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A Comparison of Morphological, Jump, and Sprint Kinematic Asymmetries in Division I Track and Field Athletes

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ABSTRACT

International Journal of Exercise Science 16(1): 1306-1319, 2023. Inter-limb asymmetries are the difference in performance in one limb with respect to the other. Running events in track and field are considered symmetrical while jumping and throwing events are considered asymmetrical. It is unknown if competing in these different events result in differences in inter-limb asymmetries, thus, this study compared the magnitude of jump, sprint, and morphological asymmetries in track and field athletes who compete in symmetrical and asymmetrical events. Forty-six Division I track and field athletes performed a series of vertical jumps (VJ) and broad jumps (BJ) with force platforms measuring peak force of each limb, and 30-meter fly sprints with kinematics (step length (SL), flight time (FT), and contact time (CT)) recorded during the sprints. Additionally, thirty-eight of these subjects underwent body composition analysis via dual x-ray absorptiometry to determine morphological asymmetries. Asymmetries were calculated using the symmetry index and the asymmetry measures were compared between sprinters, distance runners, throwers, and jumpers utilizing a one-way analysis of variance or Kruskal-Wallis tests with post-hoc comparisons as necessary. There were no differences in VJ, BJ, and sprint kinematic asymmetries found between groups but there were differences in leg fat mass asymmetries ($H(3)=8.259$, $p=0.041$, eta2= 0.101) as well as arm lean mass ($H(3)=9.404$, $p=0.024$, eta2=0.152), fat mass ($H(3)=17.822$, $p<0.001$, eta2=0.353), and tissue mass ($H(3)=11.632$, $p=0.009$, eta2=0.206) asymmetry measures. While morphological asymmetry differences may be present in athletes competing in different events, there does not appear to be differences in asymmetries during the VJ, BJ, and 30-m fly sprint.

KEY WORDS: Inter-limb asymmetry, vertical jump, broad jump, body composition

INTRODUCTION

Inter-limb asymmetry is defined as the difference in the performance of one limb with respect to the other (2, 4). These asymmetries can be referenced by their magnitude or by their direction; magnitude refers to the percent difference between limbs and direction refers to the limb of preference (4). Studies on inter-limb asymmetries have focused on injuries and injury risk (9) with some suggesting that asymmetries can be used to determine the risk of injury (9). Researchers have also examined the relationship between inter-limb asymmetries and physical performance during running, jumping, and change of direction (2, 4, 6, 7, 22). Madruga-Parera and colleagues reported moderate associations between asymmetries of unilateral countermovement jump height and repeated sprint completion time for both dominant (r = 0.40) and non-dominant limbs (r = 0.35) in adolescent handball athletes (24). Similarly, Bishop and colleagues reported moderate associations between asymmetries observed in unilateral countermovement jump height and 5m (r = 0.49), 10m (r = 0.52), and 20m (r = 0.59) sprint completion times in elite youth female soccer players (6). Such findings suggested that inter-limb asymmetries may be detrimental to athletes.

The demands of a sport may contribute to the development of asymmetries as athletes can become asymmetrical as a sport adaptation (15, 17, 20). For instance, Kruger and colleagues reported limb length and girth asymmetries when examining the dominant and non-dominant sides of the upper body in elite male javelin throwers (20). Kutac and Uchytil also reported lower limb bone mineral density and bone mineral content differences between preferred and non-preferred limbs when examining long jumpers and high jumpers (21). Hart et al. reported that elite soccer players developed asymmetries in tibial mass, cross-sectional area, and stress-strain measures over time when examining the tibial scans of more experienced (training age >3 years) and less experienced (≤3 years) athletes (17). In examining cricket fast bowlers, more symmetrical abdominal muscles were associated with lower back pain in comparison to those who were more asymmetrical (15).

Track and field athletes can have symmetrical or asymmetrical sport demands depending on which events they compete in. Athletes can compete in running events that are considered symmetrical in nature (32) or they can compete in throwing and jumping events that may be asymmetrical in nature (23). To date, few studies have compared asymmetries in athletes who have symmetrical and asymmetrical sport demands. The current focus in the literature has primarily been on between sports comparisons. For instance, a recent study by Bishop and colleagues found unilateral drop jump height and reactive strength index asymmetry differences between professional soccer (jump height asymmetry = 6.51%, reactive strength index asymmetry = 5.95%) and cricket players (jump height asymmetry = 11.49%, reactive strength index asymmetry = 10.37%) (3). Luk and colleagues also reported significant differences in jump force asymmetries between powerlifters (2.75 ± 2.45%) and collegiate field jumpers (6.81 ± 5.16%) (23). Additionally, Kalata and colleagues compared the isokinetic knee extensor and knee flexor strength of youth athletes competing in symmetrical (triathlon and sport aerobics), asymmetrical (tennis and volleyball), and hybrid (soccer) sports and reported greater asymmetries in the quadriceps strength in the asymmetrical athletes than both symmetrical and hybrid athletes (18).

While these studies examined the differences in athletes competing in symmetrical and asymmetrical sports, this has not been examined in the sport of track and field. As a result, it is currently unknown if the asymmetries would differ between those who compete in running events (sprints and distance running) and those who compete in asymmetrical events (jumpers and throwers). Thus, the purpose of this study was to examine the differences in morphological, vertical jump (VJ), broad jump (BJ), and sprint kinematic asymmetries between athletes competing in symmetrical and asymmetrical events within track and field. It was hypothesized that the athletes competing in asymmetrical events would have greater asymmetries than those competing in symmetrical events.

METHODS

Experimental Approach to the Problem: This study used a single session design in which division I track and field athletes completed two trials of the VJ, BJ, and 30-meter fly sprints. During the VJ and BJ, ground reaction forces were collected using force platforms. During the 30-m fly sprints, sprint kinematics were collected by photoelectrical cells to include step length (SL), flight time (FT), and contact time (CT). In addition, a subset of athletes underwent dual-energy x-ray absorptiometry (DEXA) scans to obtain measures of lean mass, fat mass, tissue mass, and bone mineral density. Following data collection, inter-limb asymmetries of sprint kinematic measures, VJ and BJ peak force measures, and morphological measures were calculated. Asymmetrical differences between athletes who compete in sprinting, distance running, throwing, or jumping events were then determined.

Participants

This study used a convenience sample of 46 male and female Division I track and field athletes consisting of 17 sprinters, 14 distance runners, 8 throwers, and 7 jumpers, with descriptives displayed in Table 1. The sprinters consisted of athletes running distances of 400 meters or less. The distance runners consisted of athletes running distances of 800 meters or more. The throwers consisted of athletes competing in throwing events such as the shot put, discus throw, and javelin throw. Lastly, the jumpers consisted of athletes competing in the long jump, triple jump, and pole vault. Out of these 46 athletes, 38 athletes (14 sprinters, 10 distance runners, 8 throwers, and 6 jumpers) underwent DEXA scans, the other 8 athletes were unavailable for DEXA scans. All athletes were free of injury and had not sustained an injury within the past six months prior to participation in this study. This study was approved by the University of Texas at El Paso institutional review board (IRB: 1659477-10**)** and all subjects provided written consent prior to study participation. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (28).

Table 1. Means ± Standard Deviations of Anthropometric and DEXA Measures.

	Sprinters	Distance	Throwers	Jumpers
Height (cm)	172.53 ± 10.16	168.57 ± 8.51*	182.29 ± 9.65	178.93 ± 9.69
Weight (kg)	68.04 ± 11.13*	58.09 ± 7.27*,§	117.18 ± 18.67§	72.51 ± 5.17
Right Leg				
Lean Mass (g)	10,080.43 ± 2,390.54†,§	81,77.20 ± 1,330.41§,*	14060.25 ± 2648.45§	10374.33 ± 1333.41
Fat Mass (g)	2,052.71 ± 761.82§	2,223.10 ± 895.09*	6751.38 ± 2763.83§	2318.50 ± 1389.08
Tissue (% Fat)	17.41 ± 6.81§	21.27 ± 7.89§,*	32.04 ± 8.30§	18.07 ± 10.21
BMD (g/cm²)	1.53 ± 0.15†,*	1.34 ± 0.10*,§	1.71 ± 0.13	1.62 ± 0.17
Left Leg				
Lean Mass (g)	10,270.93 ± 2,546.99†,,§	7,988.40 ± 1,342.99*,§	13941.63 ± 2384.25§	10016.00 ± 1250.39
Fat Mass (g)	2,048.00 ± 782.67,§	2,191.50 ± 864.99*	6570.00 ± 2322.07§	2141.83 ± 1181.96
Tissue (% Fat)	17.07 ± 6.57†,§	21.57 ± 8.36*,§	31.76 ± 7.63§	17.62 ± 9.59
BMD (g/cm²)	1.52 ± 0.14†,*	1.32 ± 0.11*,§	1.71 ± 0.15	1.62 ± 0.14
Right Arm				
Lean Mass (g)	3,798.14 ± 1,352.50†,*	2,653.30 ± 596.95*,§	4853.50 ± 1548.36	3928.00 ± 707.23
Fat Mass (g)	637.00 ± 228.00*	625.50 ± 181.91*	2227.88 ± 692.80§	722.17 ± 322.76
Tissue (% Fat)	15.46 ± 6.49†,*	19.53 ± 6.29*,§	32.18 ± 9.14§	15.88 ± 8.05
BMD (g/cm²)	0.93 ± 0.14†,*	0.72 ± 0.08*,§	1.17 ± 0.19§	0.96 ± 0.13
Left Arm				
Lean Mass (g)	3,646.21 ± 1,190.13†,*	2,622.50 ± 696.73*,§	4800.38 ± 1541.71	3897.67 ± 795.90
Fat Mass (g)	636.43 ± 206.96*	664.20 ± 188.72*	2229.38 ± 694.88§	727.33 ± 311.71
Tissue (% Fat)	15.98 ± 6.51†,*	20.89 ± 6.97*,§	32.43 ± 9.08§	16.30 ± 8.45
BMD (g/cm²)	0.91 ± 0.15†,*	0.71 ± 0.07*,§	1.15 ± 0.21	0.97 ± 0.13
Right Trunk				
Lean Mass (g)	12,590.36 ± 2,727.36*	10,716.10 ± 1,662.10*,§	16708.75 ± 3190.98	13607.83 ± 1786.68
Fat Mass (g)	2,095.43 ± 891.24*	2261.50 ± 928.65*	10922.75 ± 3845.09§	3106.33 ± 1459.41
Tissue (% Fat)	14.56 ± 6.13*	17.38 ± 6.34*,§	38.88 ± 8.84§	18.70 ± 9.15
BMD (g/cm²)	1.24 ± 0.10†,*	1.02 ± 0.11*,§	1.44 ± 0.10§	1.26 ± 0.04
Left Trunk				
Lean Mass (g)	12,876.29 ± 2,937.70*	10,895.60 ± 1,780.27*,§	16916.75 ± 3459.87	13495.17 ± 1454.70
Fat Mass (g)	2,101.64 ± 956.55*	2,272.40 ± 923.17*	10838.88 ± 3525.79§	2949.00 ± 1450.95
Tissue (% Fat)	14.22 ± 5.94*	17.21 ± 6.25*,§	38.60 ± 8.79§	17.90 ± 8.92
BMD (g/cm²)	1.22 ± 0.11†,*	1.00 ± 0.11*,§	1.41 ± 0.12§	1.24 ± 0.06
Right Total				
Lean Mass (g)	28,067.36 ± 6,595.18*	23,201.70 ± 3,406.43*,§	37649.25 ± 7703.66	29403.50 ± 3695.50
Fat Mass (g)	5,193.93 ± 1,817.54*	5,545.40 ± 1,883.07*	20486.38 ± 6653.35§	6533.33 ± 3077.99
Tissue (% Fat)	16.08 ± 5.85†,*	19.31 ± 6.18*,§	35.05 ± 7.88§	18.27 ± 8.83
BMD (g/cm²)	1.37 ± 0.14†,*	1.20 ± 0.11*,§	1.58 ± 0.10	1.42 ± 0.08
Left Total				
Lean Mass (g)	28,470.43 ± 6,515.18†,*	22,956.50 ± 3,870.04*,§	37457.13 ± 7288.92	29301.67 ± 3731.78
Fat Mass (g)	5,214.43 ± 1,864.99*	5,508.70 ± 1,824.58*	20158.88 ± 5947.32§	6315.00 ± 2833.28
Tissue (% Fat)	15.86 ± 5.72†,*	19.47 ± 6.50*,§	34.88 ± 7.58§	17.87 ± 8.49
BMD (g/cm²)	1.39 ± 0.12†,*	1.17 ± 0.10*,§	1.56 ± 0.12	1.44 ± 0.07

† = significantly different from the Distance group; § = significantly different from the Jumpers Group; * = significantly different from the Throwers Group.

Protocol
All testing was conducted on a synthetic outdoor track. All testing was done on a day with a temperature of 27°C with an average wind speed of 0.9 miles per hour. Upon arrival to the track, anthropometrics were taken. Height was measured using a stadiometer to the nearest centimeter (Seca 213, Seca GmbH, Germany) and weight was measured using a scale to the nearest hundredth of a kilogram (Seca 813, Seca GmbH, Germany). Following anthropometric measures, subjects performed 15-20 minutes of their regular practice warm-up, this included a general warm-up as well as dynamic stretches and practice sprints. At the conclusion of the warm-up, subjects completed two 30-meter fly sprints, two trials of the VJ, and two trials of the BJ in a counterbalanced order with each group completing the three tests in differing order. On a separate day, participants underwent DEXA scans to determine body composition and morphological asymmetries.

Vertical Jump Assessment: Subjects performed two trials of the bilateral VJ with hands akimbo with a minimum of two minutes rest in between trials. Subjects completed jump trials while standing on two PASSPORT 2-Axis Force Platforms (1,000 Hz, Pasco Scientific, Inc., Roseville, CA, USA) with kinetic data recorded using the Pasco Capstone Software (v.2.2.0) separately for the left and right legs. Force data were then used to calculate jump height using the takeoff velocity (Jump height (cm) = velocity at takeoff^2 / 2*gravity) method and peak force data from each leg were also used to determine inter-limb asymmetries (11, 12, 26, 27, 31). Peak force values were also normalized to the individual's mass. The VJ trial with the greatest jump height was used for analysis.

Broad Jump Assessment: Similar to the VJ, the subjects performed two trials of the BJ starting from a stationary position whilst standing on two force platforms. Trials were conducted with hands akimbo with a minimum of two minutes of rest in between trials. The distance of the BJ was measured to the nearest centimeter using a measuring tape and was measured as the distance from the takeoff point to the back of the subject's heel at landing (11). Subjects were required to stick the landing; if not, the trial was not counted. Peak force from each leg was then used to calculate inter-limb asymmetries. Additionally, peak force values were normalized to the individual's mass. The trial with the greatest distance achieved was used for analysis.

Sprint Assessment: Subjects performed two 30-meter maximal speed sprint trials with completion times measured utilizing a photocell timing system (Brower Timing Systems, Draper, Utah). Subjects were given 30 meters to achieve maximal velocity before entering the 30-meter timing zone as previously described by Dietze-Hermosa et al. (11). Subjects were instructed to attain maximal velocity upon arriving at the first marker of the 30-meter timing zone. Six meters of Optojump photoelectrical cells (Microgate, Bolzano, Italy) were placed 12 meters into the 30-meter sprint area as illustrated in Figure 1. Kinematics obtained from the Optojump photoelectric cells were recorded using Optojump Next software (v.1.12.17) at a capturing frequency of 1,000 Hz and included SL, CT, and FT. Kinematic measurements of two consecutive steps (one full stride cycle) were used for analysis. The Optojump photoelectric cells system is a valid and reliable field assessment method to obtain running kinematics (10, 13, 19, 33). The trial with the shortest completion time was used for analysis.

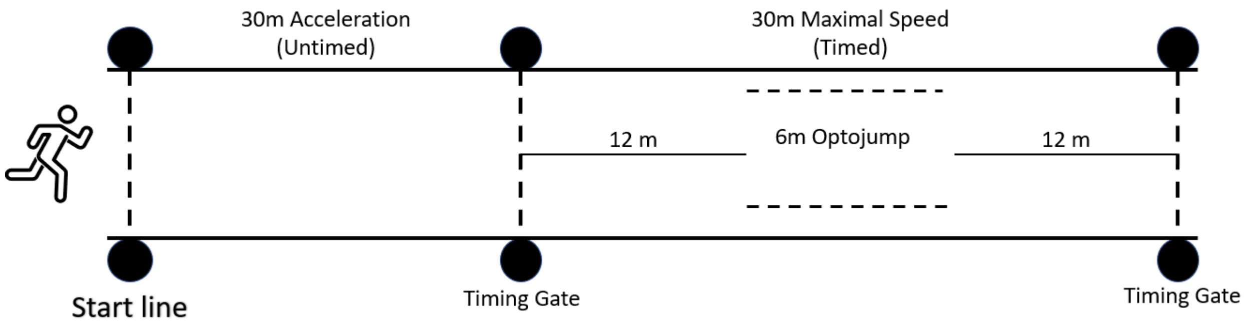

Figure 1. Illustrates the set-up of the fly sprint assessment and area of measurement for kinematic measures.

Dual-Energy X-Ray Absorptiometry: Full body DEXA scans were obtained using a Lunar iDXA machine (GE Healthcare, General Electric Company, Illinois, USA) by a certified medical imaging technologist from 38 of the track and field athletes who participated in this study. Prior to the DEXA scan, height was measured using a stadiometer and weight was measured using a scale. These measures were then entered into the computer DEXA system along with age and ethnicity. The subjects were instructed to remove any metal objects and then lie in a supine position with their torso aligned in the center of the scanner. The subjects' arms were placed to the side of the body with thumbs pointed upward and were instructed to keep their toes pointed upward as well. From the DEXA scans measures of lean mass (g), fat mass (g), tissue mass (g) and bone mineral density (BMD g/cm^2) were obtained from the left and right side of the arms, legs, trunk, and totals. The symmetry index was then used to determine the magnitude of asymmetries for each of these measures.

Data Processing: Left and right force platform data from each respective trial of the VJ and BJ were summed and exported to MATLAB (v.R2021a, MathWorks, Natick, MA, USA) and filtered using a digital fourth-order low pass Butterworth filter with a cutoff at 50Hz; this cutoff frequency was selected after a visual analysis of the force signal via Fast Fourier Transform (16). Vertical jump force data were then used to determine VJ height as well as inter-limb asymmetries of the peak force of each leg achieved during the VJ. Broad jump resultant force data were used to determine inter-limb asymmetries by examining the peak force of each leg achieved during the BJ. Asymmetries of each variable measured were calculated using the symmetry index equation [(higher value-lower value)/total*100] which has been recommended for bilateral movements (5, 7).

Statistical Analysis

Data were compiled from each respective software into a comprehensive Excel spreadsheet (Microsoft Excel, Microsoft, Redmond, WA), and then imported into SPSS 28 (SPSS, Inc., IBM, Armonk, NY) for statistical analysis. Shapiro-Wilk tests were used to determine data normality. Within-session reliability of each measure of interest was determined using two-way random

intraclass correlation coefficients (ICC) with consistency and 95% confidence intervals as has been conducted in other asymmetry research (29). The magnitude of the ICC was classified as excellent (>90), good (0.75-0.90), moderate (0.50-0.75), and bad (<0.50) (29).
For normally distributed variables, a series of individual one-way analysis of variance were conducted with eta squared calculated to determine effect size. Post hoc pairwise comparisons with a Bonferroni correction along with Cohen's d effect size were calculated when appropriate. For non-normally distributed variables, Kruskal-Wallis tests were conducted with eta squared values calculated using the equation $eta^2 = (H - k + 1)/(n - k)$ to determine effect size. Post hoc Mann-Whitney U Tests with a Bonferroni correction were conducted as necessary with effect size calculated as $r = \frac{z}{\sqrt{n}}$. Significance was set at an α level of < 0.05. Eta squared values were interpreted as small (0.1), medium (0.6), and large (0.14). Post hoc effect sizes were classified as trivial (0-0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0), and very large (>2.0) (14).

RESULTS

Vertical Jump, Broad Jump, and Sprint data are reported in Table 2. Kruskal-Wallis test indicated no group differences for the VJ peak force asymmetry percentage ($H(3) = 4.137$, $p = 0.247$, $eta^2 = 0.027$). There were also no significant group differences in BJ peak force asymmetry percentage ($H(3) = 0.194$, $p = 0.979$, $eta^2 = -0.067$). In examination of the sprint asymmetries, there were no significant differences in the step length asymmetry ($H(3) = 2.668$, $p = 0.446$, $eta^2 = -0.008$), contact time asymmetry ($H(3) = 2.413$, $p = 0.491$, $eta^2 = -0.014$), and flight time asymmetry ($H(3) = 0.712$, $p = 0.870$, $eta^2 = -0.054$) between groups (See Table 3).

In examination of the morphological asymmetries, Kruskal-Wallis test indicated there were significant differences in fat mass symmetry index of the legs ($H(3) = 8.259$, $p = 0.041$, $eta^2 = 0.101$) between groups. Post-hoc pairwise comparisons determined that the distance runners had a lower fat mass symmetry index than the throwers ($U = 13.000$, $z = -2.399$, $p <0.001$, $r = 0.565$; small effect). In addition, there were differences in the symmetry index measures of arm lean mass ($H(3) = 9.404$, $p = 0.024$, $eta^2 = 0.152$; trivial effect), fat mass ($H(3) = 17.822$, $p < 0.001$, $eta^2 = 0.353$; small effect), and tissue mass ($H(3) = 11.632$, $p = 0.009$, $eta^2 = 0.206$; small effect) between groups (See Table 3).

Table 2. Means ± Standard Deviations of Vertical Jump, Broad Jump, and Sprint Measures.

	Sprinters	Distance Runners	Throwers	Jumpers	ICC (95% CI)
Vertical Jump Height (cm)	40.73 ± 11.04†	23.62 ± 6.46	32.40 ± 9.02	37.50 ± 13.03	0.90 (0.80-0.95)
Vertical Jump Right Leg Peak Force (N)	1032.29 ± 323.31†,*	658.19 ± 141.69*,§	1384.91 ± 335.94§	894.53 ± 91.68	0.99 (0.98-0.99)
Vertical Jump Left Leg Peak Force (N)	1000.15 ± 303.59†,*	654.46 ± 149.78*,§	1384.44 ± 253.31§	885.27 ± 64.88	0.99 (0.98-0.99)
Vertical Jump Normalized Right Leg Peak Force (N/kg)	15.09 ± 3.82†,*	11.31 ± 1.88	11.72 ± 1.45	12.73 ± 1.48	0.97 (0.95-0.99)
Vertical Jump Normalized Left Leg Peak Force (N/kg)	14.59 ± 3.16†,*	11.28 ± 2.40	11.66 ± 1.64	12.27 ± 0.69	0.98 (0.96-0.99)
Broad Jump Measures					
Broad Jump Distance (cm)	214.29 ± 21.51†	161.07 ± 32.74§	195.00 ± 32.17	235.29 ± 21.56	0.97 (0.94-0.98)
Broad Jump Right Leg Peak Force (N)	916.39 ± 237.19†,*	656.77 ± 137.73*,§	1329.40 ± 207.85§	852.95 ± 107.31	0.99 (0.98-0.99)
Broad Jump Left Leg Peak Force (N)	914.01 ± 280.68†,*	638.39 ± 118.16*,§	1254.37 ± 189.87§	900.77 ± 168.42	0.94 (0.89-0.97)
Broad Jump Normalized Right Leg Peak Force (N/kg)	13.36 ± 2.86†,*	10.97 ± 1.33	10.65 ± 0.71	12.38 ± 1.72	0.97 (0.95-0.99)
Broad Jump Normalized Left Leg Peak Force (N/kg)	13.50 ± 2.95†,*	11.33 ± 2.21§	10.87 ± 0.42	13.49 ± 2.62	0.79 (0.62-0.88)
Sprint Measures					
30m Fly Sprint Completion Time (s)	3.38 ± 0.30†,*	3.99 ± 0.48§	4.13 ± 0.46§	3.31 ± 0.21	0.97 (0.95-0.98)
Right Foot Step Length (cm)	203.00 ± 15.21	193.43 ± 12.63	189.13 ± 17.30§	212.00 ± 18.45	0.92 (0.85-0.96)
Left Foot Step Length (cm)	202.12 ± 16.91	194.93 ± 16.04	188.63 ± 23.28	210.29 ± 17.69	0.94 (0.89-0.97)
Right Foot Contact Time (s)	0.11 ± 0.17†,*	0.13 ± 0.02§	0.15 ± 0.02§	0.11 ± 0.02	0.78 (0.56-0.89)
Left Foot Contact Time (s)	0.11 ± 0.02†,*	0.13 ± 0.02*	0.16 ± 0.02§	0.12 ± 0.01	0.88 (0.76-0.94)
Right Foot Flight Time (s)	0.11 ± 0.01	0.12 ± 0.02*	0.10 ± 0.02	0.11 ± 0.01	0.72 (0.45-0.86)
Left Foot Flight Time (s)	0.11 ± 0.02	0.12 ± 0.02*	0.10 ± 0.01§	0.13 ± 0.01	0.67 (0.34-0.83)

† = significantly different from the Distance group; § = significantly different from the Jumpers Group; * = significantly different from the Throwers Group.

Table 3. Means ± Standard Deviations of DEXA and performance asymmetry measures.

	Sprinters	Distance	Throwers	Jumpers
Leg Asymmetry				
Lean Mass SI (%)	1.91 ± 1.05	1.93 ± 1.57	1.02 ± 0.78	2.17 ± 1.36
Fat Mass SI (%)	2.36 ± 2.07	1.46 ± 1.18*,§	3.92 ± 2.42	3.94 ± 2.26
Tissue SI (%)	1.52 ± 1.10	1.66 ± 1.31	1.61 ± 1.15	2.28 ± 1.82
BMD SI (%)	1.31 ± 1.41	0.71 ± 0.61	0.97 ± 0.79	1.02 ± 0.61
Arm Asymmetry				
Lean Mass SI (%)	4.75 ± 3.89*	4.40 ± 3.72*	1.01 ± 1.47	2.22 ± 2.10
Fat Mass SI (%)	4.85 ± 3.95*,§	6.82 ± 4.46*,§	0.27 ± 0.39	1.35 ± 2.56
Tissue SI (%)	4.49 ± 3.88*	4.58 ± 3.03*	0.73 ± 1.07	1.96 ± 1.89
BMD SI (%)	2.85 ± 2.38	1.07 ± 1.00	1.18 ± 2.04	1.22 ± 1.51
Trunk Asymmetry				
Lean Mass SI (%)	2.10 ± 1.38	2.05 ± 1.24	1.76 ± 1.30	1.74 ± 0.64
Fat Mass SI (%)	5.11 ± 3.86	3.08 ± 2.15	2.00 ± 1.71	3.50 ± 3.37
Tissue SI (%)	2.03 ± 1.76	2.09 ± 1.34	1.90 ± 1.36	1.48 ± 1.07
BMD SI (%)	1.32 ± 0.85	1.33 ± 1.07	1.24 ± 0.67	0.88 ± 0.57
Totals Asymmetry				
Lean Mass SI (%)	0.98 ± 0.86	1.80 ± 1.52	0.62 ± 0.69	0.75 ± 0.19
Fat Mass SI (%)	1.93 ± 1.45	1.78 ± 1.05	1.60 ± 1.55	1.80 ± 1.41
Tissue SI (%)	0.91 ± 0.73	1.57 ± 1.30	1.08 ± 0.67	0.89 ± 0.45
BMD SI (%)	1.98 ± 2.84	1.73 ± 1.58	1.14 ± 0.92	1.02 ± 0.82
Performance Asymmetry Measures				
Vertical Jump Peak Force SI (%)	3.52 ± 3.07	3.45 ± 1.83	5.05 ± 1.93	3.41 ± 3.86
Broad Jump Peak Force SI (%)	4.87 ± 6.10	4.44 ± 3.71	3.72 ± 2.41	3.93 ± 3.99
Step Length SI (%)	2.37 ± 1.96	1.49 ± 1.33	2.04 ± 1.68	2.81 ± 2.56
Contact Time SI (%)	4.70 ± 8.98	1.53 ± 1.25	4.48 ± 7.42	5.55 ± 8.54
Flight Time SI (%)	5.57 ± 5.47	5.15 ± 2.90	5.57 ± 4.86	5.73 ± 7.08

SI = Symmetry Index; BMD = Bone Mineral Density; † = significantly different from the Distance group; * = significantly different from the Throwers Group; § = significantly different from the Jumpers Group.

DISCUSSION

The purpose of this study was to examine the differences in morphological, jump, and sprint kinematic asymmetries between athletes competing in symmetrical and asymmetrical track and field events. It was hypothesized that the athletes competing in asymmetrical events would have greater morphological and performance asymmetries than those competing in symmetrical events. This was partially supported as morphological asymmetry differences were observed between these groups but no differences in peak force asymmetries during the bilateral VJ and BJ were found. Additionally, during the 30-meter fly sprints, there were no significant differences in SL, FT, or CT asymmetries between the groups.

Studies comparing asymmetries in different sports have reported significantly greater asymmetries in those with asymmetrical sport demands. Luk and colleagues reported greater VJ peak force asymmetries in collegiate jumpers in comparison to powerlifters (23). There have also been differences in isokinetic strength asymmetries observed when comparing young athletes who competed in symmetric, asymmetric, and hybrid sports (18). In comparison to soccer and cricket players, classified as symmetrical and asymmetrical athletes respectively, Bishop and colleagues reported that cricket players had significantly greater asymmetries during unilateral drop jumps but not unilateral VJs (3). While these studies report greater asymmetries in those athletes competing in asymmetrical sports, in contrast the current study showed no differences between athletes practicing symmetrical and asymmetrical sports. The difference in findings may be attributed to the difference in assessments utilized, differences in the populations assessed, as well as differences in the methods of calculating the magnitude of the asymmetries.

While differences were observed in peak force values and normalized peak force values between groups during the VJ, there were no differences in peak force asymmetries between these subsets. Currently, to the best of the authors knowledge no other study has compared the jump asymmetries in track and field athletes competing in different events. However, studies have reported VJ asymmetries in track and field athletes. Luk and colleagues found that the collegiate jumpers had peak force asymmetries during the VJ of 6.73 ± 1.84% which were significantly greater than the powerlifters (2.74 ± 0.74%) (23). It should be noted that the magnitude of peak force asymmetries observed in the current study was 3.41 ± 3.86%, lower than the asymmetries observed by Luk and colleagues. A possible explanation for this could be the inclusion of male and female jumpers in the current study whereas Luk and colleagues assessed male athletes only. Weatherholt and Warden also reported bilateral VJ asymmetries in collegiate jumpers and distance runners of 10.4% and -1.2% respectively (34). Differences in the asymmetries observed by Weatherholt and Warden and the current study may be attributed to differences in the method of calculating the inter-limb asymmetries. While Weatherholt and Warden calculated the asymmetries based on the dominant and non-dominant legs of the participants, the current study utilized the symmetry index which calculates the asymmetries based on the higher and lower values and does not use a reference leg. This study did not utilize the dominant and non-dominant legs as it has been recommended to avoid reference limbs for asymmetry calculations (30).

In examination of the BJ, the current study found no significant differences in peak force asymmetries between groups. To the authors knowledge, there are no other studies that compare the asymmetries in the BJ between athletes who compete in asymmetrical and symmetrical sports. While recent studies reported that the bilateral BJ was a greater predictor of sprint performance and sprint profile measures than the VJ in collegiate track athletes (11), researchers have yet to examine the relationship between BJ asymmetries and sprint performance in this population. Associations have been reported between unilateral broad jump distance with sprint and change of direction performance in team-sport athletes (22). There were also associations between unilateral BJ distance with repeated sprint performance reported in adolescent handball athletes (24). Given these observed associations, future studies should seek to examine if there is a relationship between BJ asymmetries and sprint performance in collegiate track and field athletes.

Researchers have yet to compare the asymmetries of sprint kinematics across athletes who compete in different track and field events. Studies have examined how sprint asymmetries differ between men and women, across youth of different age groups, and across different sprint training levels. Bissas and colleagues found no differences in any asymmetry measure between the male and female athletes when examining sprinters competing in the 100 meters event at the 2017 world championship (8). In addition, the same research team reported no associations between sprint asymmetries and sprint performance (8). Mo and colleagues compared the sprint kinetic and kinematic asymmetries between novice, recreational, and competitive runners at increasing velocities (25). This study found group by speed interactions for the time to peak vertical ground reaction forces asymmetry measures with novice runners increasing their symmetry index with increasing speeds and competitive runners decreasing in asymmetries with increasing speeds. When comparing the different groups in the current study, there were no differences in the asymmetries measured for SL, FT, and CT. A potential reason for this may be the use of a single stride cycle (two consecutive steps) in the current study as opposed to calculating mean values across multiple sprint steps. Future studies should measure these variables over multiple stride cycles to see if greater asymmetries are observed over longer distances.

Of the subset of subjects who underwent DEXA scans, there were only differences found in asymmetry measures of the fat mass of the legs, and asymmetry measures of the arms. Studies have previously reported morphological asymmetries in javelin throwers (20) and jumpers (21), but have yet to determine if these differ between sprinters, jumpers, distance runners and throwers. In examining the current findings, distance runners had lower asymmetries in the leg fat mass than both the jumpers and throwers. Whereas in the arm asymmetry measures throwers had lower asymmetry measures than the distance runners and sprinters. As has been previously suggested by other researchers, these findings may be attributed to sport demands (15, 17). Runners perform cyclical lower body movements when running whereas jumpers and throwers utilize a dominant limb when performing throwing and jumping events. Thus, this may explain the differences in fat asymmetry of the legs shown in the current findings; however, this would not explain why there were no asymmetry differences in the lean mass, tissue mass, or bone mineral density asymmetry measures. On the other hand, the throwers had lower arm asymmetry measures than the sprinters and distance runners, which can also be attributed to the demands of the sport as throwers need to train the upper body for their event more than sprinters and distance runners. Given these findings, future studies should seek to examine this further to determine if different populations yield different findings. Additionally, future studies should seek to examine if the morphological asymmetries play a role in the performance asymmetries during jumping and sprinting tasks.

There are limitations to this study. First is the collection of only two steps during the sprints. Future studies should seek to collect a greater number of steps during maximal velocity sprints to determine if the asymmetries would differ over longer distances. Additionally, this study included both male and female athletes potentially affecting the comparison between groups. While Bissas and colleagues reported no differences in sprint asymmetries between males and females (8), differences in asymmetries between males and females during the VJ were reported by Bailey and colleagues (1). Thus, future studies should seek to subset track and field athletes by events and by sex. The current study did not have a large enough sample of female athletes for the events by sex comparison and thus both males and females were examined together. Another limitation would be the sample size as there were small sample sizes in the thrower and jumper groups. Thus, subsequent studies should utilize larger sample sizes to determine if different findings are observed.

In conclusion, despite having differences in movement demands between track and field athletes competing in sprint, distance running, jumping, and throwing events, there does not appear to be any differences in the magnitude of asymmetries during the VJ, BJ, and maximum velocity sprints. Yet, small morphological differences in symmetry were noted across track and field events potentially driven by sport demands.

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