GENDER ANALYSIS OF HIP ABDUCTOR AND ADDUCTOR FORCE RATIOS

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The strength of hip abductors (ABD) and adductors (ADD) have been implicated in athletic injuries. This study assessed ABD:ADD in a variety of testing conditions and sought to assess gender differences therein. Fifteen men and fifteen women participated in this study. Subjects performed maximum voluntary isometric muscle actions for hip ABD and ADD against a portable force plate which was manually applied statically by research personal. Subjects were tested in four conditions included supine, supine with hip flexion, seated with knee extension, and standing. Results revealed no significant main effects or gender interaction for testing position for ABD:ADD, ABD force, or ADD force ($p \leq 0.05$). Results show that easy to use, valid, and reliable methods of assessing ABD:ADD exist, irrespective of testing position.

Keywords: agonist, antagonist, muscle balance, strength, injury prevention

INTRODUCTION: Frontal plane hip musculature, including the hip abductors and adductors, has been implicated in a range of clinical issues including groin strains and anterior cruciate ligament (ACL) injures. On the one hand, peak abductor torque, or insufficient adductor to abductor strength, may increase groin strains (Maffy & Emery, 2007). On the other hand, insufficient abductor strength may impair frontal plane landing mechanics and predispose athletes to ACL injuries (Ebben & Suchomel, 2018). Thus, the study of abductor and adductor strength is important for injury prevention. Unfortunately, research examining the performance ratio of hip abduction to adduction (ABD:ADD) reveals large inconsistencies, potentially as a result of the methods used and the testing position of the subjects.

Wide variability in ABD:ADD ratios are demonstrated in the research literature. This includes some studies showing abductor forces which were higher than adductor forces. Examples include ABD:ADD ranging from 1.04:1 to 1.19:1 (Thorborg et al. 2011), 1.38:1 to 1.44:1 (Hollman et al. 2006), and 1.20:1 to 1.44:1 (Morcelli et al. 2016). More commonly, abductor muscle groups have been shown to produce less force than the adductor group. Research shows ABD:ADD as low 0.43:1 (Donatelli et al. 1991). Other studies demonstrate ABD:ADD of 0.57:1 (Sugimoto et al. 2014), 0.78 to 0.89:1 (Jung et al. 2017), 0.88:1 (Kollock et al. 2013), and 0.96:1 (Saduaskaite-Zarembiene et al. 2013; Thorburg et al. 2011). Thus, the research shows abductor dominance, adductor dominance, and ABD:ADD ratios ranging from 0.43:1 to 1.44:1, thus obscuring the understanding of this issue.

The large variability in published ABD:ADD may be due to a variety of factors including the methods used and the subject position during assessment. Studies have employed isokinetic testing devices (Donatelli et al. 1991; Jung et al. 2017; Kollock et al. 2013; Morcelli et al. 1993; Sugimoto et al. 2014), hand-held dynamometers (Hollman et al. 2006; Saduaskaite-Zarembiene et al. 2013; Thorborg et al. 2011) and a fixed isometric dynamometry (Kollock et al. 2013). Of these studies, there is a greater variability in the resultant ABD:ADD associated with the use of isokinetic testing compared to handheld dynamometry.

Research assessed ABD:ADD of in a variety of subject positions. These include standing (Kollock et al. 2013; Sugimoto at al. 2014), supine (Thorburg et al. 2011), seated (Jung et al. 2017, Saduaskaite-Zarembiene at al. 2013), and side-lying (Donatelli et al. 1991;Jung et al. 2017; Morcelli et al. 2016). Of these positons, the standing and side-lying positons produced the greatest range in ABD:ADD with approximately 200% and 300% differences, respectively, between the studies. Unfortunately, 200-300% differences in research outcomes is not instructive, offering little guidance to practitioners who may be interested in assessing these ratios.

The purpose of this study was to assess ABD:ADD of subjects in a variety of testing positions previously assessed in a variety of studies, in order to determine differences between these conditions. In the process, this study sought to determine if a more consistent ABD:ADD is attainable. This study also assessed gender differences in ABD:ADD. Finally, this study evaluated the reliability of a low-cost handheld force plate.

METHODS: Fifteen men (mean ± SD, age 20.26 ± 1.16 yr; body mass 87.40 ± 11.36 kg; height 183.38 ± 8.96 cm) and fifteen women (mean ± SD, age 20.0 ± 1.41 yr; body mass 69.22 ± 3.83 kg; height 169.16 ± 5.50 cm) participated in this study. The subjects were informed of the risks associated with the study and provided informed written consent. The study was approved by the institution's internal review board.

Subjects participated in two research sessions. Prior to each session, subjects performed a general warm-up, followed by dynamic, activity specific stretching. The first research session was designed to assess leg dominance and familiarize the subjects to the test exercises. Subjects performed a depth jump from a twelve inch box, landing in a single leg stance of their choice, in order to determine leg dominance. Subjects then performed maximum voluntary isometric muscle actions for hip abduction and adduction in four different testing positions. The positions included supine, supine with hip flexion, seated with knee extension, and standing. The order of each test position was randomized using a random number generator. Each condition was performed at sets of 50%, 75%, and 100% volition, with each performed for five seconds. Subjects rested for one minute between all warm-up repetitions.

After three to five days of recovery, subjects returned for the testing session. During this session the general warm-up and dynamic, activity specific stretching was the same as the first research session. Subjects then performed two sets of hip abduction and adduction, one at 50% and one at 75% volition to further warm-up for testing. During these warm-up sets, subjects performed abduction and adduction at each of the four test positions for five seconds, with one minute of rest in-between each repetition. Subjects then received three minutes of rest before the testing. Subjects performed two sets of abduction and adduction at each test position at 100% volition, for five seconds. Subjects rested three minutes between each repetition and test position.

Subjects performed all hip abduction and adduction movements in all test positions against a portable force plate (Vernier Software & Technology, Beaverton, OR, USA), which was manually applied statically by research personnel. The force plate surface was applied an equal distance above and below medial condyle of the tibia for hip adduction testing and on the lateral condyle of the tibia as well as the lateral head of the fibula for hip abduction testing. The force platform was calibrated with known loads to the voltage recorded prior to the testing session. Kinetic data were collected at 600 Hz, real time displayed, and saved with the use of computer software for analysis. Peak reaction forces were obtained and used to determine abduction and adduction forces and the ABD:ADD.

Data were analyzed with statistical software (SPSS 25.0, International Business Machines Corporation, Armonk, New York). A repeated measure ANOVA was conducted, with repeated measures for exercise type, and with gender as a between subjects factor, in order to assess differences in ABD:ADD, abductor force, and adductor force, and across test conditions and gender. Paired samples *t*-tests was used to assess gender differences in force production. The trial to trial reliability of the abduction and adduction forces for each testing position were assessed using Intraclass correlation coefficients (ICC). Assumptions for linearity of statistics were tested and met. Statistical power (d) and effect size (η_p^2) are reported and all data are expressed as means ± SD. The *a priori* alpha level was set at $p \leq 0.05$.

RESULTS: Results revealed no significant main effects for testing position for ABD:ADD (p = 0.91), abductor force (p = 0.73), or adductor force (p = 0.47). No gender interaction was found for ABD:ADD (p = 0.62), abductor force (p = 0.86), or adductor force (p = 0.75). Mean data and the ABD:ADD ratio or each test position are presented in Table 1. Results show a non-significant mean difference of 10.97% difference in abductor force, and 21.76% difference in adductor force, between all test positions. Significant gender differences ($p \leq 0.01$) were found for both abductor and adductor force, for all test conditions as shown in Table 2. Results of the Intraclass correlation coefficients are depicted in Table 3.

Table 1. ABD and ADD Forces (N) (Mean ± SD) and Ratio For Each Test Postion

Position	ABD	ADD	ABD:ADD
Supine	211.93 ± 51.54	187.36 ± 63.60	1.13:1
Standing	228.74 ± 57.53	239.61 ± 77.93	0.95:1
Supine w/ Hip Flexion	203.28 ± 52.13	197.36 ± 60.73	1.03:1
Seated w/ Knee Extension	225.10 ± 53.88	209.41 ± 53.54	1.07:1

ABD= Abduction: ADD= Adduction

Table 2. Gender Specific ABD and ADD Forces (N) (Mean ± SD) in Each Test Position

Position	Men	Women	Women's % of Men
Supine ABD	247.65 ± 45.05	176.22 ± 27.20	71.15*
Supine ADD	228.43 ± 50.87	146.29 ± 46.64	64.40*
Standing ABD	264.40 ± 51.26	193.09 ± 38.79	73.02*
Standing ADD	282.91 ± 72.20	196.31 ± 57.88	69.39*
Supine w/ Hip Flex ABD	243.81 ± 36.84	162.76 ± 27.43	67.75*
Supine w/ Hip Flex ADD	243.54 ± 44.75	151.17 ± 32.65	62.07*
Seated w/ Knee Ext ABD	263.65 ± 42.38	186.54 ± 32.14	70.75*
Seated w/ Knee Ext ADD	248.38 ± 35.64	170.44 ± 37.61	68.62*

ABD= Abduction: ADD= Adduction; Flex = Flexion; Ext = Extension
*Significantly different between men and women ($p \leq 0.01$)

Table 3. Intraclass Correlation Coefficients

	Supine	Standing	Supine w/ hip Flex	Standing w. Knee Ext
ABD	.94	.98	.95	.96
ADD	.89	.98	.96	.92

ABD = Abduction; ADD = Adduction; Flex = Flexion; Ext = Extension

DISCUSSION: This study demonstrates only 11.51% differences in the ABD:ADD across all testing positions. This is in marked contrast with the literature demonstrating differences in ABD:ADD as high as 334%, even when comparing studies that assessed subjects in the same testing position (Donatelli et al. 1991; Morcelli et al. 2016). Research examining the effect of isokinetic test position, speed, and gender on ABD:ADD, showed little variability in the resultant ratios (1:01 to 1:1.22), across a variety of conditions including side-lying (Mohammad et al. 2017). However, other studies employing isokinetic testing at similar speeds revealed side-lying ABD:ADD of 1.60:1 to 3.04:1 (Belhaj et al. 2016). Some evidence supports the possibility that side-lying testing positons produce higher ADD values, potentially due to the influence of gravity on the limb segment, which may inflate the ADD and suppress the ABD forces (Donatelli et al, 1991). However, even standing isokinetic conditions produced only slightly more ABD, resulting in ABD:ADD that were still low (0.57:1 to 0.64:1). Other research shows that testing conditions not influenced by gravity and that use of handheld dynamometry, such as in the present study, tend to produce ABD:ADD values closer to a 1:1 (Kollock et al. 2013; Thornburg et al. 2011; Saduaskaite-Zarembiene et al 2013).

The current study demonstrated an ABD:ADD for most test positions that was indicative of slightly greater abductor, compared to adductor strength. This finding is consistent with some previous research (Hollmann et al. 2006; Kollock et al. 2013; Morcelli et al. 2016). Among these studies, no pattern can be determined with respect to study instrumentation, since these studies used isokinetic (Kollock et al. 2013; Morcelli et al. 2016), and handheld dynamometry (Hollman et al. 2006). Alternatively, the findings of the present study are in contrast to those which showed greater adductor compared to abductor strength (Donatelli et al. 1991; Jung et al. 2017; Kollock et al. 2013; Saduaskaite-Zarembiene et al. 2013; Sugimoto et al. 2014; Thorborg et al. 2011). In the present study, the relatively high

ABD:ADD may be explained in part by the anecdotal reports of the systematic training of hip abductors as part of the strength and conditioning program of a number of the subjects.
Results of the present study show no gender differences in the ABD:ADD, consistent with previous research (Jung et al. 2017; Sugimoto et al. 2014). In the present study, women demonstrated abductor strength that was in a range of approximately 68% to 73% of the values attained by men, demonstrating less lower-body strength differences than typical (Miller et al. 1993). The adductor strength of women was approximately 62% to 69% of the values produced by men. These gender differences were fairly typical of lower body strength differences between men and women (Miller et al. 2004).
Results of the current study show that the low-cost hand-held dynamometer employed was highly reliable and yielded higher correlation coefficients than previously shown (Kollock et al. 2013). The current study demonstrates that trained personnel can produce reliable test results using hand-held force plate dynamometry, tempering the previous documented concern about the ability of the clinician to effectively stabilize the dynamometer against high adduction and abduction forces (Kollock et al. 2013).

CONCLUSION: Results show that subject's ABD:ADD ratios can be reliably tested in a variety of subject positions. Hand-held dynamometry is valid and reliable when deployed by trained practitioners. Easy to use, valid, and reliable methods of assessing ABD:ADD may be valuable to practitioners seeking to monitor abductor and adductor strength, in order to prescribe exercise with the goal of potentially preventing groin and ACL injuries.

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