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Comparison of Isokinetic Knee Flexion and Extension Strength between Trained Dancers and Traditional Sport Female Collegiate Athletes

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ABSTRACT

International Journal of Exercise Science 10(8): 1196-1207, 2017. Traditional sport athletes and dancers experience various injuries while participating in their respective sport. Injury rates, especially to the anterior cruciate ligament (ACL), differ between these populations. Isometric and isokinetic strength and hamstring:quadriceps (H:Q) ratios may help to explain the difference in ACL injury rates between these populations. The purpose of this investigation was to determine the difference in isometric and concentric knee flexion and extension peak torque, and H:Q strength ratios between female dancers and division I collegiate soccer and track and field athletes. Seventeen dancers (20.53±1.51yrs, 65.60±2.06in, 62.29±8.63kg) and 24 traditional sport athletes (19.63±1.17yrs, 65.68±2.52in, 62.84±7.17kg) performed bilateral isometric and concentric knee flexion and extension peak torque on a Biodex System 3 dynamometer. Peak torque and peak torque/body weight were recorded, and H:Q ratios were calculated for both isometric and concentric trials by dividing peak knee flexion torque by peak knee extension torque and were recorded as a percentage. A 2 by 2 (group by limb) ANOVA was used to analyze each dependent variable. Bilaterally, non-dance female athletes demonstrated significantly stronger knee flexion torque and increased H:Q ratios when compared to female dancers. These results, although different from the a priori hypothesis, may be attributed to the strength training the traditional athletes participate in. Future research should investigate other variables, such as hip strength, to better explain the differences in ACL injury rates between dancers and traditional sport athletes.

KEY WORDS: Isokinetic dynamometer, lower extremity injury, musculoskeletal injury

INTRODUCTION

Traditional sport athletes and dancers experience various injuries when training and competing in their respective sports. Musculoskeletal injuries in female traditional sport athletes are very common, even though many of these athletes are considered to be in top physical shape. The extensive hours spent training and competing can be taxing on the body, resulting in both acute and chronic injuries. Injury incidence rates for collegiate female track and field and soccer athletes have been documented at 3.3 and 5.5 injuries per 1000 hours of sport participation, respectively (7, 35). One common injury, especially in female soccer athletes is anterior cruciate ligament (ACL) injury. The incidence of ACL injury in female soccer athletes has been reported between 0.06 to 3.7 ACL injuries per 1000 hours of soccer participation (9, 16). In comparison, the incidence of ACL injury in dancers is much lower with documented rates between 0.005 and 0.015 and per 1000 hours of dance participation (26).

In 1975, dance was first mentioned in the literature as a sport, and since then, research has documented the high physical demands involved in dance participation and some now consider dancers to be the ultimate athlete due to the motor skills required for participation (13, 28). In order to perfect their skills, high level dancers often spend 5-6 days and up to 45 hours per week training depending on their level (12). Similar to a traditional sport athletes, the high demand required in dance training often results in injury. The average incidence rate of injury among female amateur and professional dancers has been documented between 0.99 and 1.06 injuries per 1000 dance hours, but has been reported as high as 4.44 injuries per 1000 hours of participation (4, 11, 15, 34). Even with the high demands placed on the dancer's body, reported injury rates are still lower than those reported in collegiate track and field and soccer athletes (7, 9, 16, 35). Specifically, the lower ACL injury rate in the dance population has been attributed to the choreographed movements and extensive training in landing technique that dancers receive (26).

Previous research has investigated the strength and muscle activation in female traditional sport athletes in an effort to explain the high rate of ACL injuries in this population (20, 29, 30). Female traditional sport athletes have demonstrated increased quadriceps activation during jump-landing while hamstring activation did not change (29). This quadriceps dominant activation strategy during landing puts these individuals at greater risk for lower extremity injury (18, 29, 37). In addition, researchers have analyzed the isokinetic hamstring: quadriceps (H:Q) ratio in female athletes in order to identify those individuals who have poor hamstring strength or are more quadriceps dominant. In healthy individuals, H:Q ratios of 50-80% have been reported as normal, depending on the angle and/or angular velocity used during testing (23). Others report that a H:Q ratio of 60% or less would indicate a strength imbalance between the hamstring and the quadriceps which could potentially predispose an athlete to injury (14, 23). Previous research on traditional sport female athletes identified greater imbalances (lower H:Q ratios) and relatively weak hamstring strength in female track and field athletes who sustained hamstring injury and in female soccer athletes who sustained an ACL injury (31, 35). In contrast, dancers have recorded H:Q ratios between 35% and 50% which would indicate an increased risk of injury, while other have reported ratios between 62% and 68% which would be considered normal (2, 13, 21, 24, 27). Additionally, when compared to sedentary females, professional dancers demonstrated significantly higher hamstring isokinetic strength, but no difference in quadriceps strength; however H:Q ratios were not recorded (25). To our knowledge, there has not been a direct comparison of quadriceps and hamstring strength, or H:Q ratio between dancers and traditional sport female athletes.

Previous research has provided evidence that dancers have a lower overall injury incidence rate and a lower ACL injury incidence rate than traditional sport female athletes, however research is lacking in information comparing quadriceps and hamstring strength and H:Q ratio between these two groups (4, 11, 15, 26, 34). Therefore, the purpose of this investigation was to determine if there was a difference in isometric and isokinetic knee flexion and extension peak torque, and H:Q strength ratios between female theater dance majors and division I collegiate soccer and track and field athletes. We hypothesized that the traditional sport female athletes would demonstrate higher isokinetic and isometric knee flexion and extension peak torque values than the dancers, while the dancers would demonstrate significantly higher isokinetic and isometric H:Q ratios than the traditional sport female collegiate athletes.

METHODS

Participants

This investigation utilized a cross-sectional research design to analyze isometric and isokinetic knee flexion and extension strength between female university theater dance majors and division I traditional sport female soccer and track and field athletes. This study was approved by the university's institutional review board. Seventeen female dancers (dance group) from the university's theater dance program volunteered for study participation. (Table 1) These dance program majors reported an average of 13.25±5.17 years of overall dance experience, but the type of dance experience varied among participants (Table 2). Twenty four division I collegiate female athletes (traditional sport group) from the university's women's soccer (n=14) and track and field (n=10) teams (Table 1) also volunteered to participate in this study. Prior to study participation, participants signed the university approved informed consent form, and completed the medical history questionnaire and the dance history questionnaire (dance group only). All participants were injury free and cleared for full dance/sport participation at the time of testing. Additional exclusionary criteria included history of lower extremity fracture, surgery or history of ACL injury.

Table 1. Participant Descriptive Information (Mean ± SD).

	n	Age (yrs)	Height (in)	Weight (kg)
Dance Group	17	20.53±1.51*	65.60±2.06	62.29±8.63
Trad Sport Group	24	19.63±1.17	65.68±2.52	62.84±7.17

*Significant difference between groups (p<0.05)

Table 2. Type and Length of Dance Experience in Years (Number (percentage %) of participants).

Dancers (n=16*)	<5 years	5 to 10 years	10-15 years	>15 years
Ballet	6 (37.5%)	2 (12.5%)	2 (12.5%)	6 (37.5%)
Jazz	7 (43.8%)	3 (18.8%)	3 (18.8%)	3 (18.8%)
Tap	3 (18.8%)	3 (18.8%)	2 (12.5%)	3 (18.8%)
Modern	7 (43.8%)	4 (25.0%)	2 (12.5%)	0
Contemporary	5 (31.3%)	7 (43.8%)	2 (12.5%)	1 (6.3%)
Hip Hop	4 (25.0%)	5 (31.3%)	3 (18.8%)	1 (6.3%)

*One participant did not complete the dance history questionnaire.

Protocol
A Biodex System 3 dynamometer (Biodex Medical Systems Inc, Shirley, NY) was used to measure bilateral isometric and concentric knee flexion and extension peak torque. Isometric testing was chosen to evaluate peak torque at a set point in the mid-range of the joint. Isokinetic testing at $60°sec^{-1}$ was chosen because the angular velocity of $60°sec^{-1}$ is considered a "strength assessment speed" and has been shown to be more consistent than faster speeds (8, 32). Calibration and patient positioning were performed according to the manufacturer's guidelines (5, 8).

For both isometric and concentric testing, the seat back was reclined 10°, and the dynamometer was aligned with the knee's axis of rotation for the test leg. The knee flexion/extension attachment was secured to the lower leg approximately 5 cm superior to the lateral malleolus (1, 2). (Figure 1) Stabilization straps were used at the chest and mid-thigh to minimize movement during testing. Participants completed familiarization trials before each test that included completion of three submaximal extension and three submaximal flexion repetitions in both the isometric and concentric settings. All testing was conducted bilaterally and the order of test and side completion was randomly assigned. Dominant leg was determined by asking the participant which leg they would kick a ball with. Participants were given two minutes recovery between tests. During each test, participants were instructed to give their best effort and verbal and visual encouragement was given during all tests to help encourage maximal effort.

Figure 1. Patient position for isometric and isokinetic testing.

Isometric knee flexion and extension were collected with the knee fixed at 60° of flexion. The participant was instructed to push out into knee extension as hard and as fast as possible for five seconds. They were given a five second rest period and were then instructed to pull into knee flexion as hard and as fast as possible for five seconds, which was again followed by a five second rest period. The five seconds of knee extension, five second rest, five seconds of knee flexion, and five second rest was considered one repetition. Three consecutive repetitions were completed for each leg

Concentric knee flexion and extension were collected at 60°sec^{-1} through a range of motion of 0° to 90°. The participants were instructed to push out into knee extension as hard as possible, and when end range of motion was reached, they were instructed to pull in to knee flexion as hard as possible. Full knee extension followed by full knee flexion was considered one repetition. Three consecutive repetitions were completed for each leg.

Isometric and concentric peak knee flexion and extension torque (Nm) and peak torque/body weight (kg) (PT%BW), were recorded for both the dominant and non-dominant legs. The maximal value of the three repetitions for each test was used in analysis. The H:Q strength ratio was calculated for both concentric and isometric trials by dividing peak knee flexion torque by peak knee extension torque and were reported as a percentage (23).

Statistical Analysis

Descriptive statistics were calculated for group demographics using independent t-tests. (Table 1) The Shapiro-Wilk test was used on each dependent variable to determine normal distribution. A 2 (group: dance and traditional sport) by 2 (limb: dominant and non-dominant) analysis of variance (ANOVA) was used to analyze each dependent variable. All statistics were performed using SPSS version 22. Significance level was set a priori at $p<0.05$.

RESULTS

There was a significant difference in age between groups ($p=0.04$, dance group: 20.53±1.51 yrs, traditional sport group: 19.63±1.17yrs). There were no significant differences in height or weight between groups (Table 1). Sixteen of seventeen participants in the dance group completed the dance history questionnaire (Table 2). Results of the Shapiro-Wilk test of normal distribution revealed no significant differences, indicating that all dependent variables were normally distributed.

Table 3. Isometric and isokinetic test scores, dominant leg (mean ± standard deviation).

	Dance Group		Trad Sport Group	
Isometric Measures	Extension	Flexion	Extension	Flexion
Peak Torque (Nm)	126.44 ± 39.69	85.42 ± 17.94*	130.06 ± 35.40	101.19 ± 19.10
Peak Torque/BW (%)	202.22 ± 53.57	137.37 ± 25.46*	206.81 ± 50.41	161.08 ± 26.49
HS: Quad Ratio (%)	70.76 ± 14.96*		80.49 ± 14.48	
Concentric Measures				
Peak Torque (Nm)	95.85 ± 34.49*	68.57 ± 20.37*	116.60 ± 36.69	82.48 ± 20.73
Peak Torque/BW (%)	156.35 ± 53.57	111.25 ± 31.68*	185.55 ± 53.26	131.35 ± 29.93
HS: Quad Ratio (%)	74.97 ± 18.19		73.42 ± 15.64	

* Significance difference between groups (p<0.05).

Isometric Variables: There were no significant group by limb interaction effects for knee flexion or knee extension peak torque, PT%BW or H:Q ratio (p>0.05). The traditional sport group generated significantly more isometric peak knee flexion torque (dominant: p=0.001, non-dominant: p=0.03) and isometric peak knee flexion PT%BW (dominant: p=0.001, non-dominant: p=0.03) compared to the dance group. The traditional sport group also generated a significantly higher isometric H:Q ratio in both the dominant (p=0.005), and non-dominant (p=0.05) limbs, compared to the dance group. (Figure 2) There were no significant within group differences between limbs (p>0.05). (Tables 3 and 4).

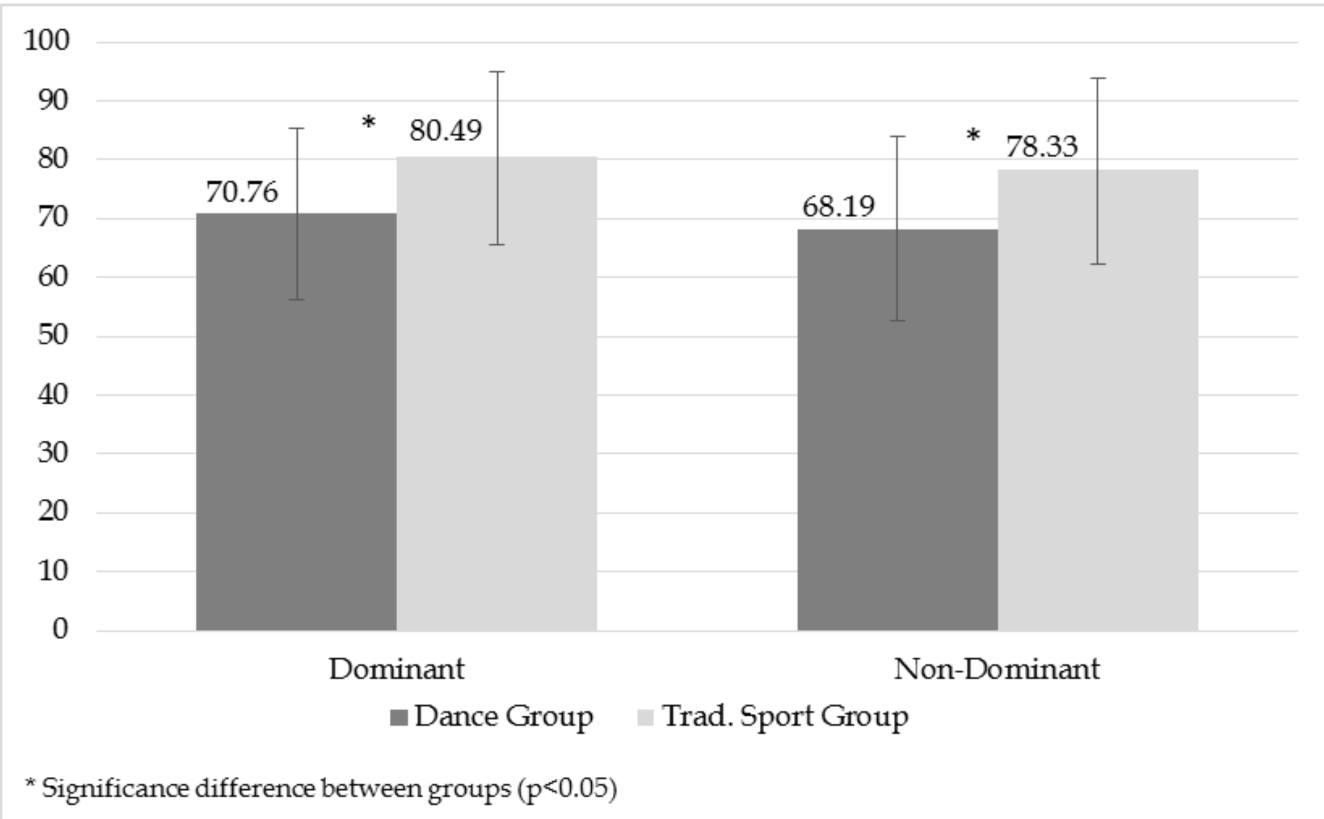

Figure 2. Isometric H:Q ratio for dominant and non-dominant limbs.;

Table 4. Isometric and isokinetic test scores, non-dominant leg (mean ± standard deviation).

	Dance Group		Trad Sport Group	
Isometric Measures	Extension	Flexion	Extension	Flexion
Peak Torque (Nm)	128.07 ± 41.01	83.48 ± 19.96*	128.33 ± 30.78	97.79 ± 19.60
Peak Torque/BW (%)	205.28 ± 58.42	133.47 ± 30.64*	203.98 ± 44.81	155.78 ± 28.18
HS: Quad Ratio (%)	68.19 ± 16.16*		78.33 ± 15.62	
Concentric Measures				
Peak Torque (Nm)	92.74 ± 26.46*	66.57 ± 18.67*	110.53 ± 25.01	80.20 ± 17.13
Peak Torque/BW (%)	150.05 ± 37.31*	107.57 ± 25.38*	176.37 ± 35.64	127.86 ± 24.26
HS: Quad Ratio (%)	72.45 ± 10.87		73.62 ± 13.54	

* Significance difference between groups (p<0.05).

Concentric Variables: There were no significant group by limb interaction effects for knee flexion or knee extension peak torque, PT%BW or H:Q ratio (Figure 3) (p>0.05). The traditional sport group generated greater concentric peak knee extension torque (dominant: p=0.008, non-dominant: p=0.036), concentric peak knee extension PT%BW (dominant: p=0.009, non-dominant: p=0.029), concentric knee flexion peak torque (dominant: p=0.002, non-dominant: p=0.022), and concentric peak knee flexion PT%BW (dominant: p=0.002, non-dominant: p=0.014) compared to the dance group. There were no significant within group differences between limbs (p>0.05).

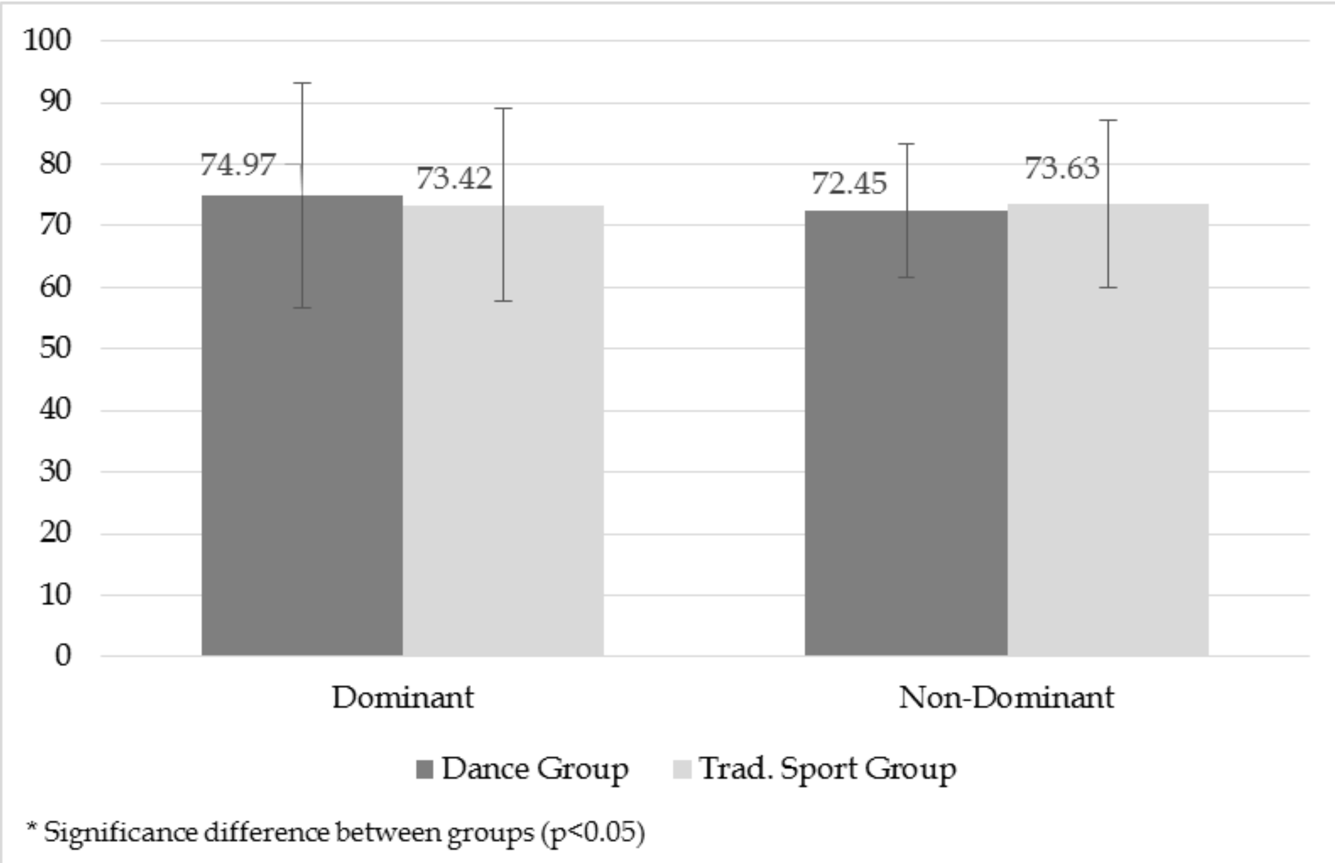

Figure 3. Concentric H:Q ratio for dominant and non-dominant limbs.

DISCUSSION

The aim of this investigation was to evaluate the difference in isometric and isokinetic knee flexion and extension peak torque and H:Q ratio strength between female dancers and division I collegiate soccer and track and field athletes. Our results demonstrated significantly lower knee flexion and extension peak torque and isometric H:Q ratio in the dance group compared to the traditional sport group (Figure 2). This result is contrary to our hypothesis and indicates that the dance group is more quadriceps dominant than the traditional sport group. A more quadriceps dominant individual is thought to be at higher risk for ACL injury (29, 35, 37). The range of isometric H:Q ratio for both the dominant and non-dominant limbs of the dance group ranged from 68-70%. These scores are greater than the values previously reported in the dance population which range from 35-68%, indicating that the dancers in the current study demonstrated more balanced strength between the hamstrings and quadriceps (2, 13, 21, 24, 27). Additionally, although the dance group reported a lower isometric H:Q ratio compared to the traditional sport group, the range of 68-75% is above the previously documented 60% threshold for increased risk of ACL injury. The traditional sport group reported dominant limb isometric H:Q ratios of 80%. Previous research on female college athletes have reported H:Q ratios ranging from 49-73% (2, 22, 31, 33). One possible explanation for high H:Q ratio could be the required strength training programs these athletes complete. Due to the importance of hamstring strength in knee injury prevention, strength coaches have increased emphasis on hamstring strengthening in order to maximize balanced hamstring and quadriceps strength and minimize injury. This emphasis on hamstring strength could be an explanation as to why these athletes demonstrated increased ratios compared to the dance group and compared to previously published data, as all of the traditional sport athletes in this study participated in formal strength training programs.

In the current study, a significant difference was found between groups for isometric H:Q ratio, but no difference was found for concentric H:Q ratio at 60°sec^{-1} (Figure 3). This result was contrary to our hypothesis that both isometric and concentric H:Q ratios would be higher in the dance group compared to the traditional sport group. Generally, as velocity increases, the decline observed in knee extension peak torque is greater than the decline observed in knee flexion peak torque, which results in a higher H:Q ratio at higher velocities (6, 19). Interestingly, in the current study, the dance group lost a greater percentage of knee extension peak torque at 60°sec^{-1} which resulted in a greater H:Q ratio compared to the traditional sport group, while the traditional sport group lost a greater percentage of knee flexion peak torque which decreased the H:Q ratio at 60°sec^{-1} compared to the dance group. These changes observed in both groups between isometric and concentric H:Q ratios resulted in no significant difference between groups in the concentric trials.

The decrease in H:Q ratio at 60°sec^{-1} in the traditional sport group may help to explain why there is a higher injury incidence rate in traditional sport female athletes. Isometrically, the traditional sport group reported high H:Q ratios, but when the angular velocity was increased to 60°sec^{-1}, the ratios decreased. Dynamic activities such as running and landing result in angular velocities up to 500°/sec at the knee joint (36). Although both the quadriceps and hamstring muscles are strong in the traditional sport group, the ability to produce a strong contraction at greater speeds may be limited, putting them at increased for injury. It is likely that the traditional sport group spends more time performing resistance training, while the dance group spends more time practicing/performing dynamic activities. The traditional sport group still report greater peak torque at 60°sec^{-1}, but the dance group demonstrated improvement in H:Q ratio as angular velocity increased. The dance group may be able to produce more balanced H:Q ratios at higher velocities which may help protect this population from injury. Future research should evaluate isokinetic strength at higher velocities to make comparisons with more dynamic activities and possibly relate the information to injury risk.

We hypothesized that the traditional sport group would have increased isometric and isokinetic strength compared to the dance group. This hypothesis was confirmed with significant differences displayed between groups for isometric knee flexion and isokinetic knee flexion and knee extension. As mentioned above, the emphasis of balanced quadriceps and hamstring strength through organized strength and conditioning programs with the traditional sport group, could put them at an advantage compared to the dancers who may not have exposure to an organized strength and conditioning program. More balanced lower extremity musculature and stronger muscles in general could increase dynamic control of the lower extremity and potentially decrease injury risk (18, 29, 37).

In the current study, there were no bilateral strength differences found within groups. However, a common mechanism for lower extremity injury, especially ACL injury, is an off balance, unilateral landing (3, 10, 17). The participants in this study all participated in athlete activities which require both bilateral and unilateral landings. Dancers often use their dominant limb during the take-off phase of a jump and during landing and balance (2). Track and field athletes also use similar strategies as the dominant limb is usually preferred for push-off and landing. Soccer athletes may differ, as kicking a ball is most often done by the dominant leg, and the body is supported by the non-dominant leg. Previous research on bilateral knee flexion and extension strength differences in female track and field athletes found that individuals with a 15% bilateral knee flexion strength difference had a 2.6 times greater risk of lower extremity (22). Although, the participants in the current study did not demonstrate bilateral strength differences, this factor could still increase injury risk and should be considered with injury prevention.

One limitation of this investigation was the diverse background of the dance group. The dance group was made up of university theater dancers with varying levels of experience in several different types of dance. All of the dance participants had at least some experience in ballet training, but also had experience in various other types of dance including: modern, jazz, tap, contemporary and hip hop. This diverse dance population did not allow us to identify characteristics of dancers who specialized in a specific form of dance, however; the dance population in this investigation can represent overall characteristics of dancers as a whole.

Another limitation was the speed of isokinetic testing used to measure peak torque. Isokinetic knee flexion and extension peak torque at $60°sec^{-1}$ were used in this study because of the consistency of measurements at this speed (8, 32). Faster isokinetic speeds may be beneficial in comparing to more dynamic activities and relating measures taken in a laboratory setting to a more practical setting. Measurements at $60°sec^{-1}$ are difficult to relate to injury risk because injuries are likely happening at much higher velocities. Future research should investigate isokinetic testing at higher rates of speed to better compare to actual dynamic activities performed during athletic participation. Even if isokinetic testing could be performed at higher velocities, caution should be made when comparing these laboratory open kinetic chain movements, to the closed kinetic chain movements that are occurring during injury mechanisms.

In conclusion, bilaterally, traditional sport female athletes demonstrated stronger knee flexion and better H:Q ratios when compared to female dancers. These results were in partial agreement with our hypothesis that traditional sport female athletes would produce higher isometric and isokinetic peak torque values, and that dancers would demonstrate higher H:Q ratios. The high H:Q ratios exhibited by the traditional sport athletes could be attributed to the required strength training programs these athletes complete. The dance population used in this study did not specialize in one particular type of dance, rather many of the dancers had experience in several types of dance which may have impacted the results. The broad group of dancers in this study may make it difficult to compare to other investigations which have used more specialized groups of dancers; however, it could make the results more generalizable for use over wider populations. Future research should consider comparing knee flexion and extension peak torque at higher isokinetic speeds to provide better comparison to functional movements and should consider comparing hip strength, along with other variables, between dancers and traditional sport athletes. Making comparisons of additional variables between these two populations may help to better explain the differences in injury rates, specifically ACL injury rates between dancers and traditional sports.

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