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Dancers' Physical Fitness across Their Four-Year Collegiate Programs: A Prospective Analysis

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Abstract: Dance is physically demanding, requiring physical fitness(PF) that includes upper body, lower body, core fitness, and balance for successful performance. Whether PF changes as dancers advance from when they enter(freshmen) to when they graduate from their collegiate program(seniors) is unclear. We prospectively compared collegiate dancers' freshman-to-senior PF. We recorded PF of the upper body strength-endurance(push-ups, n=number), core strength-endurance(front, left-side, right-side, and extensor plank hold times, s=seconds), lower body power(Single-leg-hop-SLH distances % Height; Leg Symmetry Index: LSI=higher/lower*100, %), and balance(Anterior Reach Balance, %Leg-Length, LL; LSI balance=higher/lower*100, %) in 25 collegiate dancers(23 females, 2 males; freshmen age=18.2±0.6yrs). Paired t-tests($p \leq .05$) compared measures from freshmen-senior years. Across their collegiate programs, dancers' PF remained unchanged: upper body strength-endurance push-ups numbers($p=.93$), core strength-endurance plank times(left: $p=.44$, right: $p = .67$, front: $p=.60$, $p=.22$), SLH distances(left: $p =.44$, right: $p =.85$) and SLH symmetry($p=0.16$). Dancers' right leg balance($p =.08$) remained similar, while the left balance($p =.02$) improved with better symmetry($p<.001$) in senior balance scores. Overall, dancers' PF did not change across their collegiate programs, except for greater left leg balance scores. Findings suggest that kinesiology practitioners can use collegiate dancers' freshmen baseline PF when devising rehabilitation programs and making return to activity decisions post injury throughout their dance programs.

Keywords: Performing Arts; Core; Push-ups; Planks; Single Leg Hops; Training; Health; Performance; Star Excursion Balance Test; Balance

1. Introduction

Dancing, like athletics is a physically challenging activity, but is also unique as it has the added demands of aesthetically appealing artistry [1–3]. Specifically, dancers regularly perform jumping, landing, and other physically demanding movements [1–3]. Dancing uses similar components of physical fitness as in sport athletes, [4,5] placing dancers at high injury risk [5–7]. Accordingly, researchers note that 50-85% of dancers suffer injury during a performance season [6–8].

Contrary to the misguided belief that physical attributes detract from the aesthetic of dance, adequate muscular strength, endurance, and power are desirable and necessary qualities for dancers to perform well and prevent injury [3,9]. These parameters, which the American College of Sports Medicine combines into the category of "physical muscular fitness" can influence affect dancers' injury risk. [10] Thus, it is important for dancers to have sufficient physical fitness (PF) comprised of muscular strength-endurance, balance, and power to perform well and not get injured when dancing [11–14].

Dance is taught as a formal collegiate program in over 450 colleges and universities in the United States alone and in many more collegiate dance programs globally [15]. Given that collegiate dancers should be physically fit [16,17] combined with observations of high injury rates in dancers [16,18,19], prior authors have suggested that collegiate dance programs should assess their students PF levels [18,20]. Researchers also suggest that practitioners should conduct pre-participation PF screening in dancers [18,21,22]. This suggestion is in line with athletic settings, where practitioners commonly perform annual pre-participation screenings [23,24]. These screenings have multiple components including general medical, biochemical, and PF assessments [23]. While researchers note that yearly laboratory and extensive biochemical screens may not yield substantial clinically significant outcomes from a cost-effectiveness perspective [24–26], screenings are still recommended for athletes as they are often among the only formal medical and health assessments for athletes before participation [23].

In a systematic review and meta analyses of screening tools used as an injury predictor in dance, Armstrong et al. found some evidence for using dance-specific positions as predictors of dance injury [18]. Kinesiology healthcare practitioners working with dancers also use PF screening measures as baselines when creating rehabilitation and return-to-dance protocols for injured dancers [14]. Kinesiology practitioners conducting assessments could also identify freshman dancers with suboptimal levels of PF. Still, some authors conducting PF screening note that the screenings require time and personnel resources [24].

Overall, whether yearly PF testing in collegiate dancers is needed in collegiate dancers is unknown. Relatively little literature[17,27] exists describing PF in collegiate dancers. At present it is unclear if dancers' PF changes as they progress through their collegiate programs. Finally, whether collegiate program dance training alone is enough to maintain PF also remains unknown. Thus, we prospectively compared collegiate dancers freshman and senior PF scores. Our purposes were to describe collegiate dancers' PF, examine asymmetries and relationships in PF, and compare if dancers' PF changed across their collegiate programs. Our primary null hypotheses was that dancers' PF measures would remain unchanged as they progressed from freshmen to senior years in a 4-year collegiate dance program. The secondary null hypothesis was that dancers PF scores would not be related to each other. Our final purpose was to compare dancers' PF to other studies reporting the same measures in collegiate athletes across other sports.

2. Materials and Methods

2.1. Study Design

We used a prospective study design to determine PF in undergraduate collegiate dancers over two 4-year periods (2014-18 and 2015-19). All PF testing was performed in a single session as part of an annual physical fitness assessment which took place at the start of the academic year by trained investigators. Generally, these were all performed at the same time of day to minimize circadian variation in testing [28]. All investigators followed instructions from the same standard instruction manual and were trained by the same lead investigator in this prospective longitudinal study.

2.2. Participants

Twenty-five collegiate dancers (Females: n=23, Males: n=2: freshmen age=18.2±0.6yrs; dance experience = 12 ± 4.2 years; weekly dance training (including classes, rehearsals, and performances = 25.6 ± 5.6 hours) participated in the study. All participants were dance major students in a collegiate program that emphasizes modern dance. However, all dancers had prior experience in other dance styles including, but not limited to ballet, jazz, and hip-hop dance. The George Mason University Institutional Review Board approved the study (IRB # 1849959-1), and all participants gave their written, informed consent before participation.

2.3. Procedures

A member of the research team led participants through a standard warm-up prior to testing. The warm-up session included dynamic movements to increase heart rate and blood flow to muscles and allow dancers to get ready for testing. The warmup session included four exercises performed for one minute each. These exercises were: 1) jumping jacks, 2) overhead arm circles in both directions, 3) buttock heel kicks, and 4) mountain climbers. We then recorded anthropometrics and PF of the lower body, upper body, core, and balance in a station-based format. The primary investigator guided dancers to the different stations using a randomized format to mitigate fatigue and systematic errors effects due to the testing order. All test sessions were conducted by researchers at George Mason University. For all testing sessions, at least two researchers were National Strength and Conditioning Association Certified Strength and Conditioning Specialist and multiple researchers were state licensed and national board certified Athletic Trainers. The PF assessments used in the present study were selected based on reported test-retest reliability necessary for annual testing of dancers [29].

2.4. Measures

2.4.1. Anthropometrics and Training History

We collected dancers' anthropometric data: height was measured to the nearest millimeter using a Seca 216 Stadiometer (Scale Co. Inc, Brooklyn, NY), and body mass to the nearest 0.1 kg using a digital scale (Precision Digital Bathroom Scale, HealthTools LLC, Mahwah, NJ). Dancers also self-reported their dance training history, and their types and volumes of weekly supplementary and cross training outside of dance class.

2.4.2. Upper Body Strength Endurance

Dancers' upper body strength-endurance was examined using the push-up test as described in the American College of Sports Medicine's *Guidelines for Exercise Testing and Prescription* [30] as follows: The participant assumed a straight leg (for males) or modified "knee push-up" posture in the down position (for females): legs together, lower leg in contact with a mat with ankles plantar-flexed, back straight, hands shoulder width apart, head up, using the knees as the pivotal point. The dancer then raised the upper body by straightening the elbows until fully extended. Next, the dancer returned to the "down" position by lowering the upper body until the chin touched the mat. The stomach was not allowed to touch the mat, and the dancer's back was required to remain straight. The test was stopped when the participant strained forcibly or was unable to maintain the appropriate technique within two repetitions. The test has been previously reported to be reliable for examining upper body physical fitness [31].

2.4.3. Core Strength-Endurance

We measured dancers' core strength-endurance using plank tests (or bridge tests – used synonymously in the current study) assessing flexor, right, and left lateral sides using procedures described in prior literature [32,33]. Plank tests have been reported as being valid tests to evaluate core function [34]. For the extensor plank test, we used a modified version of Biering-Sorensen Extensor Endurance Test [35]. Dancers first performed a single practice trial for a few seconds to confirm that they were able to successfully attain the test position. Then, dancers performed one recorded test trial. For all tests, we recorded the maximum time (s) that the dancers were able to hold and maintain the correct test position.

For the front plank test, dancers assumed a push-up posture in the up position: legs together, toes in contact with a mat with ankles plantar-flexed, back straight, hands shoulder width apart, head up. We stopped recording time when any segment of the dancers' body did not remain parallel to the floor as described in prior literature [32].

To perform the left lateral plank test, dancers placed their feet one on top of the other, their left arm (side being tested) perpendicular to the floor, with the elbow resting on the mat and the right arm across the chest on the left shoulder. We used a similar position for the right lateral musculature plank test, with the right arm perpendicular to the floor. The time point when the participants could

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not maintain a straight line between the trunk or lower body (thigh or shank) segments on visual observation was recorded by the investigator [36].

For the extensor test, participants lay prone on an examination table with both their anterior superior iliac spines on the edge of the table, their hands on the seat of a chair placed in front of them at the edge of the table. A research team member held the participants legs above and below their knees to secure participants' lower body (instead of straps to reduce strap friction discomfort). Time was started when participants assumed a horizontal position of the trunk, removing their hands off the chair and crossed them across their chest, and stopped when participants were unable to remain in that position.

2.4.4. Lower Body Power

We examined dancers' lower body power using the Single-Leg-Hop (SLH) test as described in previous literature [37]. Dancers first stood on one leg with their big toe at a marked starting line. Then they performed a single hop, covering as much distance as possible horizontally, and landed on the same leg. The dancers' Single-leg-hop distance was measured from the starting line to heel. Dancers' arms were unconstrained during the hop. The trial was repeated if (1) the dancer's contralateral foot touched the floor, (2) the dancer lost balance, or (3) the dancer took additional hops after the single hop. Dancers performed 3 successful trials on each leg, alternating between sides to prevent fatigue. Then, the hop distance was normalized to the dancers' height (SLH , % height) to reduce the effects of inter-individual anthropometric variations and report these distances for both legs [38]. We averaged dancers' SLH across their freshmen and senior hop distance measures to calculate average SLH during their collegiate programs.

We also examined hop symmetry across legs. Leg symmetry index (LSI) allows bilateral comparison on a test by calculating a ratio of low score divided by high score, which is multiplied by 100 to obtain a percentage [39]. Scores range from 0% to 100% where 100% suggests full functional symmetry [39]. LSI is commonly used for return to activity decisions with a target of 85% LSI before full return to activity [39–41], and asymmetries greater than 15% associated with an increased injury risk [40]. In the current study, LSI was calculated as (higher value/lower value)*100 across legs at two time points: freshmen and senior scores [42].

2.4.5. Balance

We measured balance using the using the Star Excursion Balance Test (SEBT) as it is reported to be able to quantify dynamic postural-control deficits from lower extremity impairment [43,44]. In the current study, we used only the anterior direction reach of this test, as this direction is reported to be a prospective predictive musculoskeletal injury risk factor in a physically active population [45] and in collegiate athletes [46,47].

We showed participants how to perform the test using both verbal instruction and demonstration, and participants were then allowed 3 practice trials before actual test performance consistent with previously published instructions [36]. Participants first assumed a single-leg stance, and then maximally reached along marked lines using the other leg while keeping the stance leg stable at the center of a grid, and then returned the reach leg back to the center without losing balance.

Dancers first performed right leg and then left leg reaches. Dancers had a 15-second rest interval between each trial and on the same leg, and a 1-minute rest interval when changing feet [36]. We did not count a trial and asked the participant to repeat it if: (a) the dancer was unable to maintain single leg stance, (b) the heel of the dancer's stance foot did not remain in contact with the floor, (c) the dancers' weight shifted onto reach foot, or (d) the dancer did not maintain start and return positions each for one second. We averaged and normalized all reach distances across the three trials to % leg length (LL). LL was measured from the anterior superior iliac spine to the medial malleolus. We averaged dancers' balance across their freshmen and senior measures to calculate average anterior reaches during their collegiate programs. We calculated balance asymmetry across legs as several researchers [45,47–49] have used reach asymmetry as an outcome measure of balance. Asymmetry was again calculated using Leg Symmetry Index, where LSI = (higher value/lower value)*100 across legs at two time points: freshmen and senior scores [42].

2.5. Data Extraction and Statistical Analyses

Data were compiled and inputted into a Microsoft Excel (Microsoft Inc., Redmond, WA, USA) worksheet. The mean and standard deviation of all measures were computed. For the push-ups, the maximum number of push-ups performed consecutively without rest was counted as the score [50]. Dancers' push-up scores were averaged across their freshmen and senior measures to calculate average push-ups during their collegiate programs. The dancers' core plank times in each direction across their freshmen and senior measures were averaged to calculate average core plank during their collegiate programs. For SLH, we averaged dancers' SLH across their freshmen and senior hop distance measures to calculate average SLH during their collegiate programs.

Paired t-tests ($p \leq .05$) compared the outcome measures between the two times (Freshmen-Seniors). Pearson correlations compared relationships between outcome variables. All statistical analyses were performed using Jamovi (Jamovi software, version 0.70) and statistical significance level was set to $p<0.05$ for all tests.

3. Results

Dancers' upper body strength-endurance, core endurance, and SLH distances and symmetry remained similar from freshmen-to-senior year (See Table 1). Dancers' right side balance remained similar but left side balance improved from their freshmen to senior year over their collegiate program resulting in better symmetry in senior year balance.

Table 1. Physical Fitness of Collegiate Dancers (Means ± Standard Deviation).

Measure	Side	Freshmen	Seniors	Average	t-value	P-value
Height (cm)		162.9 ± 6.7	163.0 ±6.5		-0.66	0.52
Weight (kg)		59.0 ± 8.3	60.6 ± 9.4		-1.61	0.12
Push Ups (number)		19.3 ± 5.1	19.2 ± 6.5	19.3 ± 4.5	0.79	0.94
Core Plank Test Times (seconds)						
	Flexor	115.1 ± 43.8	108.7 ± 46.4	112. ± 40.4	-1.36	0.44
	Left	67.8 ± 33.3	70.6 ± 19.0	69.2 ±. 21.9	-0.43	0.67
	Right	65.0 ± 30.6	67.7 ± 16.3	66.4 ±. 21.0	-0.52	0.61
	Extensor	130.6 ± 32.7	125.4 ± 41.2	128.0 ± 30.3	0.59	0.56
Single Leg Hop Distance (* Body Height)						
	Left	81.6 ± 11.4	85.9 ± 10.6	83.8 ± 8.3	0.08	0.19

	Right	84.2 ± 13.0	87.6 ± 10.8	85.9 ± 9.3	-1.08	0.29
LSI Single Leg Hops (%)		95.1 ± 4.8	96.2 ± 3.4	95.6 ± 3.8	-1.45	0.16
Anterior Reach Balance Distance ; % Leg Length)						
	Right	71.8 ± 6.5	74.7 ± 6.3	73.3 ± 5.2	-1.87	0.08
	Left	71.5 ± 6.6	75.7 ± 5.9	73.6 ± 5.0	-2.58	0.02
LSI Balance (%)		92.1 ± 5.3	97.0 ± 2.4	94.6 ± 2.7	-4.1	$3.89e^{-4}$

Dancers' plank times across the multiple directions were positively correlated (r values ranging from 0.4 to 0.6), balance reach distances across legs were positively correlated (r=.9), SLH distances across legs were positively correlated (r=.8). However, the different PF measures were not related to each other. (See Table 2)

Table 2. Correlation Analyses Matrix of Physical Fitness in Collegiate Dancers.

		Flexor Plank	**Right Plank**	**Left Plank**	**Extensor Plank**	**Balance – Right**	**Balance – Left**	**SLH – Left**	**SLH – Right**	**Push Ups**
Flexor Plank	r	—								
	p	—								
Right Plank	r	0.6**	—							
	p	*0.0015*	—							
Left Plank	r	0.41*	0.8***	—						
	p	*0.05*	*5.69E-08*	—						
Extensor Plank	r	0.3	0.4*	0.4*	—					
	p	*0.1*	*0.03*	*0.04*	—					
Balance – Right	r	0.01	0.4*	0.2	0.2	—				
	p	*0.95*	*0.04*	*0.3*	*0.3*	—				
Balance – Left	r	0.06	0.4	0.25	0.29	0.9***	—			
	p	*0.7*	*0.05*	*0.2*	*0.19*	*2.72E-09*	—			
SLH - Left	r	-0.1	-0.1	-0.2	-0.04	0.3	0.3	—		
	p	*0.4*	*0.6*	*0.4*	*0.8*	*0.21*	*0.13*	—		
SLH - Right	r	-0.2	-0.3	-0.3	-0.4	-0.06	-0.1	0.8***	—	
	p	*0.18*	*0.1*	*0.1*	*0.05*	*0.8*	*0.7*	*4.16E-06*	—	

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Push Ups (n)	r	0.2	0.02	0.08	-0.15	-0.1	-0.3	-0.06	0.1	—
	p	*0.1*	*0.9*	*0.7*	*0.4*	*0.7*	*0.3*	*0.8*	*0.7*	—

Note. * p < .05, ** p < .01, *** p < .001; r = Pearson's r value, p = -value; Flexor Plank = Flexor Plank Time (s), Right Plank = Right Plank Time (s), Left Plank = Left Plank Time (s), Extensor Plank = Extensor Plank Time (s), Balance - Right = Anterior Reach Balance Distance - Right (% Leg Length-LL), Balance - Left = Anterior Reach Balance Distance - Left (% LL), SLH – Left = Single Leg Hop Distance - Left (* Body Height, BH); SLH – Right = Single Leg Hop Distance - Right (* Body Height).

4. Discussion

In the current study, we examined collegiate dancers' PF scores for changes from freshmen to senior year. Our findings support the primary null hypothesis as we detected no changes in collegiate dancers PF scores. Our secondary hypothesis was partially supported in that the PF measures were positively correlated for tests examining the same body part (e.g., all core PF tests were related) but not correlated over the different PF tests (e.g., core tests were not related to lower leg power).

4.1. Upper Body Strength-Endurance

The upper body strength-endurance (i.e., number of push-ups) of the current dancers values (average ~ 19-20 push-ups) are similar to previous reports in collegiate dancers [50] and recently published norms in collegiate dancers [14]. The current data suggest that collegiate dancers displayed higher upper body strength-endurance as compared to female collegiate soccer players (13.6 ± 2.3) but lower than female collegiate gymnasts (30.5 ± 3.4) [51]. These differences could partially be explained considering the differing demands across these activities. Specifically, soccer is a lower body intensive sport, while gymnastics while it is a full body sport that often relies heavily on upper body strength-endurance. The dancers in the current program were in a collegiate dance program that emphasizes modern dance. Modern dance has both lower and upper body demands [52]. Additionally, as the dancers are in a formal collegiate program, they also take classes in other dance styles that are lower body intensive dance styles like ballet. Therefore, it is understandable that the current dancers push-up scores were in between collegiate soccer players and gymnasts.

Interestingly, the average numbers of push-ups of the current dancers were in the "good" range (15-20) of upper body strength-endurance as classified by the American College of Sports Medicine [10]. This finding supports the notion that dancers are aesthetic athletes and need good upper body PF to perform successfully [14].

In the current study, dancers upper body strength-endurance did not change from freshman year to senior year. This finding suggests that collegiate program dance training helps maintain but does not enhance upper body PF in collegiate dancers. Depending on the perspective, this observation can be interpreted as either a positive - i.e., dancers' stayed fit over their collegiate program; or as a negative i.e., despite collegiate dancers taking part in a rigorous collegiate program – where they are improving their technical dance skills and expertise as they progress from their freshmen to their senior year – their upper body strength-endurance does not improve. We propose a possible theory to explain this observation. As dancers get more skilled (progress from being freshmen to seniors), they become more efficient and can perform higher skilled movements without needing to use their maximal PF capacity to maintain aesthetics. In support of this theory, dancers have been previously reported to subconsciously down modulate jump heights and maximal electrical muscle activity of the quadriceps muscles likely in an effort to maintain the aesthetic component of dance [53]. We recommend additional research to verify this theory to examine whether as dancers progress in their careers (from freshmen to seniors and beyond), they subconsciously downmodulate their maximal PF values – in the upper body, lower body, in functional activities, and in dance-specific movements.

Prior researchers have found a high incidence of shoulder injuries in collegiate modern dancers and suggested that upper body fitness should be included in pre-participation physical screening [52].

However, the authors did not examine baseline upper body strength measures. The current findings support the need to create norms for upper body strength-endurance in dancers' across different genres (e.g., hip-hop, Indian classical dance, jazz) and levels (e.g., adolescents, professional dancers). This work can help rehabilitation clinicians to determine initial pre-injury PF levels and they can use these values as appropriate target rehabilitation cut-offs when working with injured dancers [14].

4.2. Core Strength-Endurance

We chose the plank tests to examine core PF in the current study as they are commonly used in the literature, are reliable, are valid global core muscle fitness measures, and are easy to administer with low technical demands [33,54]. The current dancers' average core flexor plank scores (~115.3 s) are similar to prior reports in collegiate students (~108 s) [55] but somewhat lower than past ranges (~149 - 171 s) in healthy collegiate females [33], collegiate dancers [56], and resistance trained females [57]. The dancers' right and left plank core strength-endurance scores (~65 - 67 s) are similar to previous observations in collegiate dancers [56], college students [55], healthy collegiate females [33], and resistance trained females [57], but somewhat lower than those of elite state level athletes (~80 - 85 s) [54]. The current dancers' extensor plank scores (~164 s) are similar to reports in female cross-county athletes (151 s) [58] and elite state level athletes (~164 s)[54] and somewhat higher than in college students (125 s) [55].

Consistent with prior observations [56], the current dances' core strength-endurance plank scores had large standard deviations, possibly due to the nature of the plank tests that allowed participants to use different strategies to maintain test positions. Prior authors [56] have noted that multiple muscles may influence plank test results: For example, different dancers may have used their shoulder and leg musculature differently to maintain their bodies in the plank position suggesting need to consider other tests to examine core function. Furthermore, core stability exists in a continuum where the core muscles need to produce increasing amounts of force over decreasing amounts of time from core endurance to strength to power [59]. Also other tests exist to examine core PF including the bent knee lowering test [60] among others. Thus, researchers examining core PF should consider both types of tests, ones that isolate the core muscles, and ones that include core and other muscle activity to perform whole body functional movements.

Overall, the current results support reports that dancers require good core PF to allow them to perform successfully while not getting injured [59]. Therefore, researchers should establish baseline core strength-endurance norms in collegiate and other dancers to aid kinesiology practitioners choose appropriate norms to grade their dancers' baseline PF based on their participants' level and task demands.

4.3. Lower Body Power

The present findings indicate no changes in SLH distances from freshman to senior year in collegiate dancers. In dancers, one group of authors [12] found that dancers whose SLH distances were less than 78.2% of their height had increased risk of lower body injury. However, in athletes, the majority of the research on SLH tests focuses on recovery from Anterior Cruciate Ligament reconstruction surgery [37,61,62]. To our knowledge, we could not find research examining changes in SLH in the same individuals over time. Thus, future research is needed investigate this gap in the literature and clarify if regular participation in physical activity influences PF changes in single leg hop distances over time in dancers and athletes.

The current dancers' SLH scores (~81 % BH) are similar to those reported in collegiate dancers (80-81 % BH) [12,38] but lower than some reports in 18-29 year old adults (~89 % BH) [63] and 15-16 year old soccer athletes (99 % BH) [64]. The differences in scores could partially be explained from differences in training and task demands. Clinically, these findings indicate that dancers lower body strength should not be directly compared to lower body power norms in sports and supports the need to establish dancer specific norms for lower body power.

We also recognize that the PF can be examined using different outcome measures: for example, power can be measured using a variety of hop tests including the triple leg hops for distance and multiple hop tests. Still some recent evidence exists noting that in dancers, SLH performance is positively correlated to balance [38] and can prospectively predict lower body injury risk [12]. Dancers also regularly perform hops and jumps within class, rehearsal and performance [65]. Overall, we recommend the use of the SLH test as an easy to administer and interpret test in dancers as a measure of lower body power and PF.

4.4. Balance

The current dancers' left and right anterior reach balance scores (~ 81% LL)are similar to ranges in collegiate dancers [38] and active adults [66] (~75 % LL) but lower than female lacrosse players (96% LL) [60]. A possible reason for this difference could be different exercise regimes, and different demands of the sports. We chose the anterior reach distance to examine dancers' balance as it has been reported to predict injury risk. [46,47] Thus, we are reasonably confident in this test as a measure of balance.

Although the anterior reach distance may be an appropriate balance measure, some authors have cautioned against using only this anterior distance reach or only the Y-balance test as predictive injury measures [49]. This is because the Star Excursion Balance test or its modification - the Y-balance test, may not conclusively predict injury risk in all athletes [42]. Variations of the Star Excursion Balance test exist in dancers [67–69] but these do not appear to have robust face or content validity as balance screens [68] or are not different than the Star Excursion Balance test when controlling for upper body motion [69]. Thus, the anterior reach direction may offer a better option for kinesiology practitioners examining balance in their dancers as it can conducted in lesser time and has low technical resources and effort needs.

When considering LSI, previous researchers suggest that a 3-8% asymmetry (i.e., 93-98% LSI) on dynamic balance tests is normal in healthy adults [39]. The current dancers' LSI was within these ranges both when they were freshmen and when seniors, indicating that the dancers were functionally symmetrical in their lower body power PF. Still, the dancers balance symmetry improved from their freshman to senior year (92% to 97%) that is – their balance was more symmetrical when they were seniors. This observation is encouraging as it indicates that there was no lateral biasing in the current dancers during their time in the collegiate program. This lateral biasing due to dance training has been previously suggested to be related to dance injuries [70].

Another point to note regarding asymmetry is the caution suggested by some authors [71] of not using a single cut off point (e.g., difference of > 4 cm across sides) to determine injury risk. This is because injury risk is often multi-factorial and population dependent and not generalizable across different populations. Thus, future researchers should continue examine leg asymmetries and individual balance reach distances when using the Star Excursion Balance test, the Y-Balance test or its components as part of a larger comprehensive assessment of PF in dancers.

4.5. Relationships among Physical Fitness Measures

Dancers' different PF measures were understandably positively correlated across sides. Specifically, the four core plank tests were positively correlated to each other, the balance reach distances and hop distances across legs were positively correlated. However, the different PF measures were not related to each other. This finding implies that PF differs across different body regions and may be demand and task dependant. Thus, practitioners should use multiple tests that test individual body parts like plank tests for the core, and also functional tests like the hop tests that examine overall body function during movement as components of a larger comprehensive assessment of PF in dancers across different genres. Using this comprehensive approach can provide kinesiology practitioners a holistic perspective of dancers' PF in their natural settings and not limited to laboratory settings.

4.6. Physical Fitness and Supplementary Training in Collegiate Dance Programs

The current finding that dancers' PF remains unchanged over a 4-year period in collegiate dance program indicates that regular collegiate dance training practice may assist maintenance of PF in dancers. However, dance training alone may not improve PF. Rather, added supplemental training may be needed to enhance dancers' performance as the progress in their program [72]. Collegiate dance programs are suggested to include some consistent form of PF and supplementary training for their dancers [73]. In a study examining health literacy in collegiate dancers and collegiate dance programs, Kozai and Ambegaonkar [73] found that while several collegiate programs discuss some PF aspects in their curricula, not all dance programs provided formal curricular instruction about PF training in the program [73].

Also, while some collegiate programs had dedicated healthcare support [74], how much training and conditioning is offered in these programs is still unclear. In a systematic review examining the effects of supplemental training in dance, the researchers [72] found that generally in female collegiate dancers, supplemental training does enhance dancers' performance, with limited evidence for injury risk reduction. Specifically, the researchers found that supplemental PF training programs that included multiple exercises, lasted around 1 hour per session, and were implemented 2 to 3 times per week for around 8 weeks enhance dancers' performance, and had limited evidence in reducing dancers' low back pain and injury risk.

The current dancers indicated that they took part an average of ~2 hours/week of supplementary PF training outside of their formal curriculum dance classes. The training included combinations of conditioning, Pilates, jogging, CrossFit training, and other PF training regimens. However, this training was not part of the formal dance program. Also, this training was not designed or supervised by a trained practitioner. Thus, we are unsure about the rigor and intensity of these training sessions and cannot state as to whether these training programs had any specific effect on the dancers' PF. Based on the current findings, we can speculate that dance alone may not elicit a strong enough stimulus to induce significant PF changes without additional supplementary fitness training. As discussed in the sections above, the PF levels of the dancers were comparable to athletes in other sports. Thus, their baseline fitness levels were indicative of relatively PF levels that would require targeted fitness programs that incorporate basic design principles of specificity and progressive overload to promote further positive physiological adaptations [75]. Accordingly, future researchers should examine whether supplemental PF training interventions designed and implemented by trained practitioners can enhance the PF measures used in the current study to further optimize dancers' PF and performance.

4.7. Limitations and Future Recommendations

We recognize that our findings have limited generalizability outside our study participants. Nevertheless, the current PF scores are in general agreement with prior PF measures. Thus, we suggest that others can use the tests in the present study as they are low in technology needs and can be performed in dance studios, and do not need extensive technical training. To advance work, we recommend that future researchers should examine whether any of these PF measures taken at the start of the freshman year (or beginning of the training program year) can assist practitioners to prospectively predict injury incidence in dancers across different levels and genres.

We also acknowledge that using normative values is the not the only measure practitioners can use when considering injury prevention or rehabilitation post injury. Rather, we suggest developing normative values as baselines for healthy dancers like norms in other physically active populations so that practitioners can use these values to recognize possible high risk dancers, implement training programs, and determine safe return to activity benchmarks.

4.8. Practical Implications

The practical implications of the current study are to inform multiple stakeholders in the kinesiology field. Specifically, this evidence can support dancers and dance educators to proactively include supplemental training and conditioning programs as an inherent part of dance training. The current results that dancers' freshmen year PF remains generally similar through senior year agrees with prior suggestions in professional athletes that yearly pre-season laboratory screening would not be warranted under normal clinical standards [24]. Strength and conditioning practitioners working with collegiate dancers can use freshmen PF screens as baselines and not need to repeat this testing when setting training goals. Kinesiology practitioners can use this information to determine return-to-activity in their dancers when devising rehabilitation programs for their injured collegiate dancers. Finally, the finding that dancers' PF scores were generally lower than those reported in athletes but similar to recreational and healthy populations indicates support for different norms for different groups of physically active populations [14].

5. Conclusions

In conclusion, the findings of this study suggest that dancers' PF remains consistent throughout their college program, with the exception of improved balance scores, which could have important implications for injury prevention and performance enhancement in this population. The finding that collegiate level dancers' physical fitness levels did not change during their dance programs provides valuable insights for kinesiology professionals working with collegiate dancers and suggests that dancers' freshmen scores may be reliable baseline reference measure when devising rehabilitation programs and determining readiness for return to activity post injury.

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