An unstable support surface is not a sufficient condition for increases in muscle activity during rehabilitation exercise

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Introduction

Resistance training is commonly recognized as an essential component to a rehabilitative treatment plan. Modifications of various exercises are made on the belief that different types of support surfaces and joint positions can influence muscle recruitment levels. One modification to traditional exercises is the addition of an unstable support surface (exercise balls, wobble boards, foam padding) under the assumption that this addition will result in an increase in the neuromuscular activation of the involved muscles. Anecdotally, clinicians and rehabilitation specialists are often heard to state that performing an exercise on an unstable surface causes "the little muscles to work harder to stabilize the joints." It is a prevalent assumption that the mere addition of unstable surfaces to simple tasks (e.g. sitting on an exercise) ball transforms these simple tasks into exercises which stress the "core" musculature (trunk and pelvis muscles).

The exercise biomechanics literature investigating modifications to surface stability has focused on the trunk muscle's response during resistance exercise. Increases in the amplitude of the EMG signal with the addition of an unstable support surface compared with a stable support surface have been documented during curl up exercises (external oblique),[1] trunk bridging exercises (rectus abdominis and external oblique)[2–4] and traditional strength training exercises including the squat, shoulder press, dumbbell press (lower abdominal stabilizers, upper and lower erector spinae).[5,6] However, not every exercise modified with the addition of an unstable support surface results in a consistent response across participants[3] nor in an increase in the trunk muscle's EMG amplitude.[3–6] This lack of an increase has been exemplified in research discounting the common belief and assumption that replacing a chair with an exercise ball results in increases in muscle activation.[7] Two studies have disproved this contention demonstrating no difference in trunk muscle activation levels between sitting on a Swiss ball and sitting on a chair.[8,9] There has even been evidence of decreases in the amplitude of the abdominal muscles during trunk extension resistance exercises when performed on a stability ball compared with floor.[10] The lack of increase in muscle activation levels and inconsistent responses across participants during certain exercises and amongst specific muscles with the addition of unstable surfaces suggest other factors (weight lifted, speed of movement, participant personal characteristics) may influence muscle recruitment to a greater extent than surface instability.

What is lost in the conclusions of the preceding research investigating support surface instability is the large variability in the inter-individual responses to these exercises. While the mean activity levels for specific exercises from some studies may suggest that the unstable support surface increases muscle activation levels there are often individuals who do not respond in this manner. The same can be seen when there is no change in the group mean activation level between surface conditions (stable versus labile) yet a specific individual may be greatly affected by changes in surface stability. Thus, individual factors may play a large role in how muscle activation levels are affected by the addition of an unstable surface. The intention of this proof of principle commentary is to illustrate through individual case studies, contrasted with a population mean, examples where muscle

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activation levels show unexpected responses to the exercise demands when performed on unstable/labile surfaces versus stable surfaces. Sample case studies have been extracted from our published research out of the CMCC Biomechanics Laboratory from research conducted over the past 4 years.

Proof of Principle

Example #1: Triceps and Rectus Abdominis EMG during Push Up Exercises

The following 4 cases are individual muscle responses taken from a previously published paper.[11] Male participants between the ages of 23 and 28 were recruited for this study. Individuals were excluded if they had a current or history of shoulder, upper limb or spine injury within the previous 6 months or had previous surgery on the respective areas. Individuals were required to perform push up exercises with their hands either on a 65 cm diameter Swiss ball or with their hands supported on an exercise bench of a similar height. The surface electromyographic activity was collected from the triceps, pectoralis major, latissimus dorsi, rectus abdominis and external oblique muscles. The authors found no statistically significant difference in average muscle activity between surfaces (bench vs. ball) in the pectoralis major, latissimus dorsi and external oblique muscles. The triceps and rectus abominis average activation level was increased when push ups were performed on a Swiss ball compared with an exercise bench. The average triceps muscle activity (expressed as a percentage of a maximum voluntary contraction – MVC) increased from 22.2 % MVC (standard deviation = 8.8) on an exercise bench to 43.1 % MVC (SD = 17.3) when push ups were performed on a Swiss ball. Figure 1 presents an example of an increase in triceps EMG during three push ups when performed on an exercise bench (average activity = 11.4% MVC) and on a Swiss ball (36.6 % MVC). The rectus abominis group average activity increased from 13.46 %MVC (SD = 5.42) on an exercise bench to 22.63 %MVC (SD = 8.64) when performed on a Swiss ball. Figure 2 presents a typical increase in rectus abdominis activation level for one subject during three push ups performed on an exercise bench (average activity = 16.6 %MVC) versus a Swiss ball (average activity = 22.2%MVC). However, not all individual responded in a manner similar to the mean.

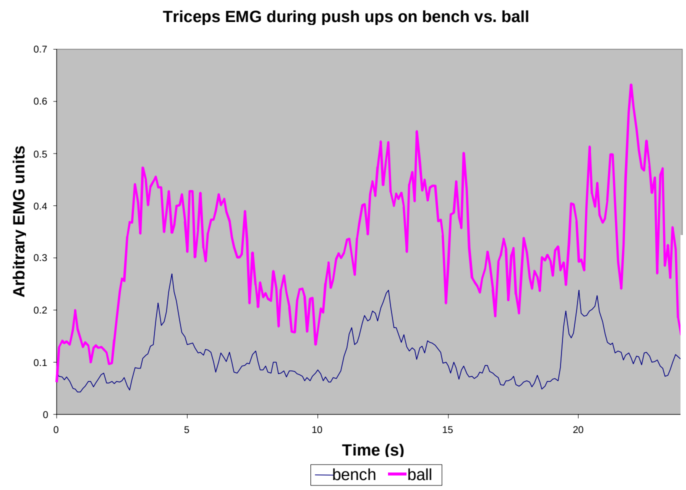

Figure 1 *Triceps EMG increase during push up exercises on ball vs. bench.*

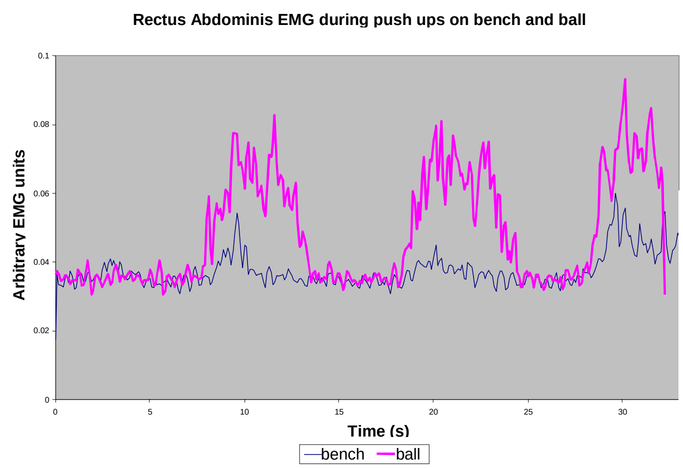

Figure 2 *Rectus Abdominis EMG increase during push up exercises on ball vs. bench.*

Instability is not a sufficient condition for increases in muscle activity

Looking at the group mean activation levels and the statistical analysis the reader (and author) is led to conclude that the instability of the Swiss ball causes increases in muscle activation of the triceps and rectus abdominis muscle. While this can be supported as a general trend it is important to note that not every individual responds in the same manner to changes in surface stability. Figure 3 presents the EMG profiles of the triceps muscle for an in-

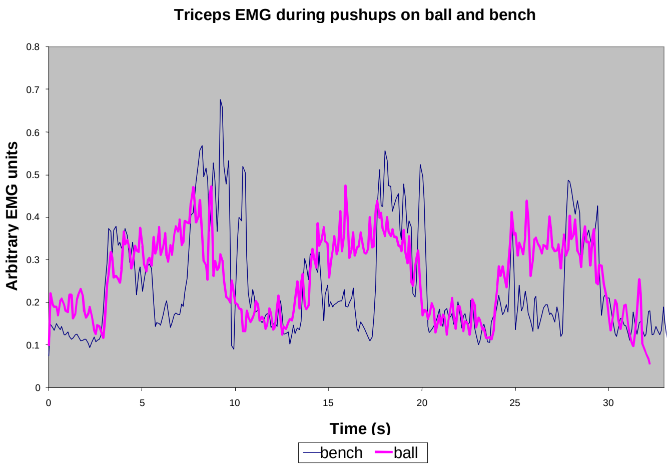

Figure 3 *Triceps EMG demonstrates similar average activation levels across different surfaces (ball versus bench).*

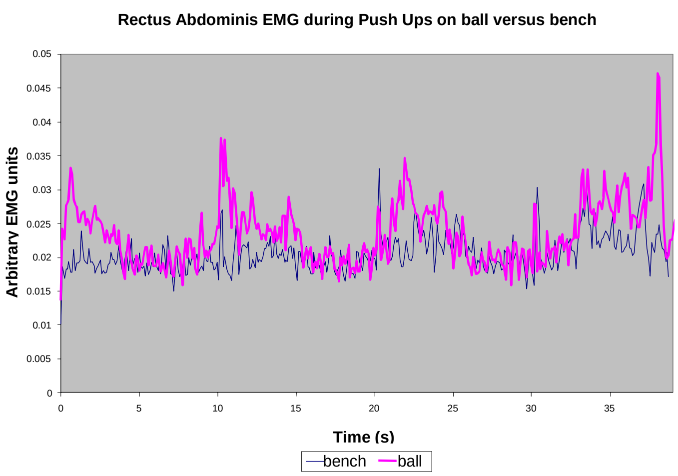

Figure 4 *Rectus Abdominis EMG uninfluenced by surface stability.*

dividual that showed a minimal change in average muscle activation when a Swiss ball replaced an exercise bench during push up exercises. This individual's activation levels were 17.1 % and 18.4% MVC on the exercise bench and Swiss ball, respectively. A similar non-effect can be seen in the rectus abominis muscle (Figure 4) for an individual whose average muscle activation levels were 12.5% MVC and 13.75 % MVC for push ups when performed on a bench and Swiss ball, respectively. These two examples illustrate that just as not all muscles increase their activation levels during push ups when performed on an unstable surface (e.g. pectoralis major, external oblique) not all individuals respond in a similar manner to changes in surface stability even in instances where the group mean is significantly different between surface conditions. The reason for this outlier is unknown. An interesting finding in Figure 3 is the difference in the shape of muscle activation profiles between the two surfaces. The triceps activity on the bench presents a bimodal shape corresponding to the eccentric (smaller hump) and concentric (larger hump) phase of the muscle action. These two humps do not exist during the push ups on the ball. This finding was not a common occurrence across participants and again suggests the variable response across individuals. During the previous study, an attempt was made to visually ensure the same performance of the push up exercise (positions, speed of movement, height of support surfaces) however, this was not vigorously controlled with elaborate means to ensure identical kinematics. The rationale for this lack of elaborate control was an attempt to mimic how these exercises would be instituted in a clinical environment since these controls would not occur in practice. These outliers are relevant to the evidenced based clinician because it suggests that merely adding an unstable surface to an exercise may not result in greater stress placed on a muscle for all individuals even when biomechanical research may support that belief. Clinicians wishing to incorporate progressive resistance training principles into their strength and conditioning programs should therefore consider other means to increase the stress on the musculoskeletal system. A method of increasing the load on the musculoskeletal system during a push up would be to stagger the position of the arms (one forward and one backward) and modify the speed of movement.[12]

Example #2: Individual responses are highly variable

The following two cases are individual responses taken from an unpublished CMCC resident research[13] pilot project (n = 10) which quantified trunk muscle activity during the performance of various exercises (squats, lunges, biceps curls, shoulder presses, triceps extensions) performed on a labile domed surface (similar to the BOSU Balance Trainer™) and while standing on the

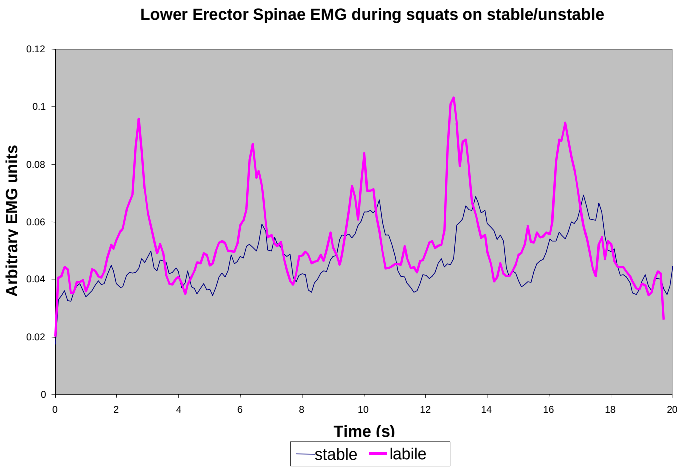

Figure 5 *Lower Erector Spinae EMG increases when performed on a labile surface.*

Figure 6 *Lower Erector Spinae EMG increases when performed on the ground.*

ground. We found that for all trunk muscles studied (upper and lower erector spinae, rectus abdominis, external oblique and lower abdominal stabilizers) there were no differences in muscle activation levels between surface conditions. However, individuals within the group responded in highly variable and different manners. The following two cases will present how two different individuals respond in different manners to modifications of surface stability during the double legged squat exercise. The group average EMG level for the lower erector spinae was 16.98 %MVC (SD = 9.13) and 15.8 % MVC (SD = 9.67) for the squat exercise when performed on the ground and the labile surface, respectively.

Figure 5 demonstrates a marked increase in average muscle activity in the lower erector spinae during squats when performed on the labile surface (26.58 %MVC) versus the ground (19.6 %MVC). Conversely, a different individual demonstrated a similar change in muscle activity yet in the opposite direction. Figure 6 depicts lower erector spinae muscle during the squat on the ground (19.4% MVC) and on the labile surface (14.7 %MVC).

What is of interest in these findings is that the mean activation level shows no response to changes in surface stability. Yet individuals may be highly influenced. For this particular exercise (squat) and muscle (lower erector spinae) studied half of participants increased their muscle activity while half showed decreases.

Conclusion and clinical relevance

The examples presented here and the findings from the literature suggest that the mere addition of a labile surface is not a sufficient condition to achieve increases in muscle activity for all muscles and for all individuals. Individuals can present markedly varied responses and can respond in a manner significantly different from the mean. This is relevant to the rehabilitation professional when designing conditioning programs that attempt to create overload conditions over time. Merely adding labile surfaces may not increase the load on the neuromuscular system for specific patients. An argument can even be made that adding Swiss balls to certain exercises (wall squats[14] and spine extensor exercises[7]) decreases the stress on the musculature due to decreases in muscle activation following the incorporation of a Swiss ball.

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