

THE RELATIONSHIP OF FORCE PRODUCTION ASYMMETRY AND PERFORMANCE IN ATHLETES OF DIFFERENT STRENGTH LEVELS

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The purpose of this study was to evaluate the relationship between force production asymmetry and performance of athletes with differing strength levels in males and females. Collegiate athletes (n=129) from various sports were ranked according to isometric mid-thigh pull peak force and the top ('strong') and bottom ('weak') 25% were used for analysis. Symmetry index (SI) scores were calculated and correlated with their respective force-time characteristics using bivariate correlations. For the weaker males, several negative moderate correlations were observed; however, no statistically significant correlations were observed for the females in either group. These findings indicate that force production asymmetry is inversely related to performance in weaker male athletes during isometric strength testing; however, similar to previous findings, this relationship is not apparent in stronger males.

KEYWORDS: bilateral strength assessment, contralateral asymmetry, isometric mid-thigh pull

INTRODUCTION: Contralateral symmetry or lack of symmetry has been gaining interest in research and practice. Some studies attempt to link asymmetry to risk of injury, while others are more interested in its role on performance (Bailey et al. 2013a, Bazylar et al. 2014, Bennel, Wajswelner, and Lew 1998, Knapik et al. 1991). While both are important for athletes, the latter may be the greater focus of sport scientists and coaches.

Lately, studies on force production asymmetry in bilateral strength assessments have surfaced. Bailey et al. (2013a) examined the relationship between isometric force production asymmetry and jumping performance in un-weighted and weighted static and countermovement jumps. Moderate to strong negative statistically significant relationships were found between isometric force production asymmetry and both jump height and peak power during all jump conditions. Their study indicated that increasing isometric force production asymmetry was related to poorer jumping performances. More recently, Bazylar et al. (2014) conducted a study examining changes in isometric force production symmetry during the squat over the course of a 12 week periodized training program. The sample was split into two groups by strength level. Similarly to the aforementioned study, results showed a strong negative relationship between force production asymmetry and performance measures. A unique finding of this study was that the weaker group was able to decrease asymmetry to a larger degree than the stronger group with training (Bazylar et al. 2014). Another recent study, Bailey and colleagues (2013b) compared isometric force production asymmetry during a mid-thigh pull between collegiate baseball and softball athletes. There was no statistically significant difference between the two populations in asymmetry magnitude; however, there was a difference in the relationship between asymmetry and performance. The softball group produced moderate to strong negative relationships between asymmetry and performance, while in the baseball group there was no apparent relationship between the two. It should be noted that the baseball players were statistically stronger than the softball players. The results of the Bazylar et al. (2014) and Bailey et al. (2013b) studies raise the question of the importance of strength level in the relationship of asymmetry and performance.

Therefore, the purpose of this study was to evaluate the relationship between force production asymmetry and performance in male and female athletes with differing strength levels.

METHODS: Subjects included 129 NCAA Division I athletes from various collegiate sports (baseball n=32, men's golf n=2, women's golf n=7, men's soccer n=18, women's soccer n=19, men's tennis n=12, women's tennis n=7, softball n=19, and volleyball n=13) (male athletes n=64, female athletes n=65) participated in this study. Data collection was part of an on-going East Tennessee State University sport science monitoring program. All athletes read and signed University Institutional Review Board approved informed consent documents before participating. Prior to testing, athletes underwent a standardized warm-up which consisted of 25 jumping jacks, one set of five mid-thigh pulls with a 20 kg bar, and three sets of five mid-thigh pulls with either a 60 kg load (male athletes) or a 40 kg load (female athletes). Evaluation of strength and bilateral strength asymmetry was completed with a maximal effort multi-joint isometric contraction, an isometric mid-thigh pull (IMTP). Bilateral strength assessments were done in a customized power rack and kinetic values were collected via a dual force plate setup (two separate 91 cm x 45.5 cm force plates, Roughdeck HP, Rice Lake, WI).

Data were sampled at 1,000 Hz. The protocol, apparatus and positioning (Figure 1) were previously described by Haff and colleagues (1997). Bar heights were set individually for each athlete, with each bar height corresponding to a $125 \pm 5^\circ$ knee angle. In order to ensure maximal efforts could be given without risking the loss of grip, athlete's hands were secured in position with weightlifting straps along with athletic tape. Prior to maximal effort trials, athletes performed two familiarization and warm-up trials at 50 and 75% of perceived maximal effort. Afterward, athletes participated in a minimum of two maximal effort trials. Trials were considered successful as long as no countermovement of greater than 200 N was observed. In an effort to ensure maximum force and rate of force development, athletes were coached to "pull as fast and as hard as possible".

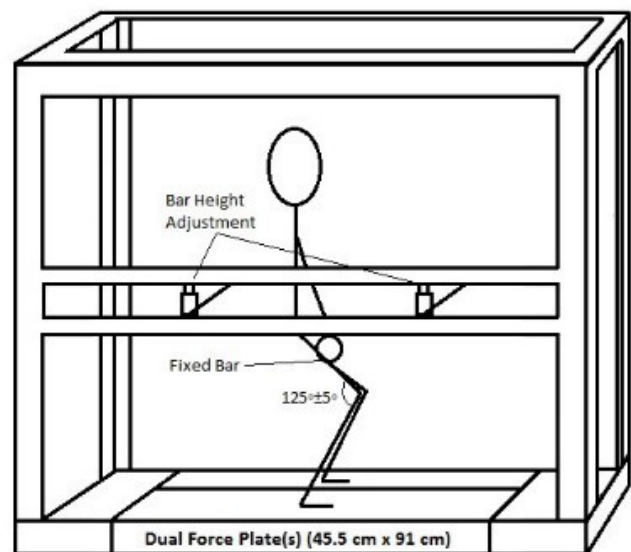


Figure 1. Isometric mid-thigh pull apparatus and positioning

A customized LabVIEW program (Version 12.0, National Instruments Co., Austin, TX, USA) was used to both collect and analyze kinetic data obtained during bilateral strength assessment. Kinetic data obtained in the IMTP were analyzed to yield both separated and summated values from both force plates. Specifically, the variables included: isometric peak force (PF), rate of force development (RFD) (0-250ms), instantaneous force at 50, 90 and 250ms (F50, F90, F250), and impulse derived at 50, 90 and 250ms (I50, I90, I250). Strength asymmetry magnitude was determined with symmetry index (SI) scores from the equation previously utilized by Sato and Heise (2012): $SI = (\text{larger value} - \text{smaller value}) / (\text{total value}) * 100$. The result of the formula is a percentage, where SI scores nearing zero represent near perfect symmetry and values larger than zero signify increasing asymmetry.

Levene's tests were run between strong and weak athletes to evaluate homogeneity of variance for all variables. Prior to relationship analysis, samples were split into strong and weak groups for male and female athletes, similarly to Kraska et al. (2009). These groups consisted of the top and bottom 25% of athletes based on PF values obtained in the IMTP and the remaining athletes were excluded. This resulted in 16 athletes in each male and female group. Independent samples t-tests were used for comparison between strong and weak groups to ensure group differences with a Bonferroni adjustment applied as eight separate comparisons were made. The statistical significance was set at $p \leq 0.00625$. In order to estimate effect magnitude between groups, Cohen's *d* effect sizes were calculated. Relationships of asymmetry magnitude and performance were evaluated with Pearson zero order, product-moment correlations between SI scores and summed variable values for each variable measured for the strong and weak groups of both sexes. Strength of relationships were interpreted using a scale created by Hopkins (2013).

RESULTS: Levene's test for homogeneity of variance was not statistically significant, so equal variances between strong and weak groups were assumed. Table 1 shows the results of the independent samples t-tests between strong and weak groups with effect size estimates. All variables were statistically different between strong and weak groups for both male and female athletes. Males had much larger effect size estimates than did the females.

Table 1. Results of independent samples t-tests and Cohen's *d* effect size estimates

Males	PF	RFD	F50	F90	F250	I50	I90	I250
t tests	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Cohen's <i>d</i>	4.293	4.916	4.769	4.471	4.605	4.984	4.753	4.428
Females	PF	RFD	F50	F90	F250	I50	I90	I250
t tests	0.000*	0.002*	0.001*	0.000*	0.000*	0.004*	0.002*	0.000*
Cohen's <i>d</i>	1.813	1.030	1.119	1.400	1.273	0.970	1.048	1.245

*denotes statistical significance ($p < 0.00625$)

Table 2 shows the correlation results between each variable and their respective SI scores. For the weaker male athletes, several negative moderate correlations were observed (F50 $r = -0.46$, F90 $r = -0.44$, I50 $r = -0.40$, and I90 $r = -0.47$). These relationships were smaller, nonexistent or possibly in the opposite direction in the stronger group. The female athletes did not express the same trend. Many negative correlations were observed, but the differences in *r* value between the strong and weak groups were not as large as those seen in the male athletes.

Table 2. Correlation results between variables and their respective SI scores

Males	PF	RFD	F50	F90	F250	I50	I90	I250
Weak	0.08	-0.11	-0.46*	-0.44*	0.01	-0.40	-0.47*	-0.25
Strong	0.08	-0.09	0.20	0.17	0.02	0.33	0.27	0.10
Females	PF	RFD	F50	F90	F250	I50	I90	I250
Weak	-0.23	-0.28	-0.11	0.01	-0.08	-0.06	-0.08	0.02
Strong	-0.26	-0.33	0.12	-0.08	-0.28	0.25	0.10	-0.23

*denotes statistical significance ($p < 0.05$)

DISCUSSION: This study determined the relationship between force production symmetry and performance in athletes of varied strength levels. The primary finding of this study was the difference in this relationship between strong and weak male athletes. Concerning the weaker male athletes, several negative moderate relationships were expressed indicating that IMTP performance may decrease as force production symmetry increases. These same variables produced different correlation results in the stronger males. Many of the relationships decreased in strength, vanished or reversed direction. This is consistent with the findings of Bazylar et al.

(2104) which found strong negative correlations between SI scores and performance in the isometric squat, but also found more improvements in symmetry in the weaker subjects with bilateral strength training. This is also somewhat consistent with the Bailey et al. (2013b) study that found larger negative correlations in the softball players and no relationship in the baseball players who were statistically stronger. The male athlete data from the current study appears to provide additional justification for the argument by Bazzyler et al. (2014) that contralateral limb force production asymmetry may decrease with bilateral strength training, possibly improving strength testing performance, but this relationship only exists to a certain point.

The female athlete data in the present study does not follow the same trend. Small to moderate negative relationships were observed, but in both groups. It should be noted that although the strong and weak groups were statistically different like the male athletes, the magnitude of that difference appears to be smaller as evidenced by the smaller effect size estimates. It is possible that repeating this study with a sample possessing larger differences between the strong and weak groups could yield different results in the correlational statistics, but further research would be needed to validate this notion.

CONCLUSION: This study indicates that force production symmetry is related to performance in weaker male athletes during isometric strength testing. Force production symmetry does not appear to be related to performance in stronger male athletes. The relationship with female athletes at different strength levels is less clear. As a result, future studies may want to statistically compare the force production asymmetry and performance relationship differences between males and females in an effort to clarify some of the remaining questions of the current investigation. Future researchers may also wish to duplicate this study with dynamic strength and performance assessments to determine if similar trends exist between isometric and dynamic force production symmetry.

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