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Transversus abdominis and multifidus asymmetry in runners measured by MRI: a cross-sectional study

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ABSTRACT

Objective The transversus abdominis muscle (TrA) is active during running as a secondary respiratory muscle and acts, together with the multifidus, as trunk stabiliser. The purpose of this study was to determine size and symmetry of TrA and multifidus muscles at rest and with contraction in endurance runners without low back pain.

Design Cross-sectional study.

Setting A medical imaging centre in Melbourne, Australia.

Participants Thirty middle-aged (43years±7) endurance-trained male (n=18) and female (n=12) runners without current or history of low back pain.

Outcome measures MRI at rest and with the core engaged. The TrA and multifidus muscles were measured for thickness and length (TrA) and anteroposterior and mediolateral thickness (multifidus). Muscle activation was extrapolated from rest to contraction and compared with the same and contralateral side. Paired t-tests were performed to compare sides and contraction status.

Results Left and right TrA and multifidus demonstrated similar parameters at rest ($p>0.05$). However, with contraction, the right TrA and multifidus (in mediolateral direction) were 9.2% ($p=0.038$) and 42% ($p<0.001$) thicker, respectively, than their counterparts on the left. There was no TrA thickness side difference with contraction in left-handed participants ($p=0.985$). When stratified by sex, the contracted TrA on the right side remained 8.4% thicker, but it was no longer statistically significant ($p=0.134$). The side difference with contraction of the TrA became less with increasing training age.

Conclusions Right-handed long-term runners without low back pain exhibit a greater right side core muscle activation when performing an isometric contraction. This activation preference diminishes with increasing training age.

Key messages

Strengths and limitations of this study

- High-quality MR images of the transversus abdominis and multifidus muscles were used for data collection.
- Muscle morphology of both core muscles was obtained at all lumbar levels.
- Unexpected right-side core muscle activation in runners without low back pain was found.
- No dynamic muscle activity data (electromyography [EMG]) were collected.

What are the new findings?

- Right-handed endurance runners activate their core muscles on the right side significantly more than on their left side.
- This activation imbalance was found in endurance runners without low back pain.
- There was no side-to-side difference in left-handed endurance runners.

How might it impact on clinical practice in the future?

- Right-handed endurance runners might benefit from neuromuscular retraining or strengthening of the left-sided core muscles even in the absence of low back pain.
- Novice right-handed endurance runners should be assessed for their running style and given preventive core exercises (this activation preference diminishes with increasing training load).

INTRODUCTION

In the USA, running is the most common moderate-vigorous physical activity in adults, with 13% of the nation reporting regular participation.[1] However, this is substantially lower than the 72% of high school students regularly undertaking this activity in the USA.[1] Given the potential health benefits associated with running, such as improved cardiovascular function[2] and improved intervertebral disc morphological profiles,[3] there is a need to facilitate long-term participation into adulthood, which may in part reduce due to health-related issues. One potential barrier to long-term running is the development of low back pain.

Low back pain (LBP) is a multifaceted condition, with a range of previously proposed nociceptive drivers.[4] From a tissue perspective, the structure and function of the transversus abdominis (TrA) and lumbar multifidus (MF) muscles are commonly associated with low back pain.[5 6] The TrA is the deepest abdominal muscle with a horizontal fibre orientation. It arises from the iliac crest, the inner surface of the lower six costal cartilages and the thoracolumbar fascia and inserts into the linea alba.[7] When it contracts concentrically, it tensions the abdominal fascia anteriorly and the thoracolumbar fascia posteriorly.[8] This decreases the cross-sectional area (CSA) of the trunk,[8] increases intra-abdominal pressure[7] and thus enhances spinal stability. The TrA is activated during restful breathing and forced expiration,[9 10] becoming more active as walking and running speed increase.[11] The lumbar MF muscle originates on the spinous process, mammillary process and superior articular process and inserts into the facet capsule and mammillary process two to three levels further caudal.[12] Its action is ipsilateral side bending and contralateral rotation when contracted unilaterally and extension of the spine when contracted bilaterally. In concert with the TrA, it stiffens the spine. The MF and TrA are part of the 'core muscles'.[13] The core is commonly viewed as a muscular cylindrical structure that is made up of the abdominals anteriorly, MF and other paraspinals as well as the gluteals posteriorly, the diaphragm cranially and the pelvic floor and hip girdle musculature caudally.[14]

The runner uses the TrA for two important tasks: as breathing muscle and as spine stabiliser. Spine stabilisation becomes necessary because of the pelvis' movement in all three cardinal planes during running.[15] For example, the pelvis is rotated in the transverse plane in order to lengthen the runner's stride. As a consequence of this pelvic rotation and to enable the runner to face forward, the trunk has to counter rotate with every step. The TrA and MF control the pelvis and spine against these rotational torques.[16 17] The pelvis also moves in the frontal[18] and sagittal[19] planes during locomotion. In addition, spine stabilisation is necessary to keep the ground reaction forces associated with running within an optimal range.[20]

Several sports activities have been shown to produce asymmetric TrA and MF muscles, mostly because of their unilateral or rotational activity requirements. However, an association between side asymmetry and LBP is not consistent. For example, Gray *et al*[21] found that symmetry of abdominal muscle morphology was associated with LBP in cricket fast bowlers but not asymmetry, and McGregor *et al*[22] found no side asymmetry in oarsmen, with and without LBP.

Running, however, is a repetitive and seemingly symmetric activity, consisting of reciprocal and alternating steps that should use core muscles equally on both sides. Every runner, men and women, exhibit their personal and unique running style that is based on differing step length, cadence and kinematics.[23 24] Leg length side differences and other orthopaedic and neurological factors also contribute to variances in running style.

Although understanding characteristics of core muscles in runners seems to be important, there are currently no studies assessing size, activation and symmetry of the TrA and MF muscles.

This study was undertaken to assess size, activation and symmetry, per lumbar level, of the TrA and MF muscles in runners without LBP. The findings will help to identify or rule out a potential risk factor that may in part explain why adults are biologically less likely to run compared with younger individuals. We hypothesised that runners without LBP have right to left symmetrical core muscles at rest and with contraction as a consequence of the repetitive, recurring, reciprocal, symmetrical movements performed during running.

METHODS

Patient and public involvement

We did not involve patients or the public in our work.

This was a cross-sectional study conducted from September 2017 to December 2017 at a medical imaging centre in Melbourne, Australia.

Endurance-trained male and female runners aged 33–55 years (43 year±7) were included in the study. This age group reflects the relationship between age and muscle mass, with the lower limit representing peak muscle mass and upper limit signifying the point of accelerated loss.[25] Inclusion criteria included participation in at least one half-marathon (approximately 21 km) distance run in the past year and trained at least twice a week for running for the last 1.5 years or greater. Exclusion criteria included: (1) regular training for other sports more than 1 day per week within the last year, (2) current or history of shoulder, thoracic, neck or lumbar spine pain for which treatment was sought ('treatment' was defined as having seen a physiotherapist, chiropractor, osteopath or medical doctor for the condition), (3) known scoliosis or osteoporosis, (4) unable to communicate in English and (5) inability to receive MRI (eg, metal or electrical implants, claustrophobia or possible pregnancy).

Volunteers were screened for exclusion criteria, and the study was explained to eligible participants. After signing the informed consent form, the participants filled out intake forms for demographic data and were scheduled for their MRI sessions.

MRI, image processing and analysis

The reliability[26] of the outcome measure is excellent, with an intraclass correlation coefficient $(\mathrm{ICC})_{2,1}$ of 0.90 for TrA length (SE of the measurement (SEM) 6.0 mm), 0.84 for TrA thickness (SEM 0.4 mm), 0.97 for MF anteroposterior (AP) thickness (SEM 0.5 mm) and 0.93 for MF mediolateral (ML) thickness (SEM 0.6 mm). These reliability measures were assessed on two repeated scans at rest (breath hold only) in all 30 participants. The coefficient of variation for abdominal muscle area segmentation using MRI has been found to be 0.025,[27] which is considered excellent.[28] The two conditions were in a supine position, with the participant: (1) at rest with knees slightly flexed over a rolled towel and (2) performing an isometric narrow chest press with arms maintained torso width apart while simultaneous raising the sternum. Resistance bands were used to provide loading through the arms during the exercise condition, with a resistive load at an estimated 20% one-repetition maximum based on the threshold between ‘fair’ and ‘good’ normative values for age, sex and weight.[29] Resistance was determined by digital force gauge (Digital Scale 40 kg, Rogue, Lawnton Queensland, Australia). This exercise was to increase intra-abdominal pressure and stimulate TrA contraction.[30] We chose an arm loading activity to cause automatic activation of the TrA muscle. In line with prior work in upright posture,[31] we wanted to study the automatic activation (ie, without conscious effort such as a ‘draw-in’ activation of the anterolateral abdominals[32]) of the TrA muscle. We argue that this automatic activation more closely relates to central nervous system programming than a synthetic ‘draw-in’ manoeuvre that needs to be learned by participants.[33] Furthermore, for scanning in the MR-bore, it was important that subject did not need to perform gross trunk movements. Rolled towels were placed under the cervical and lumbar spine to ensure that a neutral spine position was maintained throughout the scan. A rolled towel was positioned under the knees to prevent knee straightening. During both conditions, participants were instructed to hold their breath and remain static during scans.

To quantify muscle morphology on a 3T Phillips Ingenia scanner (Amsterdam, The Netherlands), a T2-weighted sequence (thickness: 3 mm; interslice distance: 7 mm; repetition time: 2643 ms; echo time: 60 ms; and field of view: 347×347 mm, 768×768 pixels) was used with spinal coils to collect 14 axial images encompassing the volume of the TrA from the perineum up to the rib cage. Data were exported for offline processing. To ensure blinding of the examiner in order to reduce any possible bias, each subject was assigned a random numeric code (obtained from www.random.org). ImageJ 1.48v (http://rsb.info.nih.gov/ij/) was used to perform all quantitative MRI measures.

Muscle activation is usually measured by thickening of the muscle with contraction.[34 35] In the case of TrA, the muscle’s lateral slide during contraction[36] or muscle shortening, as well as the decrease in CSA of the trunk as seen on MRI[37] is also used. Our methods for obtaining muscle length and thickness are as follows: after tracing around the TrA muscle (figure 1), a custom written ImageJ plugin (‘ROI Analyzer’; https://github.com/tjrantal/RoiAnalyzer and https://sites.google.com/site/daniellbelavy/home/roianalyser) was used to fit a fourth order polynomial to the region of interest, and the curvature from the muscle was removed. Mean muscle length and thickness were obtained in both conditions (at rest and during contraction). Similarly, the MF was traced around (figure 1); peak AP and ML thicknesses were obtained. Data were averaged across all slices for the left and right sides.

Subjects were instructed to avoid exercise on the day of testing. On arriving at the medical imaging facility, participants completed questionnaires detailing their demographics. Height and weight were measured using a portable stadiometer and scales. All scans were performed after midday.

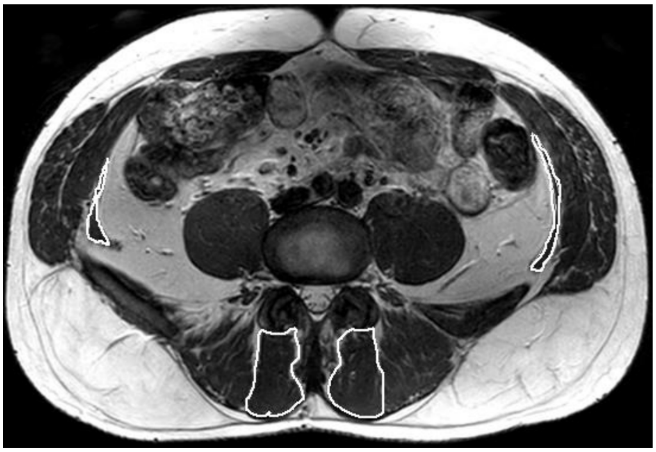

Figure 1 Transversus abdominis and multifidus parameters; tracings of the respective muscles are in white.

Definitions of running parameters used: km of running per week=running distance in km as indicated by the participant on the intake form training load=years of training * km per week training age=years of training at this load running history=years of training, km per week and training load.

Statistical analyses

All analyses were conducted using Stata statistical software V.15. Paired t-tests were used to compare right and left sides for TrA peak length and thickness, and MF peak AP and ML thickness at rest and during contraction for the total sample. Similar comparisons were then performed for all men and all women as well as all right-handed and all left-handed participants. To mitigate the risk of type I errors, all p values within the lumbar level-specific exploratory analysis were adjusted by the false discovery rate method.[38] The strength and direction of associations between differences in TrA and MF muscle variables (left/right) and running history were assessed by Pearson correlation coefficient. An alpha-level of 0.05 was adopted for all statistical tests.

RESULTS

Participant characteristics

Thirty (n=12 women) endurance-trained runners were analysed. Mean (SD) age, height and weight were 43 (7) years, 170.7 (9.0) cm and 67.9 (10.9) kg, respectively. Mean (SD) running distance per week was 39.7 (19.9) km. Mean (SD) training age (years of training at this load) was 11 (10) year. Twenty-five participants were right handed and five were left handed.

Muscle activation for all participants

Left and right side TrA length and thickness, and MF AP and ML thickness at rest and contraction are presented in table 1. Left and right TrA and MF demonstrated

Table 1 Left and right transversus abdominis (TrA) length and thickness, multifidus (MF), anteroposterior (AP) and mediolateral (ML) thickness and MF area for the lumbar spine and per lumbar level during rest and contraction in the total sample (n=30)

	Rest, mm		**Contract, mm**	
Parameter	**Left**	**Right**	**Left**	**Right**
TrA length				
L1–L5	61.1 (17.1)	63.4 (16.5)	**50.5 (17.5)#**	**53.4 (17.8)#**
L1	90.5 (17.4)	92.1 (18.8)	71.0 (14.1)	78.4 (19.8)
L2	85.0 (20.0)	83.0 (18.7)	66.9 (21.2)	71.1 (17.3)
L3	85.6 (21.6)	89.7 (19.4)	68.3 (23.2)	66.3 (20.9)
L4	55.1 (17.3)	55.4 (15.3)	45.7 (3.4)	46.0 (3.6)
L5	36.8 (11.0)	33.1 (8.6)	33.3 (11.9)	28.3 (8.6)
TrA thickness				
L1–L5	8.0 (3.1)	7.9 (1.5)	7.3 (2.0)	**8.0 (1.8)***
L1	22.6 (16.1)	24.0 (19.7)	17.6 (4.9)	15.9 (5.2)
L2	14.9 (13.3)	11.7 (5.6)	8.7 (2.7)	10.2 (3.6)
L3	7.1 (3.8)	6.3 (1.6)	7.2 (1.7)	7.2 (1.5)
L4	5.3 (1.3)	5.5 (1.2)	6.5 (1.7)	6.5 (1.8)
L5	8.7 (4.8)	8.1 (3.7)	8.1 (3.3)	8.6 (3.5)
MF AP thickness				
L1–L5	27.4 (4.1)	27.2 (4.0)	29.0 (4.5)	28.9 (4.3)
L1	18.0 (3.6)	16.9 (3.5)	18.7 (4.5)	18.3 (3.9)
L2	22.6 (4.0)	22.3 (4.4)	23.8 (5.0)	23.2 (5.0)
L3	28.5 (5.1)	28.6 (4.8)	31.7 (6.6)	31.7 (6.4)
L4	32.7 (5.4)	32.7 (5.4)	35.2 (5.9)	35.5 (5.9)
L5	28.5 (5.6)	28.4 (5.9)	29.6 (6.5)	29.8 (6.3)
MF ML thickness				
L1–L5	24.2 (3.1)	24.1 (2.9)	**15.5 (2.2)†**	**23.7 (2.5)‡**
L1	15.2 (13.9)	15.2 (14.1)	15.6 (2.9)	15.8 (2.7)
L2	17.3 (2.8)	17.2 (2.3)	17.4 (2.5)	17.6 (2.5)
L3	21.2 (3.5)	21.2 (3.4)	20.5 (3.5)	21.2 (3.0)
L4	28.3 (4.6)	27.8 (4.4)	27.7 (5.2)	27.0 (4.5)
L5	36.0 (3.7)	35.5 (4.3)	36.2 (4.4)	35.7 (4.9)
MF area				
L1–L5	458.6 (110.6)	449.0 (98.7)	465.3 (118.3)	458.9 (103.5)
L1	166.1 (61.5)	164.1 (63.5)	178.9 (69.5)	178.4 (63.7)
L2	258.3 (83.6)	249.9 (80.8)	278.2 (107.3)	266.9 (95.3)
L3	436.8 (136.5)	425.0 (115.6)	461.1 (161.2)	460.0 (143.5)
L4	621.0 (151.3)	616.8 (139.2)	638.9 (154.4)	635.9 (147.4)
L5	643.7 (137.7)	620.0 (117.0)	664.3 (161.8)	644.1 (122.9)

Data are mean (SD).
*P<0.05.
†P<0.05 compared with rest.
‡P<0.001 when compared with left side (ie, right side minus left side). P values for the lumbar level-specific analyses were adjusted by the false discovery rate method.

similar parameters at rest. With contraction, the left TrA decreased in thickness, while the right one slightly increased, although both did not reach statistical significance (p>0.05). The left MF considerably decreased in ML thickness when contracted (p<0.001), while the right MF's thickness changed only very slightly (p>0.05). During contraction, TrA thickness was 9.2% greater on the right side compared with left (p=0.038; figure 2). MF

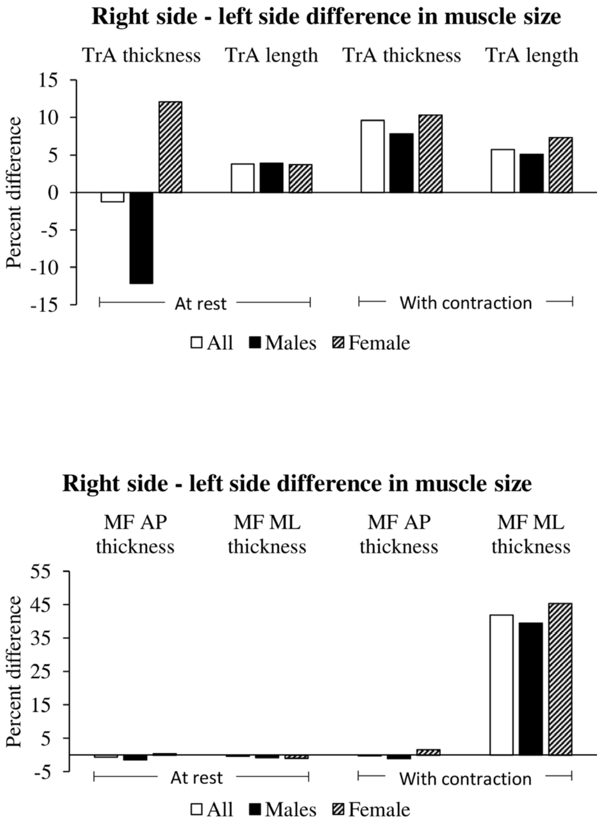

Figure 2 Percent difference between right and left transversus abdominis (TrA) length and thickness and multifidus (MF) anteroposterior (AP) and mediolateral (ML) thickness during rest and contraction in the total sample (n=30), men (n=18) and women (n=12).

ML thickness was 42% greater on the right side compared with the left (p<0.001). The results in table 1 changed when similar comparisons were made between right-handed and left-handed subjects; in left-hand dominant participants, the thickness of the left and right TrA with contraction was no longer different but instead virtually the same (7.6 mm).

Sex

Sex-stratified left and right side TrA length and thickness, and MF AP and ML thickness at rest and contraction are presented in table 2. In men, MF ML thickness was 39% greater on the right side compared with the left (p<0.001) during contraction but not at rest. Moreover, men showed a 12% difference between sides, in favour of greater TrA thickness on the left side; however, this did not reach statistical significance (p=0.142). Women demonstrated 23% greater TrA thickness on the right side compared with left (p=0.018) at rest (figure 2). During contraction, women were observed to have 45% greater right MF ML thickness compared with the left side (p<0.001).

Correlations

Training load had a positive association (r=0.405) with the difference in TrA thickness during rest (p=0.029). In contrast, training load displayed a negative association (r=–0.385) with the difference in TrA thickness during contraction (p=0.039). Similar associations in terms of direction were shown for km of running per week, although only the negative association (r=–0.389), with the difference in TrA thickness during contraction reached significance (p=0.037). For MF parameters, training age had a positive association (r=0.368) with the difference in AP thickness during contraction only (p=0.045).

DISCUSSION

Change in muscle thickness with contraction has been used in other studies[34,35] as an indirect means or indication of muscle activation pattern, that is, a larger change in (increased) thickness signifies greater muscle activation. The findings of our study indicate that long-term

Table 2 Left and right transversus abdominis (TrA) length and thickness and multifidus (MF) anteroposterior (AP) and mediolateral (ML) thickness during rest and contraction in men (n=18) and women (n=12)

	Rest, mm		Contract, mm	
Parameter	**Left**	**Right**	**Left**	**Right**
Men (n=18)				
TrA length	66.7 (17.8)	69.3 (15.2)	57.2 (18.3)	60.1 (18.6)
TrA thickness	9.1 (3.3)	8.0 (1.6)	7.7 (2.1)	8.3 (1.6)
MF AP thickness	29.4 (3.5)	29.0 (3.6)	31.4 (3.7)	31.0 (3.7)
MF ML thickness	25.0 (3.3)	24.8 (2.7)	16.3 (2.2)	**24.3 (2.6)‡**
Women (n=12)				
TrA length	51.9 (11.5)	53.8 (14.2)	39.6 (8.8)	42.5 (9.5)
TrA thickness	6.1 (1.7)	**7.7 (1.6)***	6.8 (1.7)	7.5 (2.1)
MF AP thickness	24.5 (3.0)	24.6 (3.0)	25.5 (3.3)	25.9 (3.3)
MF ML thickness	23.1 (2.3)	22.9 (2.8)	14.3 (1.5)	**22.7 (2.3)‡**

Data are mean(SD).
*P<0.05.
†P<0.001 when compared with left side. All measurements are averaged over all lumbar levels.

runners do not activate their core muscles symmetrically when performing an isometric contraction. That is surprising since running consists of repetitive, seemingly equally reciprocal rotational pelvic and lower back movements that should act with similar torques bilaterally on the muscles of the trunk. Specifically, the right TrA and MF (when ML thickness is measured) are activated significantly more during an isometric contraction, compared with their left-side counterparts.

If we generalise our findings of morphology differences during an isometric contraction to muscle activation during running, we can discuss the results of this study in the context of running mechanics: when the right leg advances, the pelvis rotates to the left and the right arm moves posteriorly, taking the trunk into a right rotation. Thus, there is a stimulus to the right TrA to either eccentrically control pelvic rotation to the left or concentrically facilitate trunk rotation to the right. It is also conceivable that the right lower TrA is involved in the eccentric control of the left pelvic rotation, while the right upper TrA is involved in the concentric trunk rotation to the right. The unilateral activation of the TrA is supported by the findings by Allison *et al*,[39] who found that when the left arm is lifted, there is an advanced initial activation of the right TrA muscle acting as a counter rotary torque.[39] While the same argument can be made for the left TrA during left leg advancement, our findings do not support that claim.

Alternatively, when the left leg advances, the pelvis rotates to the right, the left arm moves posteriorly, taking the trunk into a left rotation. Thus, there is a stimulus to the right MF to either eccentrically control right pelvic rotation or concentrically facilitate left trunk rotation. It is also plausible that the right lower MF is involved in the eccentric control of the pelvic rotation to the right, while the right upper MF is involved in the concentric trunk rotation to the left. The greater activation of the right-sided core muscles leads us to believe that the cyclical trunk rotations performed during running are produced and controlled by mostly the muscles on the right side, with the right TrA controlling pelvic rotation to the left (trunk rotation to the right) and right MF controlling pelvic rotation to the right (trunk rotation to the left).

As a point of interest, while there was no overall TrA length difference between right and left sides, the muscle was shorter at rest and with contraction on the right side at level L5. The only other side difference at a lumbar level was seen for the MF AP thickness, which was noted at level L1. However, these observations no longer persisted after applying the false discovery method to account for type I error in these lumbar level-specific exploratory analyses. There were no other muscle size differences at rest, suggesting that there were no hypertrophic changes of the involved muscles as a whole.

Other studies have investigated TrA muscle side differences in athletes involved in side dominant or rotational sports. For example, Gildea *et al*[40] explored TrA muscle thickness in ballet dancers who usually have the preference to perform pirouettes to the right. Hides *et al*[41] assessed side difference in TrA thickness in fast bowler cricket players. Side asymmetry of the MF has also been investigated in athletes involved in rotational sports. Smyers Evanson *et al*[42] recruited ballroom dancers who are known to assume a rotated posture for most of their training and performances, and McGegor *et al*[22] assessed athletes involved in competitive rowing, which is an asymmetrical activity. No study has assessed TrA and MF muscle symmetry in runners, which is not considered a side dominant sport.

Our study revealed several correlations between core muscle thickness at rest, with contraction and training load. The positive association between training load and difference between right and left side resting TrA thicknesses indicates that the longer one runs, the larger the side difference becomes. In contrast, the negative association between training load and TrA thickness difference with contraction indicates that the longer one runs, the more symmetrically right and left TrA get activated. This suggests that there is a 'functional adaptation' occurring in TrA activation with prolonged running. Specifically, this likely reflects the emphasis on core stability exercise training as a component of traditional resistance exercise training prescribed concurrent to running.[43]

There was a negative correlation in number of km run/week compared with the difference in right-left muscle thickness during contraction. This finding indicates that the longer the running distance, the less side difference there is in muscle thickness when muscles are activated in a controlled isometric contraction in an MRI machine, or, stated differently, there is more right side activation (increase in TrA thickness) or less left side activation (decrease in TrA thickness) in less experienced/trained individuals. There was a positive association between AP MF thickness increase with contraction and training age, also potentially indicating a preferred activation of the right MF compared with the left that becomes more pronounced with increasing years of training.

All muscle measurements were larger in men compared with those in women, confirming results from other studies.[40 44] Gildea *et al* found larger TrA at rest and with contraction in men, even when controlling for subject height.[40] Rho *et al* reported a larger resting TrA in men, but this difference disappeared when the muscle was contracted.[44] Our results showed similar muscle morphology side differences between men and women, with the exception of TrA thickness at rest. In men at rest, the TrA was thicker on the left side, while in women, it was thicker on the right side. Our findings are in contrast to the results by Rho *et al*,[44] who found no side-to-side differences in TrA thickness at rest or with contraction in healthy, low back pain free men and women. There are two major differences between the Rho *et al*'s and our methodology that could be responsible for our diverging findings: the participants in the Rho *et al* study performed an abdominal drawing-in manoeuvre, while ours performed a more functional core muscle contraction.

Our muscle morphology data were collected with MRI, while their data were collected using ultrasound.

In an attempt to explain our unexpected results, we investigated if handedness was associated with muscle thickness, although Springer *et al*[45] found that hand dominance had no impact on TrA activation in 32 healthy participants aged 18–45 years. When our data were stratified for hand dominance, we found that there was no difference in TrA thickness with contraction in left-hand dominant runners. In fact, the thickness of both TrA with contraction was virtually the same (7.6mm). Therefore, it seems that the side difference we found was driven by the right-hand dominant participants.

It is not likely that the differences in core muscle morphology are the result of other habitual unilateral movements performed on a daily basis. We asked the participants about their occupation. The answers ranged from sedentary, such as 'administrator', 'customer service representative', 'medical scientist', 'broker' or 'manager' to more dynamic, such as 'orthopaedic surgeon', 'teacher' and 'running coach'.

Further possible explanations for the right to left side differences at rest and with contraction include previous unilateral training protocols (eg, resistance training), leg length difference, previous injuries and their rehabilitation protocols. We did not measure any of those variables. Additionally, it is possible that running the same route repeatedly and exclusively, the runner could have obtained muscle imbalance from environmental factors, such as running in circles on a track or on the side of a sloped road.

We have to reject our hypothesis that runners without low back pain exhibit right to left symmetrical core muscles at rest and with contraction. Our study showed that asymmetries in core muscles are found in athletes engaged in endurance running, a seemingly symmetrical activity. An asymmetry in core muscles at rest has been associated with low back pain in several studies,[46–49] with the usual finding being that the side of pain demonstrated a smaller MF CSA. Since our study recruited subjects who were pain free, it is not surprising that their MF was symmetrical at rest. The muscle asymmetry found with contraction has to be linked to a mechanism other than pain.

Limitations of this study include the limited generalisability of the results of this study. We measured trunk muscle morphology during an isometric contraction performed in an MRI tube and tried to explain the differences with running mechanics, inferring that isometric muscle contractions performed in supine position and muscle contractions performed during running were similar. Given the rotational, concentric and eccentric characteristics of the actual movements that occur during running, our results can only declare that an isometric contraction in supine position yielded the results described in this study. Our intake form did not include questions on previous unilateral training protocols, leg length discrepancies, previous injuries nor on environmental factors that could impact core muscle imbalance. We only included middle-aged subjects from the Melbourne, Australia area who were asymptomatic and had no history of low back pain. It is not clear if the findings can be generalised to younger and older subjects, to subjects from different geographical regions or to endurance runners who have a history or current low back pain. Lastly, we cannot be sure that a 15% difference in muscle length during contraction is clinically relevant, especially since the participants were free of low back pain.

CONCLUSION

Right-handed long-term runners without low back pain do not activate their core muscles symmetrically during an isometric core contraction and exhibit a greater activation on the right side. This activation preference diminishes with increasing training load. Core muscle asymmetry may not be a potential risk factor that can explain why adults are biologically less likely to run compared with younger individuals.

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