

Observation of Age-related Decline in the Performance of the Transverse Abdominis Muscle

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Abstract

The core abdominal muscles provide support to the low back. One of the principle muscles of this group is the Transverse Abdominis (TrA) but being a deep muscle it is difficult to measure without invasive procedures. As we age skeletal muscle performance declines. The ageing population also suffers from low back pain and it is hypothesised that a decline in core muscle performance may contribute. Some previous investigations have used intramuscular EMG to assess TrA performance but no study has previously looked at the effect of age on the performance of the muscle. Therefore this study compared the time difference (D) of the TrA to rapid abduction of the shoulder joint of old and young adults using non-invasive ultrasound imaging. 18 young adults (18 males, age 27.0yrs \pm 7.0) and 11 older adults (5 males 6 females, age 59.6yrs \pm 4.0) were recruited for this study. The older group were significantly slower than the younger group to engage their TrA in response to the rapid arm abduction ($p = 0.036$). The result adds further evidence to the age-related decline in skeletal muscle performance. Consideration is given to the possible mechanisms responsible for the findings.

Key words

Transverse abdominis, ultrasound imaging, skeletal muscle, ageing

Introduction

The core abdominal muscles including the transverse abdominis (TrA), the internal and external obliques and the multifidus provide support to the low back [1] and poor functioning of this muscle group is linked to low back pain [2]. The TrA in particular has a multifunctional role as it potentially functions as a stabiliser muscle, as well as having a minor role in trunk rotation [3] and respiration [4].

The ability to stabilise the lumbar spine requires that the TrA initiates contraction prior to the application of any force. Such forces typically result from limb loading during locomotion [5] and lifting tasks [6]. Grillner *et al.* [7] reported the engagement of abdominal muscle activity preceded

the foot contact in walking, running and jumping. More recent work has shown that in healthy adults rapid upper limb movement, results in activation of the TrA (and other core muscles) before limb muscles [8] described as a 'feed forward' activity or 'anticipatory contraction' [9].

It is clear then, that in order for the TrA to adequately support the lumbar spine, both speed and coordination of activation are equally important. Poor coordination of core musculature in response to rapid arm movements has been reported in low back pain patients compared to healthy controls [2]. The same authors later reported similar findings in low back pain sufferers compared to healthy controls when asked to perform single leg actions such as flexion, extension and abduction whilst the other limb was weight bearing in stance [10].

Ageing is accompanied by a considerable decline in both muscle mass and performance. Some of this is related to the disuse that often accompanies old age [11], however, there is also a decline in 'muscle quality' (force per cross sectional area; [12]) suggesting other contributing factors. Additionally deficits with age are evident in reductions in the rate of neural activation [13] as well as in peak force and time to achieve peak force [14]. Such age-related deficiencies in muscle activity will affect both speed and coordination of contractions of skeletal muscle [15].

While such decrements have been identified in skeletal muscle under voluntary control, it is not known if activation patterns of involuntary muscles relating to postural control, such as the TrA also change with age. While some authors have used ultrasound imaging to describe the morphology of the core musculature in ageing individuals [16] and changes in morphology during stabilisation [17-19] less is known about the effect of ageing *per se* on the coordinated activation of abdominal muscles.

To the best of our knowledge, no research has been published that compares the contraction characteristics of the TrA in young and ageing adults. It was therefore the purpose of this study to use ultrasound imaging to test for any age-related differences in the activation of the TrA. Given the changes describes in voluntary muscles, we hypothesised that there would be a reduction in the response of the TrA to rapid loading in older relative to younger individuals.

Materials and Methods

18 young adults (18 males, age 27.0 yrs \pm 7.0, body mass 79.46 kg \pm 11.17, height 1.78 m \pm 0.06) were compared against an older group of 11 adults (5 males 6 females, age 59.6 yrs \pm 4.0, body mass 71.14 kg \pm 12.51, height 1.65 m \pm 0.08). All participants signed an informed consent form and were provided with both a written and verbal explanation as to the purpose of the study and the procedures to be followed. In addition, participants completed a medical screening form (PAR-Q) to ensure that participants were healthy and were capable of performing the task. No participant reported any

history of major back injury. All were recruited by advertisement and word of mouth. Ethical approval for the method was granted by the University of Bedfordshire Research Ethics Committee prior to any data being collected.

Test Protocol

Each participant was positioned on a treatment table on their left side with both their left arm and legs being kept as straight as possible. The head was allowed to rest on their uninjured arm and their right arm was resting on the couch in a forward flexed position. A recumbent position was selected as it was felt that it offered the best opportunity to start the procedure with the TrA fully relaxed. The position selected was an adaptation of what has been used previously to image the TrA [20-21], who had previously imaged the TrA from a recumbent position. Participants in those studies were being scanned in a stationary position as well as during relatively slow movements that did not involve any arm movement. The adaptation to a side-lying position was made in this study to allow for rapid abduction of the right arm without affecting the positioning of the probe during the measurement.

Prior to the procedure, the subjects were provided with aerobics-type wrap-around weights to secure to their right wrist. The added resistance helped ensure the contraction of the TrA when the arm was raised. Each participant performed four repetitions of the arm abduction manoeuvre. The data for each repetition was later averaged to generate one overall mean value for each participant (\pm SD). Movement commenced when the tester gave verbal instruction for each repetition. These commands were deliberately issued at random intervals with no set timing pattern so as to prevent anticipatory bracing of the TrA. The participants were requested to abduct their arm away from the couch as quickly as possible. A demonstration of the required technique was provided as was the opportunity to practice first.

Data Acquisition

The ultrasound probe was placed with its long axis in line with the mid-axillary line, 2cm above the superior border of the iliac crest. Any positional changes beyond this were slight and made to optimise the image quality of the target muscle ensuring that the TrA muscle was positioned as horizontal as possible along the display. Ultrasound images were recorded with an ATL HDI 3000CV Ultrasonography device (Advanced Technology Laboratories Inc., Washington, USA) using an ATL L7-4 (38mm) 14 MHz linear array transducer.

Surface EMG (sEMG) was used to determine the activation of the deltoid muscle to indicate arm abduction. sEMG data for the right shoulder and the ultrasound data for the TrA were synchronised and displayed in real-time on the same screen by adapting the systems inbuilt ECG input channel (figure 1). <insert figure 1 near here> Although the device typically detects cardiac electrical activity,

the surface electrodes when attached to the skin overlying the deltoid muscles are equally capable of detecting the electrical activity of the superficial skeletal muscles, as the electrodes are able to detect any common electrical signal, which was displayed by the device in the same way. The electrodes used were round Ag/AgCl 24mm Kendall/ Tyco Arbo ECG electrodes (Henleys Medical, Welwyn Garden City, UK). The skin was prepared with an alcohol swab prior to the electrodes being positioned parallel to the underlying muscle fibres. A disposable razor was available if needed. Anatomically, the electrodes were positioned on the mid-deltoid muscle midway between the deltoid tuberosity and the lateral aspect of the spine of scapula. A 1.8cm gap was left between the centres of the two electrodes. A third, reference, electrode was positioned on the lateral epicondyle of the humerus. No quantification or processing of the EMG signal was required as the onset of muscle activity was the parameter being determined. For determination of EMG onset using the raw signal is generally preferred to applying digital filters as the filters can affect the identification of the onset position itself [22]. It should also be stressed that when synchronising sEMG with ultrasound in this way, it is not possible to process the EMG signal as the electrical trace is a visual display only and has no numerical component. If the sEMG had been set up through a more conventional data logger, synchronicity with the ultrasound images would have been lost.

The time difference (D) between the contraction of the TrA and the initiation of electrical activity of the deltoid was measured separately as a post-hoc technique. The footage was converted from its original analogue format to a digital (.avi) file using a Pinnacle Movie Box Plus™ unit with Pinnacle Studio™ Ultimate 14 software (Pinnacle Systems Ltd., Iver Heath, UK). The footage was then deinterlaced using a Bob Doubler filter from a standard video processing software package (VirtualDub, Web Version 1.9.11, Avery Lee). This doubled the frame rate to 50 frames per second and made the calculation of time to onset more sensitive than the standard recorded PAL format.

D was obtained by determining the onset of the TrA from the M-Mode image of the TrA and then counting the number of frames from this point until the EMG signal showed the onset of deltoid activity (figure 2). <insert figure 2 near here> If the EMG signal commenced following the TrA onset the value was considered positive (+) and if the EMG signal commenced before the TrA onset then the value was considered negative (-). The number of frames between the two events was then multiplied by 0.02 to provide a time value of D measured in seconds. Positive values were achieved when the TrA fired first and were thus considered evidence of a feed-forward anticipatory mechanism. It should be noted though that EMG and ultrasound measure separate events. EMG is a measure of motor unit activity, the physiological response to a motor unit action potential and therefore precedes muscle contraction. Ultrasound imaging, however, is the measure of mechanical tissue motion, and for this to have occurred it would have been preceded by a motor unit action potential. A direct comparison between the two is therefore not possible. However, as an example, if

shoulder EMG and TrA were to occur simultaneously then the action potential to the TrA must have preceded the shoulder EMG signal.

Statistical Analysis

A Mann-Whitney test was performed to test for differences between the two groups with the alpha value set at $p = 0.05$. The non-parametric approach was decided upon due to the lack of sensitivity in the frame-counting method (effectively an ordinal level of measurement) and the increased likelihood of this method producing a greater number of tied scores as a result. Statistical analysis was performed using SPSS version 19 (IBM SPSS, Armonk, NY).

Results

The group mean value of D was -0.026 s (± 0.030 ; CV = -1.15) for the older group and -0.006 s (± 0.025 ; CV = -4.17) for the younger group. These results are presented below in figure 3.

<insert figure 3 near here>

The results of the Mann-Whitney test showed a significant difference between the value of D for the two groups ($p = 0.036$). This means that on average, the older group were significantly slower to recruit the TrA muscle than the younger group in response to limb loading. For clarity in this analysis, positive values represent increasing feed-forward, anticipatory, activity and negative values represent a shift towards late activation and low back vulnerability.

A separate Mann-Whitney test was also performed between the male and female participants in the older group to check whether sex could have been a confounding factor for the difference observed between old and young. The result of the test was not significant ($p = 0.126$). This result provides support that the statistically significant difference between older and younger adults was due to age and was not due to the fact that the older group was a mix of male and female participants.

Discussion

The result of this experiment is important as it shows an age-related decline in the activation rate of the TrA muscle to upper limb loading. The magnitude of difference between the two groups seen here was not as great as the significant difference reported by Hodges & Richardson [2] when comparing TrA onset to rapid arm movement in low back pain and healthy adults. In comparing TrA onset between low back pain sufferers against non-sufferers the authors had reported a mean difference between the groups of 61.17 ms against a mean difference of 20 ms observed between the groups in this study. In the study by Hodges & Richardson [2] the low back pain group were the slower of the two to respond to protect spinal loading whereas in this study the older group were the slower of the two to respond to spinal loading. From this it is possible to state that low back pain is

likely to have a greater influence on TrA activation than the ageing process, although no study as yet is believed to have compared the two directly.

Given the acknowledged role that the muscle has in stabilising the lumbar spine, any delay in the response of this muscle to limb loading could increase spinal instability and susceptibility to low back pain. This is especially true given that the TrA movement detected by ultrasound is preceded by a neuromuscular signal. Allowing a suggested 0.02 s for this electromechanical (EM) delay [23] would indicate that younger participants initiated their TrA prior to arm movement and therefore elicited a feed-forward response whereas the older participants, on average, did not. Irrespective of the actual value allowed for the EM delay, support for the lumbar spine would only occur once movement occurred, therefore the slower value of D from the older group would result in a slower TrA stabilising response than in the younger group. This risk is due to the increased likelihood of the stabilising contractions occurring at the same time or later than spinal loading.

It has been suggested that having the subjects move their arm from an outstretched position could have led to a delay in the activation of the TrA [24]. The author cited publications [1 and 25] which demonstrate a delay in TrA response when subjects were induced with low back pain artificially by intramuscular saline injection. Lederman [24] suggested that having the arm outstretched could invoke a pain-avoiding reflexive action and that this caused a delay in TrA activation in those studies. The possibility that this has happened in this study cannot be discounted, however, it should be noted that no one from either group reported any history of major back injury. Additionally if the position of the arm did necessitate an alternative bracing strategy to perform the task, then this would have been the same for both younger and older groups and therefore does not explain the difference reported here.

The result adds to evidence for age-related deteriorations in muscle performance such as the reduction in peak muscle and time to peak force [14]. Rapid muscle activation requires the contractile apparatus to function effectively and there are, of course, likely to be multiple factors responsible for the slower TrA onset (D) seen in the older subjects. These include age-related changes to the extracellular matrix such as increased volume [26] and increased stiffness [27] as well as the number of crosslinks in the matrix itself [28]. Myogenic factors should also be considered as likely contributors to the results as ageing is typically associated with up-regulation of negative markers of muscle differentiation as well as down-regulation of positive markers of differentiation. TNF- α [29-30] and IL6 [30] have also been shown to be elevated in elderly skeletal muscle. The presence of these agents has been directly linked to reduced muscle mass and strength in the elderly [30]. Recently, a human biopsy study of young and old muscle tissue isolated satellite cells and reported reduced expression of RAGE in the older tissue [31] indicative of reduced differentiation capacity in the older tissue. In the

same study, the expression of S100B, a negative regulator of differentiation [32], was shown to increase in the older muscle tissue.

In addition, factors present in the blood could also contribute to the result found here. This was suggested as the reason for improved regenerative potential in the skeletal muscle of aged rats when cross-grafted into young hosts [33] as well as when old and young mice surgically shared a circulation [34].

Factors higher up the motor unit such as the motor neuron and neuromuscular junction could contribute to the findings. Age-related changes have been observed at the neuromuscular junction by Courtney & Steinbach [35] who reported reductions in the density of acetylcholine receptors in rat muscles, as well as the number of motor neurons which has been reported to reduce by age 60 to as much as 50% of a younger person [36].

Conclusions

This study has shown an age-related decline in the activation of the Transverse Abdominis muscle to upper limb loading. Using ultrasound imaging to measure deep muscles such as the TrA in this way is preferable to intramuscular EMG as it is a non-invasive procedure with no known risks associated with its use. There are likely multiple physiological adaptations that occur with age that could contribute to these findings.

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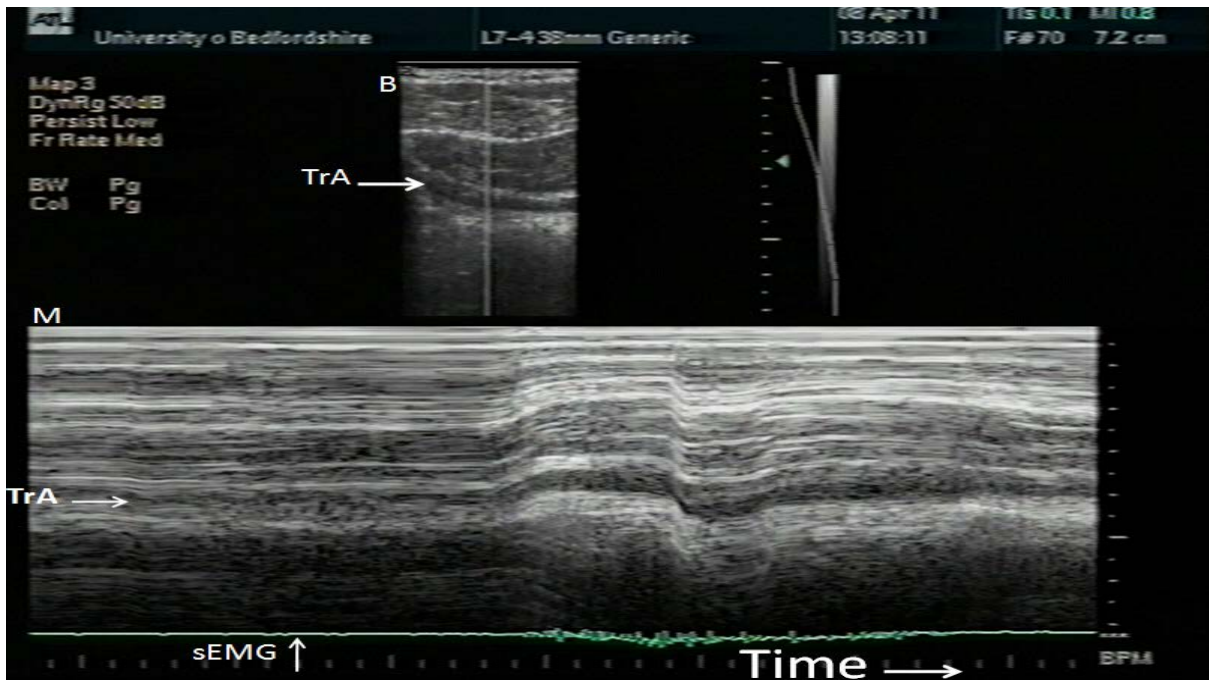


Figure 1. M-mode ultrasound image of TrA (M) taken from data from the vertical line of the B-mode image (B). The M-mode image underneath can be seen with a disruption at the mid-point resulting from muscle contraction. This contraction was initiated by rapid shoulder abduction as recorded by sEMG (green line).

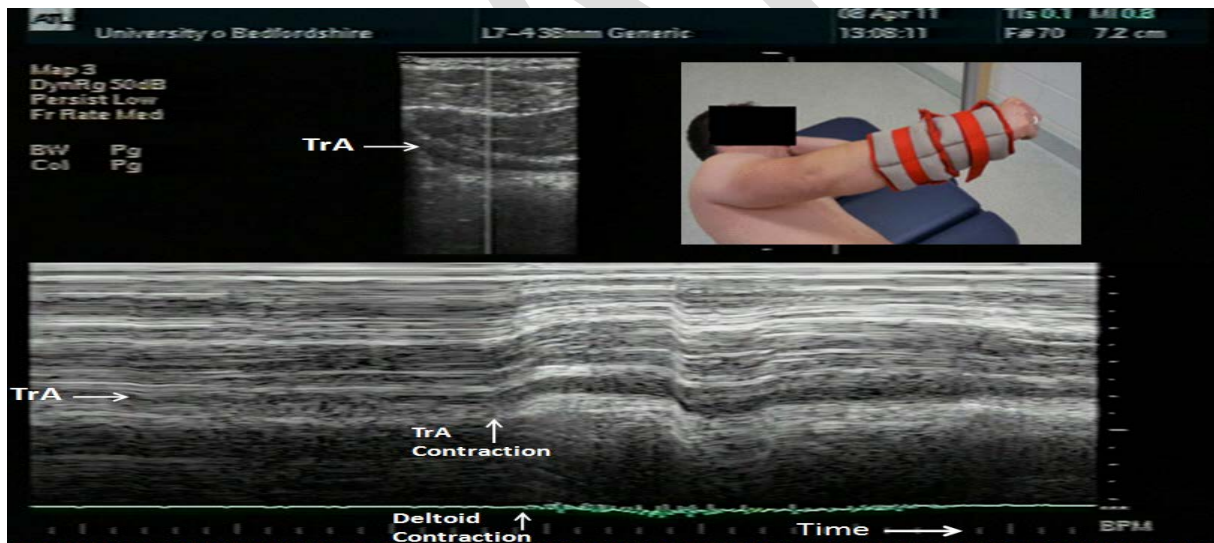


Figure 2. M Mode image taken of the contraction of the TrA in response to resisted arm abduction. The point of contraction for the TrA is indicated on the main graphic whereas the point of deltoid contraction is indicated on the green line underneath with a red arrow. The time difference between the two events is then measured.

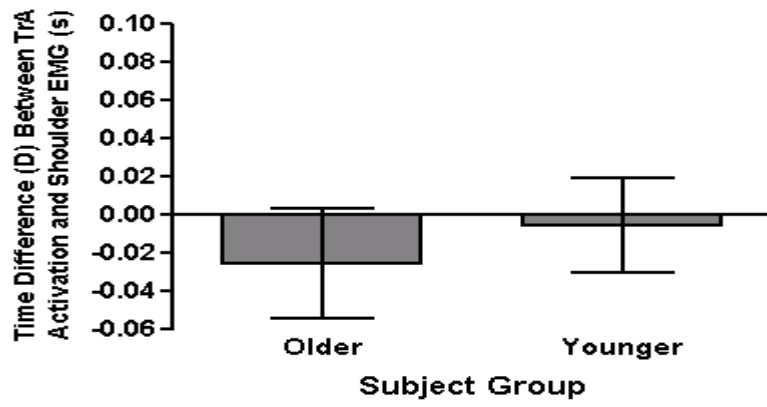


Figure 3. The mean (\pm SD) time difference (D) between TrA activation and shoulder EMG for older and younger participants.