of the rectus abdominis, internal oblique, and external oblique muscles allows for these muscles to dominate the muscular contributions to VJRS about the flexion/extension, lateral bend, and axial twist axes within the lumbar spine.

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