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Internal and External Oblique Muscle Asymmetry in Sprinters and Sprint Hurdlers: A Cross-Sectional Study

Lauren Adams

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Ulrike H. Mitchell, Chair
A. Wayne Johnson
Iain Hunter

Department of Exercise Sciences
Brigham Young University

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ABSTRACT

Internal and External Oblique Muscle Asymmetry in Sprinters and Sprint Hurdlers: A Cross-Sectional Study

Lauren Adams
Department of Exercise Science, BYU
Master of Science

Background: The abdominal muscles are vital in providing core stability for proper function in most activities. There is a correlation between side asymmetry of these muscles and dysfunction. Thus, the purpose of this study was to evaluate and compare trunk muscle morphology and trunk rotational strength between sprinters, a symmetrical sport and sprint hurdlers, an asymmetrical sport. Methods: 21 Trained collegiate sprinters and sprint hurdlers were recruited for the study (12M, 9F), average age (years) 20.2 ± 1.5, height (cm) 176.9±9.1, and weight (kg) 70.6±9.8. Using real-time ultrasound, panoramic images of the internal oblique (IO) and external oblique (EO) were obtained at rest and contracted in a seated position for both right and left sides of the trunk. Results: Average trunk rotation strength to the right was greater among all participants, \( p < 0.001 \). The IO had greater thickness changes than EO for all participants. The IO side asymmetry was significantly different between groups \( p <0.01 \). Conclusion: Sprinters, although involved in a seemingly symmetrical sport, exhibit asymmetrical trunk morphology and rotational strength, while hurdlers, involved in a unilaterally demanding sport, exhibit the expected asymmetry in muscle morphology and trunk rotational strength.

Keywords: asymmetry, internal oblique, external oblique, trunk muscle thickness, panoramic ultrasound, sprinting, hurdling
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I would like to thank Dr. Mitchell for her countless hours of mentoring, and my committee for their help in this project. To the friends I have made in the program, thank you for helping me along the journey. And to my family, thank you for the words of encouragement and support when I needed it most.
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Introduction

Efficiency in athletic function is dependent upon core stability which provides strength as a base for movements in the extremities and balance [1]. Core musculature comprises muscles of the trunk and pelvis. The external oblique (EO), rectus abdominis, latissimus dorsi and superficial erector spinae fibers make up the superficial core muscles and work to generate torque and general core stability. The internal oblique (IO), transversus abdominis, quadratus lumborum, psoas major, multifidus and deep erector spinae fibers make up the deep core muscles and contribute to segmental stabilization[1, 2].

The IO aids in increasing intra-abdominal pressure[3]. When contracted, it helps pull on the thoracolumbar facia creating a rigid compartment, decreasing the cross-sectional area of the trunk, and increasing the intra-abdominal pressure, thus stiffening the spine [3-5]. Recruitment patterns show that stabilizing core musculature are recruited prior to any movement in the extremities [6, 7]. The engagement of core muscles prior to distal segmental movement suggests that the core muscles provide key proximal stability necessary for functional mobility in the extremities.

The level of muscle activation of the different abdominal muscles varies according to the activity performed and the intensity of that activity. At walking speeds the EO and IO are minimally activated[8]. However, as speed increases to a fast running pace, there is distinct activation of these muscles in coordination with an increase in lumbo-pelvic motion[8, 9]. EO also aids in the control of anterior pelvic tilting that occurs with acceleration of the back swing phase in running[5]. Research has shown a significant correlation between an increase in this anterior pelvic tilt and injury, particularly in the hamstrings[9]. Thus, if the EO is weak there
may be a lack of controlling ability of the anterior pelvic tilting occurring during this running phase which may increase the risk of additional injury.

Sprint hurdling, by nature, is an asymmetric sport. Out of the starting block, hurdlers undergo the same motions sprinters do; however, in order to clear the hurdles a forceful unilateral rotation of the trunk must occur which adds additional torque forces. The IO and EO both play a role in forward flexion and counter rotation of the trunk that occurs during take-off. Additionally, studies have shown that the abdominal muscles are bilaterally activated during trunk rotation [10, 11] in order to help stabilize the lumbar spine[12]. This stabilization is especially vital upon the athlete’s landing after clearing the hurdle because it facilitates their balance as they quickly have to return to sprinting formation. Sprint hurdling inherently favors rotation to one side as the athlete uses the same leading leg for each hurdle. A functional between-side muscle asymmetry would therefore be expected amongst hurdlers.

Computerized tomography (CT) and magnetic resonance imaging (MRI) have been considered the “gold standards” for assessing in vivo muscle thickness[13-15]. However, there are some limitations and contraindications to using these modalities. These include x-ray exposure with CT scans and the costly nature of MRI scans. Furthermore, due to the relatively long duration of each scan, a muscle’s contraction capabilities and accompanying morphology changes cannot be accurately captured using MRI. Imaging the muscle’s contraction capabilities requires the subject to continuously hold the activated state for the duration of the scan. The muscle will most likely fatigue and thus change its morphology during the duration of the scan. Alternatively, ultrasonography (US) has been proven valid and reliable in the assessment of muscle size during rest and contraction[16-20]. Due to its portability, low costs and low risk factors US has become a popular method for muscle imaging. Abdominal muscles have been
studied via ultrasound to visualize their thickness and changes in thickness during contraction. However, one drawback is it has been rather difficult to image them in a complete anterior to posterior view.

Panoramic ultrasound imaging is a method where the ultrasound probe is moved along an anatomical structure in order to capture it in its entirety. Panoramic ultrasound imaging has been used in previous studies to analyze various skeletal muscles, such as the medial gastrocnemius[21], quadriceps[22], and anterolateral abdominal muscles[23]. This technique has been reported to be valid for monitoring atrophy and hypertrophy of the quadriceps[22], reliable for simultaneous assessment of both muscle size and quality[21] and to have high repeatability for measuring cross-sectional area, length and thickness of the anterolateral abdominal muscles[23, 24]. The purpose of this study is to measure via panoramic ultrasound imaging and compare muscle thickness asymmetry in the IO and EO amongst hurdlers and sprinters. Our hypothesis are as follows: 1) Muscle morphology asymmetry will be greater in hurdlers than in sprinters. 2) There will be greater trunk rotational strength on the ipsilateral side to the hurdler’s leading leg.

Operational Definitions

1. Core stability. “The ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities”[1]
3. Trunk muscles. Muscles that comprise the abdominal core; Transversus Abdominis, Internal Oblique, External Oblique and Lumbar Multifidus.
5. Length. Length in the transverse plane.
Methods

Participants

21 collegiate sprinters and hurdlers (10 sprinters, 11 hurdlers) volunteered for the study. Inclusion criteria consisted of (1) being 18 years of age or older, (2) currently being a practicing member on a collegiate track and field team and (3) not having an injury within the last 6 weeks which prevented them from normal participation. Approval from Brigham Young University’s Institutional Review Board was obtained prior to testing, IRB ID#2020-350.

Procedure

A set of ultrasound images was taken with the participant sitting at the edge of a treatment table. Each individual image scan lasted approximately 5 seconds. Additionally, the participants performed a trunk rotational maximal voluntary contraction in the sitting position.

Ultrasound Imaging at Rest

With the participant sitting at the edge of a treatment table, their knees and hips were positioned at a 90-degree angle and fixated to the table using soft fabric straps. Foam padding was placed between the participant’s knees so that the legs remained parallel. The arms were crossed against the chest. Panoramic images of the IO and EO were taken at the level of the umbilicus. To assure that the probe remained parallel to the level of the umbilicus during imaging, a soft Velcro strap was placed horizontally around the participant’s waist as a guide for the probe (figure1). The posterior aspect of the muscles at their attachment site was visualized. A 6-15 MHz probe and 12L probe (Logiq s8 and Logiq e, GE Healthcare, Chicago, IL, USA), placed in transverse orientation, was moved anteriorly with slow continuous movement until the anterior attachment site came into view. With the participant maintaining a calm resting
breathing pattern, two panoramic images were taken of both right and left sides for later analysis.

**Maximal Flexion-Rotation Strength Measurement**

The participants put on a specially constructed shoulder harness that was fixed to a dynamometer on a pole. The table was positioned the same for each participant, at 20-degree angle to the dynamometer. The participant made 3 separate attempts for a maximal isometric strength flexion-rotation (see figure 1). For the strength assessment for rotation to the right the athlete tried to bring their left shoulder diagonally forward and down to their right hip, keeping the core tight. The process was then repeated for the strength assessment for rotation to the left, where the right shoulder was pulled diagonally forward and down towards the left hip. Instruction and practice of this isometric contraction occurred prior to data collection. For the ultrasound imaging with contraction, 25% of the total average of the three maximal voluntary contractions (MVC) was calculated[25].

**Figure 1**

**Ultrasound Imaging with Contraction**

Panoramic images were then collected during contraction of the EO and IO in the sitting position. Since contralateral EO and IO muscles contract on any given rotation, two
sonographers imaged the participant’s trunk simultaneously, one on the left and one on the right side. While maintaining a calm resting breathing pattern, the participant performed trunk rotation to the right, as previously described, while only performing at 25% of their MVC. An additional investigator monitored the dynamometer and informed the participant when they needed to adjust their contraction in order to stay on their 25% contraction force mark. Two images were captured for both right and left trunk rotations for later analysis.

**Measurement Analysis**

Measurement of the IO and EO muscles was completed using Horos medical imaging software (Pixmeo SARL, 266 Rue de Bernex, CH-1233 Bernex, Switzerland). The open polygon tool was used to measure the transverse length of each muscle individually. The line remained equidistant between the superior and inferior facial boarders. Three thickness lines were then placed. The first line positioned at the halfway mark of the total muscle length. Two additional lines were positioned on either side of the midline measurement equidistant from midline to the end of the muscle (see figure 2). The three lines (at 25%, 50% and 75% of overall muscle length) were averaged together for an inclusive estimate of muscle thickness.

**Figure 2**
**Statistical Analysis**

Independent variables for this study were the athletic event in which the participants are involved in, sprinting or sprint hurdles. Both have similar movements they perform during their respective events; however, hurdlers have additional trunk and hip rotational movements necessary for hurdle clearance. Therefore, sprinters were used as a control group in relation to the hurdlers. The dependent variables were ratios between sides of resting and contracted muscle thickness and strength between left and right sides. The ratios for sprinters were calculated as the value of the side corresponding to the front leg in the starting block over the side corresponding to the back leg. For hurdlers, the ratios were calculated as the values of the side corresponding to their leading leg over the side corresponding to the trail leg.

Determining whether greater asymmetry exists among hurdlers for the dependent variables was completed using a mixed-model analysis with alpha set at 0.05. Additionally, a paired t-test between right side rotation strength and left side rotation strength was run to compare strength ratios amongst the hurdlers. One outlier that was greater than two standard deviations was excluded from the data set. Analysis was conducted in R (R Core Team, 2014, Vienna, Austria).

**Results**

Participant characteristics are shown in Table 1. Total sample means (standard deviations) are age (years) 20.2 ± 1.5, height (cm) 176.9±9.1, and weight (kg) 70.6±9.8; with 12 males and 9 females. Only height showed a statistically different value between the two groups \( (p=0.01) \), all other variables had \( p \)-values >0.05. Average trunk rotation to the right was greater among all participants, \( p <0.001 \).
Muscle thickness for both groups in rest and contracted conditions for the IO and EO are shown in table 2. Left IO thickened the most in the hurdlers (difference of 0.5), but right IO thickened the most in the sprinters (difference of 0.6). Across all participants, the IO had greater thickening changes from rest to contraction than the EO (Sprinters: Left IO 28.5%, EO 22.2%; Right IO 54.5%, EO 12.5%; Hurdlers: Left IO 41.6%, EO 11.15%; Right IO 18.2%, EO 5.0%). The asymmetry, between left and right sides, was significantly different between hurdlers and sprinters for the IO, $p <0.01$. When in the contracted state, there was a 0.4cm thickness difference between the hurdlers’ left and right IO, $p=0.01$, with the left IO being thicker. There was no difference in asymmetry between conditions. The sprinters and hurdlers’ asymmetry did not change differently between conditions.
Table 1: Participant characteristics including trunk rotational strength measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sprinters</th>
<th>Hurdlers</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Age (years)</td>
<td>20.4±1.9</td>
<td>20±1.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>181.7±4.5</td>
<td>172.6±10.2†</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.9±5.6</td>
<td>67.6±12.0</td>
</tr>
<tr>
<td>Average Right Trunk Rotation Strength (kg)</td>
<td>32.4±6.1*</td>
<td>27.7±9.4*</td>
</tr>
<tr>
<td>Average Left Trunk Rotation Strength (kg)</td>
<td>28.0±8.0</td>
<td>23.9±7.2</td>
</tr>
<tr>
<td>Front Foot in Starting Block</td>
<td>Right n=2</td>
<td>Left n=8</td>
</tr>
<tr>
<td>Leading Leg (Hurdlers Only)</td>
<td>Right n=8</td>
<td>Left n=3</td>
</tr>
<tr>
<td>Data are mean ± standard deviation within-group. *Right trunk rotation is significantly greater than left $p&lt;0.001$. † Statistically different from sprinters, $p=0.01$.</td>
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Table 2: Average Muscle Thicknesses

<table>
<thead>
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<th></th>
<th>Hurdlers</th>
<th></th>
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<tr>
<td></td>
<td>Rest</td>
<td>Contracted</td>
<td>Rest</td>
<td>Contracted</td>
</tr>
<tr>
<td>Left</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO Thickness</td>
<td>1.4±0.2</td>
<td>1.8±0.6</td>
<td>1.2±0.3</td>
<td>1.7±0.5*</td>
</tr>
<tr>
<td>EO Thickness</td>
<td>0.9±0.2</td>
<td>1.1±0.2†</td>
<td>0.9±0.1</td>
<td>1.0±0.2†</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO Thickness</td>
<td>1.1±0.2</td>
<td>1.7±0.3*</td>
<td>1.1±0.3</td>
<td>1.3±0.4†</td>
</tr>
<tr>
<td>EO Thickness</td>
<td>0.8±0.1</td>
<td>0.9±0.1</td>
<td>0.8±0.1</td>
<td>0.84±0.1</td>
</tr>
</tbody>
</table>

Data are mean ± standard deviation within-group. *p<0.001, †p<0.05 compared to rest within group.

Discussion

This study assessed morphology differences of the IO and EO muscles and compared trunk rotation strength between collegiate sprinters and hurdlers. Within the entire sample size, trunk rotational strength was greater to the right, p<0.001. Because we assessed athletes from two different running sports, we need to discuss this finding by each sport. Sprinters, performing a seemingly symmetrical repetitive motion, need to exhibit a high block exit velocity in order to be successful in their sport[26]. This is obtained by executing explosive forces to propel the athlete forward. Contralateral rotation of the trunk is needed to counter these forces and keep body position square to the front. A majority of our sprinter sample had a forward left leg in the start block (n=8). This necessitates a strong trunk rotation to the right with the first step out of the block, possibly explaining the stronger right trunk rotational strength. The biomechanics of
sprint starts have been studied[27-29], however to our knowledge, none discuss the rotation of the trunk.

For hurdlers, the leg that is forward in the starting block depends on the number of steps needed to ensure their leading leg is in the correct position for the first hurdle. Therefore, using the forward leg in the block as the reference side will not be as informative. Alternatively, using the leading leg to compare trunk rotational strength is more ideal. During the take-off phase the athlete flexes their leading leg at the hip and knee approaching the hurdle, then extends it and passes over the hurdle. It is critical that during this phase there is a forward lean (trunk flexion) and counter rotation of the upper body towards the leading leg to offset the angular momentum the leading leg creates[30]. As the majority of our hurdlers have a right leading leg (n=8) and need to perform a forceful counter rotation of the trunk to the right, it could explain the stronger right side trunk rotation found. To our knowledge, the relationship of trunk rotational strength and leading leg has not been studied.

A certain physical physique is a common criterion of selection for athletes at higher levels[31]. Our data showed that sprinters were significantly taller than hurdlers by 9cm. When comparing sprinters to distance runners, sprinters generally are taller and have a larger mass[32, 33]. Ground forces can exceed the body’s weight by 2.5-fold during high running speeds[32]. Thus, the large forces required at higher speeds may suggest that trained and elite sprinters need more muscle mass to produce the higher forces and more bone and tendon to aid in the safe transmission of the forces to the ground[34, 35]. Therefore, the increased in height observed in our sprinter population could aid in additional force production thus increasing performance and speed.
It has been long believed that the taller hurdlers were the easier it would be to clear the hurdles and allow for greater strides in the distance between the hurdles and at the end of the race. However, in recent history world champions and Olympic medalists have defied that stipulation. For example, Bershown Jackson, 173cm tall, won the men’s 400m hurdles world champion in 2005 and Olympic bronze medal in 2008 and Dai Tamesue, 170cm tall, was the bronze medalist of the world championships in 2001 and 2008 in the men’s 400m hurdles[31]. Proper body proportions play a more important role in increased performance than over all height. If the height of an athlete is mostly represented in their trunk, this will not help them; it is the height of the pubic bone that allows an athlete to clear a hurdle[31]. Thus, the shorter height of our hurdler sample, especially when compared to the sprinters, should not have a negative effect on their performance abilities.

The IO and EO work together to act on the trunk. The ipsilateral IO contracts together with the contralateral EO in rotational movements. For example, simultaneous right IO and left EO contraction results in a flexion-rotation movement to the right. Training of these muscles has shown to increase the thickness of the muscles[36, 37]. Additionally, muscle thickness change during contraction has been used in other studies as a means to show muscle activation patterns[24, 38, 39].

We observed that the EO had smaller thickness changes in general when compared to the IO. Very few studies have used real-time ultrasound to study the EO. Hodges (2003) stated that ultrasound cannot detect changes of the EO due to inconsistent contraction thicknesses of the muscle when compared to EMG readings[25]. However, Hodges (2003) only had a sample size of three and did not have the subjects perform movements that elicit the primary function of the EO, which is flexion with contralateral rotation. Rather the action he used was abdominal
hollowing, a movement usually used to isolate the transversus abdominis. Even with a larger sample size of fifty-seven the EO still only showed minimal changes in thickness with this hollowing maneuver[40]. One study tested abdominal muscle activity during respiration and also showed no changes in EO thickness with maximal expiratory efforts[41]. However, when measuring thickness changes of the EO with isometric trunk rotation, significant changes were found using real-time ultrasound[42]. This demonstrates that thickness changes can be visualized and measured when the subject performs the appropriate movement for muscle contraction.

The discrepancy in changes of IO and EO muscle thickness between muscles could have various explanations. One, the fiber orientation pattern may not allow us to fully investigate the contraction capabilities of the EO. The most posterior fibers of the EO run in a nearly vertical orientation and the anterior fibers take an increasingly more medial direction with the most anterior fibers approaching horizontally[43]. As we only imaged at one level in the transverse plane, a complete representation of the EO contraction may not have been represented. Two, the ultrasound method used only images in two dimensions while muscle contraction occurs in three dimensions[25]. The EO may have greater changes occurring in width rather than thickness, which we did not image via ultrasound.

Subject positioning needs to be taken into consideration when assessing thickness changes of the abdominal muscles and it varies across studies. One study showed a significant difference in thickness with the subject in a horizontal side-support position with a contracted to rest thickness ratio of 1.88±0.52[39]. Another study tested in the supine position and with contraction via abdominal hollowing and observed a significant thickness increase in the IO[44]. Our participants were in an upright seated position performing a flexion-rotation contraction which also provided significant results. This poses the question of which muscle contraction
command used and what position of the subject is most representative for these muscles. Arguably, the seated position with a flexion-rotation contraction would be most distinguishing as it targets and emphasizes the exact actions performed by the IO and EO. A study comparing the various positions using ultrasound to EMG may be warranted.

Furthermore, our sprinters showed a greater thickness change in their right IO, which could be related to their greater right side trunk rotational strength. Rankin (2006) and Teyhen (2012) both found no significant differences between sides with contraction in a normal population[45, 46]. However, neither of them had subjects placed in the same position as the current study and only captured ultrasound images at one location. Capturing a panoramic image and placing the subjects in a more functional position may allow our findings to be more representative of the muscle as a whole.

Interestingly, within our hurdler sample, the left IO displayed greater thickness changes with contraction than the right IO (difference of 0.5cm and 0.2cm respectively). We expected the right IO to show a greater change in thickness as the participants’ trunk rotational strength was greatest to the right. Conversely, there was a significant thickness change in the left EO from rest to contraction which also produces right trunk rotation and therefore could be a factor in the greater right side rotational forces.

When comparing side asymmetry between the groups, a significant difference was found in the IO. This finding supports our hypothesis that hurdlers have a greater muscle size asymmetry than sprinters. Our findings are a bit conflicting, however, because it was the left IO that was larger when contracted. We would have expected the right IO to be larger since it contributes to right trunk rotation, which we found to be greater than left trunk rotation. To our
knowledge, no other studies have looked at side asymmetry compared to trunk rotational strength in hurdlers.

**Conclusion**

Sprinting, a seemingly symmetrical sport, would be expected to produce symmetric trunk muscles and trunk rotational strength. However, this is not the case in collegiate sprinters as they exhibit a significantly greater trunk rotational strength to the right. Likewise, an asymmetrical sport, like hurdling, produces an asymmetry in trunk rotational strength in addition to a functional asymmetry in trunk muscle morphology.
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