Endurance of the Quadratus Lumborum Muscles in Response to Vibration of Dorsal Upper Cervical Muscles

ABSTRACT

Background: The quadratus lumborum muscle is involved in spinal stability, posture and pelvic biomechanics. Reflexes dependent on muscle spindle afferents from the upper cervical spine have an effect on posture. The purpose of this study was to determine if there is a correlation between vibration of the dorsal muscles of the upper cervical spine and endurance times of the quadratus lumborum (QL) muscles.

Methods: In a private practice setting, a single female subject was randomly tested for right and left QL fatigue times during: 1) no intervention, 2) right side upper cervical muscle vibration (80 Hertz, 2 mm amplitude), and 3) right side brachioradialis vibration.

Results: There was a significant reduction of QL endurance times (t-test) during cervical vibration, both right ($p<0.0001$) and left ($p<0.0001$). There was also a significant difference between the right and left QL endurance times ($p<0.007$). Vibration of the brachioradialis had no effect on QL endurance times.

Conclusion: Using vibration to unilaterally stimulate muscle spindle afferents in the dorsal upper cervical spine, this study found a significant change in the endurance times of the quadratus lumborum muscles.

Keywords: Upper cervical, vibration, quadratus lumborum, endurance

BACKGROUND

It has been known since the work of Magnus in the 1920s (1) that movement of the upper cervical spine has an influence on global posture. Movement of the head invokes both vestibular and cervical postural reflexes. Initially, the cervical effects on posture were thought to be driven by afferents from the upper cervical joints (2). Further investigation revealed the source of the postural reflexes to be from intrinsic cervical muscles, and more specifically, their spindles (3-5). Muscle spindle afferents, especially the primary (Ia) afferents, can be stimulated by mechanical vibration at approximately 60-100 hertz, with an amplitude of 0.5 - 3 mm (6). Using muscle-tendon vibration, the effects of upper cervical spine muscle afferents on global posture have been documented (6-10).

An important, if enigmatic, spinal muscle, the quadratus lumborum (QL), has not been examined in relation to stimulus from the upper cervical spine. The action of the QL is to extend and laterally flex the spine (11-13), and with the spine stable, to raise the pelvic crest (12,13). The QL has also been shown to be important for stabilizing the spine under load (14). Travell & Simons write that the QL, "is one of the most commonly overlooked muscular sources of low back pain…", and provide an extensive review of the QL muscle (13). A clinical test has been developed to examine the QL for the characteristic of endurance (11).

Given the known effect of upper cervical spine muscle afferents on posture, and the role of the quadratus lumborum in spinal and pelvic posture and stability, an hypothesis was generated that there may be a connection between stimulus to the upper cervical spine and QL function. A null hypothesis, that there is no correlation between muscle spindle stimulus in the upper cervical spine and QL function, was tested.

METHODS

Tests were done, with written consent, on a single healthy female volunteer, age 19, with no history of back or neck pain. The tests were done over a six month period only at times when the subject was rested. A hand held vibrator (Hitachi Corp.), 80 Hertz, amplitude of 2 mm, was used for muscle spindle stimulation. Preliminary testing for maximal effect on QL endurance settled on a vibration time of 30 seconds while the subject was sitting comfortably.

The QL endurance test was performed by having the subject lie on her side supported by the arm with the forearm at 90° to the torso (Fig 1). The upper leg is crossed in front of the lower, placing that foot in front of the lower leg foot. Using the arm as a supportive column and pivoting at the ankles, the knee and pelvis are raised off the floor/table and held in a straight line as long as possible (Fig 2). The test subject was instructed to hold this position as long as possible while the examiner recorded the time. This test causes an estimated 54% maximal voluntary contraction of the QL ipsilateral to the support arm side (14). McGill et al. have found the QL fatiguing test to be reliable, and the results have been found to be consistent with the endurance times of the more documented and validated Biering-Sorensen test (11).

During a session, the test to be performed – baseline, or vibration (cervical or control) QL endurance times - was determined by a random draw. Only one test was done per session, only one session per day.

The tests performed were as follows:

1. Basic QL fatigue test, done on either the right or left side (randomly assigned initially, the opposite side was done the next time). This test was done 10 times each for the right and left QL to establish a baseline value.
2. The area of the cervical spine vibrated was in the upper cervical triangle between the base of the occiput and the base of the C2 spinous, always on the right side. After a 30 second vibration stimulus in the sitting position, the subject then moved to the QL test position. The vibration of the upper cervical triangle was continued during the QL test. The support side of the QL test was initially assigned randomly, with the opposite side done the next test. The test was performed 10 times; 5 testing the right QL, and 5 the left.
3. Vibration of the right brachioradialis, using the above protocol, was done as a control. The test was performed 10 times; 5 testing the right QL, and 5 the left.

RESULTS and DISCUSSION

The subject had mean baseline endurance times of 46.6 (± 3.53) seconds for the right QL, and 44.1 (± 3.03) seconds for the left. A t-test comparing the right and left QL fatigue times demonstrated no difference ($p=0.11$). The baseline QL fatigue test results, both right and left, were compared (t-test) with 10 other subjects, both genders, aged 18-24, from another study (15) (Table 1). The baseline values of the test subject were not significantly different than the others in her age cohort.

Vibration in the right upper cervical triangle resulted in a significant (t-test) decrease in both the Rt ($p<0.0001$) and Lt ($p<0.0001$) QL endurance times relative to the baseline times (Table 2). The difference in the QL endurance times during cervical vibration from the baseline values of the Rt QL (25.6 sec) was nearly twice that of the Lt (12.7 sec). This difference was statistically significant (t-test) ($p=0.007$). Vibration of the right brachioradialis did not have a significant effect on the Rt ($p=.161$) or Lt ($p=.128$) QL endurance times over baseline.

Vibration of the muscles in the right upper cervical triangle had a significant effect on the endurance time of both the right and left quadratus lumborum muscles. These results appear to demonstrate a correlation between the stimulation of muscle spindle afferents in the upper cervical spine and the endurance of the quadratus lumborum muscles.

There are several limitations in this study. The first is that the force exerted by the vibrator was not mechanically controlled, which may have an effect on spindle afferent discharge (16). The subject was asked to grade the application pressure and comment if the pressure felt too light or heavy compared to previous applications. Other studies of vibration of the cervical spine also did not quantify the application pressure (6-10). Given the tremendous difference found in QL endurance during upper cervical vibration, it seems unlikely that the application pressure would change these findings. Regardless, quantification of the applied pressure would improve the protocol. The second limitation was that the examiner, who recorded the fatigue times, was present during the drawing and checking the record for which test was to be performed. This could have introduced bias during the timing of the QL fatigue tests. A third possible source of error is that the vibration in the upper cervical triangle may have stimulated vestibular afferents which were responsible for the changes in QL endurance. However, one study notes unpublished data in which cervical vibration towards the mastoid – closer to the skull and vestibular apparatus and away from the posterior cervical muscles - did not result in EMG or postural changes (17). Fourth, only the right side of the upper cervical spine was vibrated and the QL reactions recorded. To be complete, both sides should be tested with vibration and data collected. In this case, the number of individual sessions (n=40) represented a significant commitment for the test subject. Lastly, these tests were done on only one subject. A larger population would be necessary to firmly establish the correlation between stimulation of the muscles in the upper cervical spine and the endurance of the quadratus lumborum.

Two unexpected events occurred during testing. In preliminary experimentation to determine how long the pre-endurance test vibration should be applied, the subject was blindfolded. The idea was to remove visual postural references, perhaps to enhance the effect of muscle vibration on postural control. However, this caused what the subject described as a considerably uncomfortable off-balance feeling accompanied with nausea, so the blindfold was discontinued. Second, during a QL endurance test, the subject was observed laterally flexing her head to the right, lengthening and presumably stimulating the left neck muscle spindles. As a point of speculation, this may have been an unconscious attempt to equalize the spindle input from right to left. That particular test result was eliminated, the subject was instructed to keep her head perpendicular to her shoulders during the fatigue tests, and was monitored for the remainder of the procedures.

Biguer et al. (18) point out that vibration of the upper cervical spine stimulates a variety of muscles which have different actions and effects on posture. In this experimental setting, there is presumably increased muscle spindle output without actual movement of the head. In the absence of a vestibular sense of movement, the postural control system is thought to interpret the increased spindle output as a movement of the body below the neck. (19). One of the muscles vibrated, the splenius capitis, extends the head. Upper cervical head extensors, when vibrated with the head neutral, give the postural control centers the impression that the trunk is moving forward under the head (Fig 3). Such a trunk movement would elongate the cervical extensor muscles and stimulate their muscle spindle afferents. Automatic postural control for this movement would be to inhibit the extensors and facilitate the flexors (20). Flexor stimulation from posterior cervical vibration has been found to cause forward sway in the upright subject (10) and would explain the quadratus lumborum (a spinal extensor) inhibition found in this study.

Vibration in the upper cervical triangle also could stimulate muscles involved in head rotation and lateral flexion, such as the rectus capitis posterior major. Vibration of these muscles gives postural control centers the impression that the body is moving laterally relative to the head (Fig 4). In the case of right upper cervical triangle vibration as done in this study, the impression would be that the trunk was moving to the left, stretching the right side cervical muscles and activating their muscle spindles. To correct for this postural attitude, the lateral flexors on the right, such as the quadratus lumborum, would be inhibited and the left lateral flexors facilitated. This automatic postural reaction causes swaying to the left in the standing subject (10) and would explain the inhibition of the right QL noted on the endurance tests in this study.

Upper cervical vibration on the right would cause the left QL to be inhibited due to the perception of head-body flexion. The QL on the right would be doubly inhibited due to both the perception of head-body flexion *and* left lateral flexion (Fig 5). This could explain the difference in the endurance times between the right and left QL's shown in this study, with the right QL endurance times being significantly depressed over the left. If this is the case, a similar test using vibration on the left upper cervical spine should result in significantly increased inhibition of the left QL over the right.

Joint dysfunction has long been thought to involve muscle spindle afferents (21). There is some indirect evidence that this is the case (22-24). Joint dysfunction with abnormal muscle spindle afferent input in the upper cervical spine could affect postural control, causing facilitation or inhibition of trunk and limb muscles. This study suggests the quadratus lumborum muscles could be involved. Abnormal, asymmetrical activation of the quadratus lumborum has been associated with back pain (25). Facilitation of the quadratus lumborum due to upper cervical joint dysfunction may be one way by which lower back pain has responded to upper cervical manipulation (26-29). Such an upper cervical-low back connection may also explain the co-morbidities of cervical and low back pain found in subjects with back pain (30,31).

A recent study found the side of supine leg length alignment asymmetry (the "short leg") to be correlated with the side of decreased quadratus lumborum endurance (19). The establishment of an upper cervical–quadratus lumborum connection, as suggested by the correlation seen in this study, provides a biologically plausible rationale for the phenomenon of the functional "short leg" to be associated with, and used as a test for, upper cervical joint dysfunction. Further study into the relationship between joint dysfunction of the upper cervical spine, postural muscle function and the unloaded leg length alignment check is recommended.

CONCLUSION

This single subject study found a correlation between vibration of the dorsal muscles in the upper cervical spine and a significant change in the endurance times of the quadratus lumborum muscles.

COMPETING INTERESTS

None

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REFERENCES

1. Magnus R. **Some results of studies in the physiology of posture.** *Lancet* 1926;211:585-8.
2. McCouch GP, Deering ID, Ling TH. **Location of receptors for tonic neck reflexes.** *J Neurophysiol* 1951;14:191-195.
3. Richmond FJR, Bakker DA. **Anatomical organization and sensory receptor content of soft tissues surrounding upper cervical vertebrae in the cat.** *Journal of Neurophysiology* 1982;48(1):49-61.
4. Proske U, Schaible H-G, Schmidt RF. **Joint Receptors and Kinaesthesia.** *Exp Brain Res* 1988;72:219-224.
5. Bakker DA, Richmond FJR. **Muscle spindle complexes in muscles around upper cervical vertebrae in the cat.** *J Neurophysiol* 1982;48(1):62-74.
6. Roll J-P, Vedel J-P, Roll R. **Eye, head and skeletal muscle spindle feedback in the elaboration of body references.** *Progress in Brain Research* 1989;80:113-123.
7. Rossi A, Rossi B, Santarcangelo E. **Influences of neck vibration on lower limb extensor muscles in man.** *Arch Ital Biol* 1985;123(4):241-253.
8. Lund S. **Postural effects of neck muscle vibration in man.** *Experientia* 1980;36:1398.
9. Karnath H-O, Sievering D, Fetter M. **The interactive contribution of neck muscle proprioception and vestibular stimulation to subjective "straight ahead" orientation in man.** *Exp Brain Res* 1994;101:140-6.
10. Smetanin BN, Popov KY, Shlykov VY. **Postural responses to vibrostimulation of the neck muscle propioceptors in man.** *Neurophysiology* 1993;25(2):86-92.
11. McGill SM, Childs A, Liebenson C. **Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database.** *Arch Phys Med Rehabil* 1999;80:941-944.
12. Andersson EA, Oddsson LI, Grundstrom H, Nilsson J, Thorstensson A. **EMG activities of the quadratus lumborum and erector spinae muscles during flexion-relaxation and other motor tasks.** *Clin Biomech* 1996;11(7):392-400.

13. Travell JG, Simons DG. **Chapter 4, Quadratus Lumborum Muscle.** *Myofascial Pain and Dysfunction. The Trigger Point Manual. The Lower Extremities. Volume 2. 2nd edition.* Williams & Wilkens: Baltimore; 1999:35,35,29,29.
14. McGill S, Juker D, Kropf P. **Appropriately placed surface electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine.** *J Biomechanics* 1996;29(11):1503-1507.
15. Knutson G, Owens E. **Erector and quadratus lumborum muscle endurance tests and supine leg-length alignment asymmetry: An observational study.** *J Manip Physiol Ther* 2005;28(8):575-581.
16. Tokizane T, Murao M, Ogata T, Kondo T. **Electromyographic studies on tonic neck, lumbar and labyrinthine reflexes in normal persons.** *Jap J Physiol* 1951;2:130-146.
17. Cordo P, Gandevia SC, Hales JP, Burke D, Laird G. **Force and displacement-controlled tendon vibration in humans.** *Electroenceph Clin Neurophys* 1993;89:45-53.
18. Andersson G, Magnusson M. **Neck vibration causes short-latency electromyographic activation of lower leg muscles in postural reactions of the standing human.** *Acta Otolaryngol* 2002;122:284-88.
19. Biguer B, Donaldson ML, Hein A, Jeannerod M. **Neck muscle vibration modifies the representation of visual motion and direction in man.** *Brain* 1988;111:1405-1424.
20. Lekhel H, Popov K, Bronstein A, Gresty M. **Postural responses to vibration of neck muscles in patients with uni- and bilateral vestibular loss.** *Gait Posture* 1998;7:228-36.
21. Korr IM. **Proprioceptors and somatic dysfunction.** *JAOA* 1975;638-50.
22. Zhu Y, Haldeman S, Starr A, Seffinger MA, Su-Hwan S. **Paraspinal muscle evoked cerebral potentials in patients with unilateral low back pain.** *Spine* 1993;18(8):1096-1102.
23. Collins KF, Pfleger B. **The neurophysiological evaluation of the subluxation complex: documenting the neurological component with somatosensory evoked potentials.** *Chiropr Res J* 1994;3(1):40-48.

24. Zhu Y, Haldeman S, Hsieh C-Y J, Wu P, Starr A. **Do cerebral potentials to magnetic stimulation of paraspinal muscles reflect changes in palpable muscle spasm, low back pain, and activity scores?** *J Manipulative Physiol Ther* 2000;232(7):458-464.
25. Finneran MT, Mazanec D, Marsolais ME, Marsolais EB, Pease WS. **Large-array surface electromyography in low back pain.** *Spine* 2003;28(13):1447-54.
26. Vaillancourt P, Collins KF. **Case Report: Management of post-surgical low back syndrome with upper cervical adjustment.** *Chiropr Res J* 1993;2(3):1-16.
27. Robinson SS, Collins KF, Grostic JD. **A retrospective study: Patients with chronic low back pain managed with specific upper cervical cervical adjustments.** *Chiropr Res J* 1993;2(4):10-16.
28. Knutson GA. **Rapid elimination of chronic back pain and suspected long term postural distortion with upper cervical vectored manipulation: A novel hypothesis for chronic subluxation/joint dysfunction.** *Chiropr Res J* 1999;VI(2):57-64.
29. Murphy DR, Carr BM, Tyszkowski RJ. **A possible cervical cause of low back pain: pelvic distortion.** *J Bodywork Movement Therapies* 2000 Apr; 4(2): 83-9.
30. Ahern DK, Iezzi A, Hursey K, Follick M. **The co-occurrence of chronic low back pain and headache. Prevalence, neroticism, and treatment outcome.** *Clin J Pain* 1988;4:27-31.
31. Hestbaek L, Leboeuf-Yde C, Kyvik KO, Vach W, Russell MB, Skadhauge L, Svendsen A, Manniche C. **Comorbidity With Low Back Pain: A Cross-sectional Population-Based Survey of 12- to 22-Year-Olds.** *Spine* 2004 Jul 1;29(13):1483-1491.

Figure 1

Preliminary position for a right side quadratus lumborum endurance test.

Figure 2

Active position during a right side quadratus lumborum endurance test.

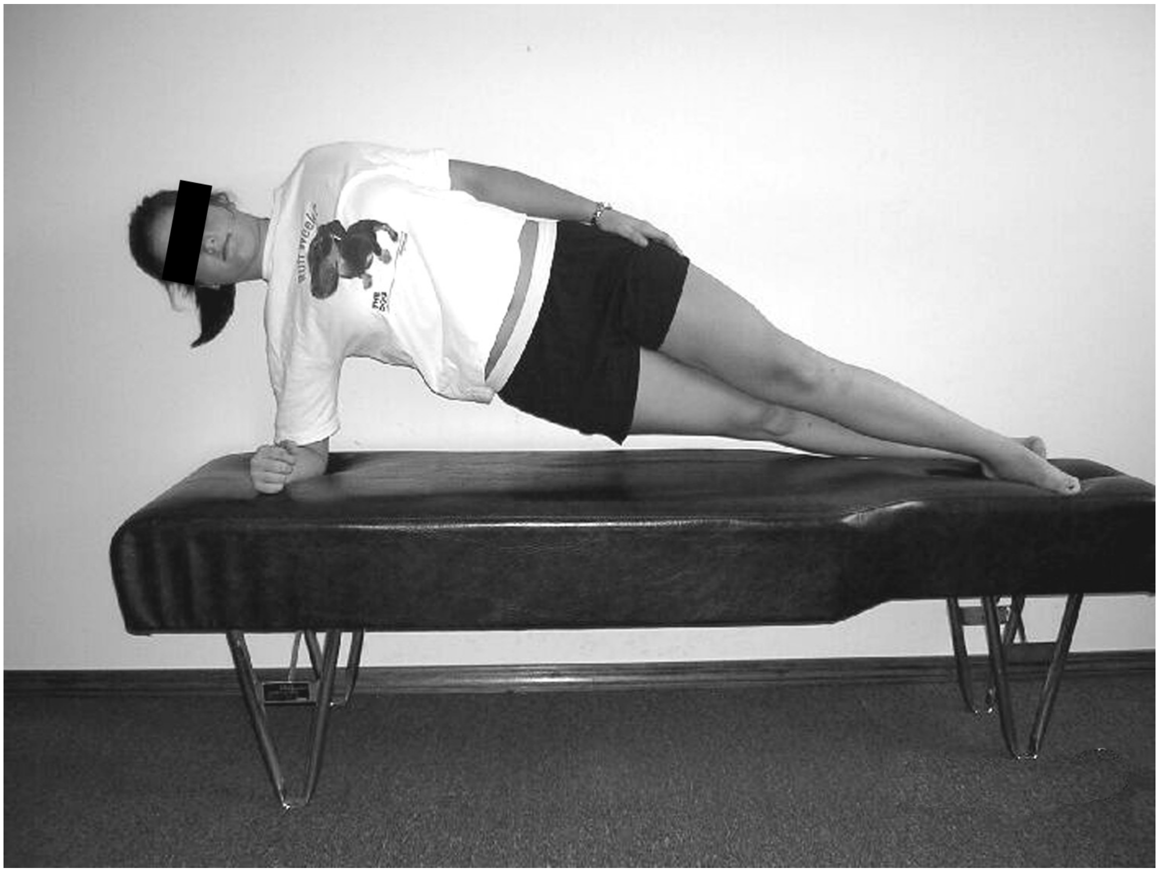


Table 1

Comparison of test subject normal QL endurance with age-related group

QL fatigue times (seconds)	Right QL (SD)	Left QL (SD)	t-test
Test Subject (10 reps, each side)	46.6 (3.53)	44.1 (3.03)	0.11
18-24 yr olds (n=10)	58.2 (29.2)	62.2 (28.8)	0.89
t-test	0.50	0.25	

Table 2

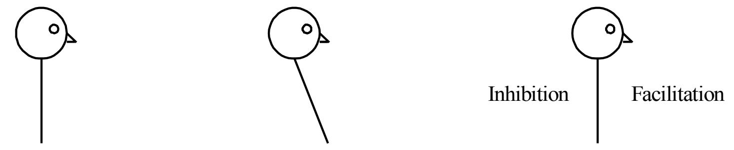
Change in QL endurance times with right side upper cervical vibration

	Baseline (n=10)	Right Cervical Vibration (n=5)	Mean Difference (SE)	95% Conf. Interval	Statistic* (df)	p value
Right QL Mean (SD)	46.6 (3.5)	21.0 (5.9)	25.6 (2.4)	(20.4, 30.8)	$t_{13} = 10.65$	0.0001
Left QL Mean (SD)	44.1 (3.0)	31.4 (2.9)	12.7 (1.6)	(9.2, 16.2)	$t_{13} = 7.76$	0.0001

* Independent samples t-test

Figure 3

Reaction to vibration of right upper cervical extensors.



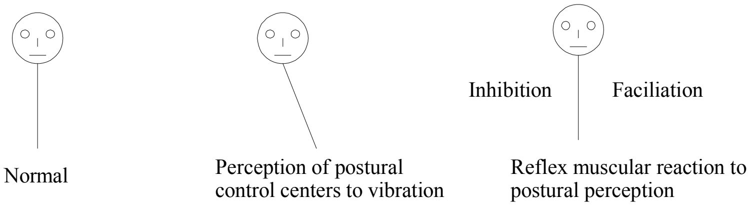
Normal

Perception of postural control centers to vibration

Reflex muscular reaction to postural perception

Figure 4

Reaction to vibration of right upper cervical lateral flexors.



Normal

Perception of postural control centers to vibration

Reflex muscular reaction to postural perception

Figure 5

Combinations of muscular facilitation (F) and inhibition (I) due to vibration in the right upper cervical triangle.