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Impact of Latin Ballroom Dance Training on Gait Biomechanics, Anxiety, and Depression

GRACE HANKS*[1], TYLER STANDIFIRD‡[1], and BARRY ANDELIN‡[2]

[1]Exercise Science Department, Utah Valley University, Orem, UT, USA; [2]Psychology Department, Utah Valley University, Orem, UT, USA

*Denotes undergraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(1): 794-809, 2024. The purpose of this study was to analyze the impact of Latin ballroom dance training on gait biomechanics, anxiety, and depression. There were twelve Latin ballroom dancers and twelve recreationally active non-dancers that participated in this research. For collecting data on gait biomechanics, participants walked on a pressure sensitive walkway system and force plates to collect information on foot and ground interactions. Reflective trackers were placed on the anterior part of their hips, knees, and ankles to measure frontal plane lower leg alignment during weight acceptance. A survey including the Generalized Anxiety Disorder-7 (GAD-7) assessment, Patient Health Questionnaire-9 (PHQ-9) assessment, and questions developed by the researchers were used to collect psychological data. Data was analyzed using independent t-tests, one-way ANOVA, chi-squared tests, and contingency tests. Results in this study showed that Latin ballroom dancers were minimally different in their gait biomechanics when compared to the non-dancers. The only statistically significant differences in the absolute value difference between legs for peak braking impulse ($p=0.04$) and the difference from left to right leg in peak braking ground reaction forces ($p=0.05$). All other variables of gait biomechanics that were measured in this study showed no statistically significant differences between the 2 groups ($p>0.05$). Dancers showed higher levels of anxiety, with 58.33% of dancers having a probable anxiety disorder and 8.33% of non-dancers having a probable anxiety disorder ($p=0.06$). However, there was no statistically significant difference between dancers and non-dancers and their likelihood of a depression diagnosis ($p=0.16$). Furthermore, there were differences in when dancers experienced symptoms when compared to non-dancers. Coaches and dancers should be aware of any positive or negative effects of Latin ballroom dance training on anxiety and depression so that they can make educated decisions to facilitate and promote health, safety, and wellness among dancers.

KEY WORDS: Dancers, mental health, mental wellness, walking

INTRODUCTION

A primary focus in dance involves moving in very specific ways to create a certain aesthetic, which requires the human body to move in ways not commonly used in day-to-day life. It also commonly involves performances and competitions where that aesthetic is critiqued and judged. Understanding of the impact that dance training and performances has had on a dancer

is valuable in assessing their overall well-being. Past research has shown that dance training can impact daily movement patterns, including gait, as well as affect levels of anxiety and depression. Additionally, research shows a relationship between mental wellness and gait biomechanics.

Studying any transference from training dance movement patterns to daily movement patterns is valuable information for understanding short- and long-term impacts of training. Past studies have focused on biomechanical changes, kinematic differences, and injury rates among dancers. This research primarily compares ballet and modern dancers to healthy and active non-dancers, and they have shown that extensive dance training has an impact on an individual's physical body and movements (1, 19, 21, 26, 28, 30). Multiple studies have shown that plantar force pressure, contact duration, peak pressures, force-time integrals, and pressure-time integrals differed between professionally trained dancers and healthy non-dancers (21, 30). For example, ballet dancers were shown to have greater pressure peaks on the medial side of their foot than non-dancers (21). There were even differences between different forms of dance; Chinese Classic dancers showed greater pressure impulse medially and lower load in the heel than ballet dancers while walking (30).

There are also statistically significant kinematic differences between ballet dancers and non-dancers with dancers showing greater hip extension, greater hip abduction, increased pelvic tilt, increased pelvic rotation, greater knee flexion, greater knee extension, decreased maximal ankle plantar flexion during loading, and increased maximal ankle plantar flexion in terminal stance (26). A different study showed that female dancers had greater leg spring stiffness than female basketball players, but no statistically significant differences in knee muscle activation or knee joint stiffness during landing from a jump (1). This conflicts with another study indicating that dancers have increased gluteus maximus contraction and smaller knee valgus angles during drop landing tests (28). Regarding force production, research shows that toe-out gait might help improve knee joint care because it decreases medial contact force at the knee and alters muscle activation levels and knee movements (19). Contrarily, improper turnout of the feet can lead to increased injury rates among dancers (17).

In addition to movement differences, research indicates a strong correlation between dance training, performance, competition, and mental wellness. However, there were mixed results on whether participation in dance increased or decreased levels of anxiety and depression. One study found that ballroom dancers experience chronic stress and had negative physiological symptoms as a result (2). This specific study showed that dancers typically reported higher levels of anxiety and more physical health complaints than the control group (2). This aligns with a separate study studying the connection between performance anxiety and competition. This study by Tremayne et al (27) showed that performance anxiety among ballroom dancers was common due to intimidation from other competitors and the constant evaluations and comparisons that take place at competitions.

Dancers have also indicated a tendency to strive for perfection and base their success on how they compare to others rather than how they compare to themselves (18). These constant comparisons and perfectionistic tendencies have been shown to increase concerns, doubts, and anxiety about performance and competitions (18). However, a different study studying college students found that individuals reported lower levels of anxiety and depression when they had higher levels of exercise frequency or participated in a college sports dance team (29). According to this study, participating on a dance team was beneficial for mental health and wellness. These conflicting results show that further study is needed for additional clarification.

Additionally, research shows a relationship between mood disorders, including anxiety and depression, and gait biomechanics. Gait characteristics are often an indicator of well-being among individuals with psychiatric conditions, and mood disorders reflect negative feelings that impact the brain's processes related to cognition, perception, and motor systems (5). Gait has even been used as a tool to analyze and evaluate patients with mental illnesses (6, 8). Individuals with anxiety have been shown to have slower walking speed, shorter step length, fewer steps per minute, greater variability in movements, and balance deficiencies (8, 9, 14). Individuals with depression have been shown to have reduced walking velocity, decreased stride length, lateral swaying, and a slumped head (6, 8, 12, 15). In Latin ballroom dancers, the potential effects of anxiety and depression on gait as shown in previous research might be compounded or amplified by the other natural effects that dance training itself has on gait.

Regarding Latin ballroom dance training specifically, little research has been done on its impact on gait or mental wellness. While there are similar trends indicating physical and mental differences between dancers and healthy non-dancers, the specifics of these differences vary due to the limited amount of research available. Additionally, many of these studies focus on ballet or modern dancers with almost no studies analyzing Latin ballroom dance training. The purpose of this study was to provide additional insight, clarification, and understanding regarding the impact of Latin ballroom dance training on individuals' gait biomechanics and experiences with anxiety and depression.

It was hypothesized that dancers will be significantly different in a variety of gait biomechanics factors such as having increased levels of toe-out angles, knee valgus angles, and peak braking forces when compared to non-dancers. It was also hypothesized that dancers will experience higher levels of both anxiety and depression, especially in relation to rehearsals and competitions, than healthy non-dancers. Given the previous research studies performed, it would be reasonable that the dancer's hypothesized anxiety and depression would exacerbate the predicted unhealthy movement patterns that result from extensive dance training, meaning that dancer's gait would be altered because of the physical dance training as well as the higher levels of anxiety and/or depression.

METHODS

Participants

Volunteer participants were recruited to participate in this study and they were recruited by word of mouth. A minimum sample size of 10 dancers and 10 non-dancers was needed for this study. Each participant was between the ages of 18 and 25 years old and was either a Latin ballroom dancer or a physically active non-dancer. The physically active non-dancers functioned as the reference group for this study. The dancers at the time of data collection were actively training in the Latin ballroom dance style at least 4 hours each week and had been doing so consistently for the past 2 years. The non-dancers at the time of data collection were working out for at least 4 hours each week consistently for the past 2-plus years. The non-dancers participated in various forms of exercise but were not part of a sports team with a coach and did not participate in any physical activity related to dance, such as Zumba or ballet. None of the participants suffered from a lower limb or spinal injury in the past 3 months and they had no chronic spinal or lower limb pain or discomfort. This research was carried out in full accordance with the ethical standards of the International Journal of Exercise Science (16).

An a priori power analysis was conducted using data from Salsich and Long-Rossi (23) to compare the main variable of interest of the peak knee adduction angle occurring during gait. The mean and standard deviation of each group was input with a significance criterion of $\alpha = 0.05$ and power = 0.80, the minimum sample size needed was 10 in each group. The current study utilized a sample size of 12 for each group to compare for differences.

Protocol

The study protocol was approved by the International Review Board of Utah Valley University prior to data collection. The participants in this study were asked to come in one time for a lab session, which lasted 30 minutes or less. The equipment used included an pressure sensitive walkway system (GaitRite system; CIR Systems, Inc., Franklin, NJ, USA), force plates (Bertec, Inc, Columbus, OH, USA), an iPhone camera using a smartphone application (OnForm, Inc., 2022), and reflective markers to collect the data.

Upon arrival at the lab, the participants sat in a chair and signed the informed consent form and filled out a survey collecting general information relating to training habits, anxiety, and depression. While they were filling out the informed consent and survey responses, the tester left the room. Both the informed consent and survey were completed via Qualtrics (Qualtrics, 2020, Provo, UT, USA) surveys. The surveys that were used included the Patient Health Questionnaire-9 (PHQ-9) (3, 10) assessment of depression, the Generalized Anxiety Disorder-7 (GAD-7) assessment of anxiety (4, 13, 24, 25), and other questions created by the researcher. The PHQ-9 provided depression scores and gave individuals a provisional diagnosis of depression to varying severities including--from lowest to highest--no depression, minimal depression, mild depression, moderately severe depression, and severe depression. The GAD-7 provided anxiety scores and gave individuals a provisional diagnosis for a probable anxiety disorder if those scores were high enough. The other questions on the survey collected information on when the participants experience their symptoms of anxiety and/or depression, such as during a rehearsal or workout, in-between a rehearsal or workout, and around a competition or performance. The final portion of the survey had participants self-assess the degree to which

they felt their participation in Latin ballroom dancing or recreational workouts impacted their levels of anxiety and depression.

Upon completion of these surveys, the tester reentered the room and participants performed a warmup by walking around the room for 3 minutes. Participants were then asked to remove their shoes and reflective trackers were placed on the anterior part of their hips, knees, and ankles and their demographic information was gathered.

After completion of the warmup and the collection of the demographic information, participants walked down the pressure sensitive track system at their own selected pace and step length towards a camera recording them from a frontal view. The video recordings were later reviewed and frontal plan knee angles were measured for each leg at mid-stance when the participant was 100% weight-bearing. Their swinging leg was also immediately next to their stance leg when the angles were measured; the angles were measured by connecting the markers that were placed on their hips, knees, and angles. After completing the trials on the pressure sensitive track system, participants completed three additional trials at the same self-selected pace while walking over 2 force plates. Timing gates were used to ensure the participants had the same self-selected pace across all trials. Finally, the reflective trackers were removed, and participants were allowed to leave.

Statistical Analysis

The biomechanical data was analyzed with Visual 3D software (5.0, C-Motion, Inc., Germantown, MD, USA) and in Excel (Microsoft Corporation, 2018). The results for the psychological survey data were also analyzed in Excel and JASP (Computer Software, 0.13.1, JASP Team, 2020, Netherlands). All data was analyzed for statistical significance with independent t tests, contingency tests, one-way ANOVA tests, and/or chi-squared tests. Statistical significance was set at alpha = 0.05. Cohen's d values were also calculated with a classified effect size of small (d=0.2), medium, (d=0.5), and large (d≥0.8).

RESULTS

There were 24 qualified participants recruited for this study, with 12 of them being dancers and 12 of them being non-dancers. The two groups had very similar average body mass index "BMI" calculations, with dancers having an average BMI of 23.2 and non-dancers having an average BMI of 23.9 (see Table 1).

Gait Biomechanics: Within the biomechanical measurements, there were only 2 statistically significant differences between the Latin ballroom dancers and the non-dancers. The first one was in the absolute value difference between legs for peak braking impulse. Non-dancers had a 178% greater variation than the dancers (dancers: 1.0 Ns, non-dancers: 2.9 Ns, p=0.04, d=0.90). The cohen's d value indicates that there is a large effect size, meaning that ballroom dance training has a large effect on inter-leg differences in peak braking impulse. The other statistically significant difference was the difference from left to right leg in peak braking ground reaction forces. Dancers had 222% greater difference than non-dancers (dancers: 6.0, non-dancers: -7.4,

p=0.05, d=0.86). There is a large cohen's d value here as well, indicating that ballroom dance training has a large effect on inter-leg differences in peak braking ground reaction forces. All other biomechanical gait factors that were measured showed no statistically significant differences between Latin ballroom dancers and non-dancers, with p-values greater than 0.05. These factors included: toe-in and toe out angles, hip to knee to ankle angles, anterior propulsion impulse, peak breaking impulse, peak breaking ground reaction force (GRF), peak lateral GRF, peak loading vertical GRF, peak medial GRF, vertical loading impulse, and the differences between each leg for each of these variables (see Table 2).

Table 1. Participant demographics (n=24).

	Latin Dancers	Non-dancers
Total Number	12	12
Number of Males	5	7
Number of Females	7	5
Age (Mean +/- SD)	19.2 +/- 1.7	22.7 +/- 1.5
Height (cm) (Mean +/- SD)	167.8 +/- 9.7	173.8 +/- 9.6
Weight (kg) (Mean +/- SD)	65.8 +/- 14.8	70.9 +/- 11.8
Left Leg Length (cm) (Mean +/- SD)	74.6 +/- 3.2	77.1 +/- 4.8
Right Leg Length (cm) (Mean +/- SD)	74.8 +/- 3.7	76.9 +/- 4.8
BMI (Mean +/- SD)	23.2 +/- 3.8	23.9 +/- 3.0

Table 2. Biomechanical measurements averages, standard deviations, and p-values for dancers and non-dancers.

Measurement	Dancer's left lower limb average and standard deviation All values are reported as Mean (SD)	Non-dancer's left lower limb average and standard deviation All values are reported as Mean (SD)	P-value and Cohen's d for Left Lower Limb	Dancer's right lower limb average and standard deviation All values are reported as Mean (SD)	Non-dancer's right lower limb average and standard deviation All values are reported as Mean (SD)	P-value and Cohen's d for right lower limb
Toe-in/Toe-out foot angle	2.17 (5.15)	2.55 (6.87)	p=0.88 d=0.06	4.04 (4.09)	3.78 (5.59)	p=0.89 d=0.05
Hip to knee to ankle angles (degrees)	178.08 (3.09)	179.25 (2.42)	p= 0.31 d=0.42	177.42 (2.54)	178.25 (1.48)	p=0.33 d=0.40
Anterior propulsion impulse (N*s)	-19.59 (4.86)	-21.95 (4.23)	p=0.22 d=0.52	-20.70 (5.84)	-21.50 (4.03)	p=0.70 d=0.16
Peak breaking impulse (N*s)	18.33 (5.50)	18.76 (4.43)	p=0.84 d=0.09	17.97 (5.58)	20.42 (4.13)	p=0.24 d=0.50
Peak breaking GRF (N)	98.32 (26.76)	108.13 (23.64)	p=0.35 d=0.39	92.26 (28.20)	115.54 (26.95)	p=0.05 d=0.84
Peak lateral GRF (N)	9.83 (6.61)	14.79 (10.03)	p=0.17 d=0.58	23.73 (8.48)	27.90 (12.81)	p=0.36 d=0.38
Peak loading VGRF (N)	653.32 (115.59)	735.96 (117.08)	p=0.10 d=0.71	671.78 (122.28)	752.56 (115.32)	p=0.11 d=0.68
Peak medial GRF (N)	-6.96 (4.52)	-8.54 (4.08)	p=0.38 d=0.37	-13.72 (5.53)	-15.42 (5.92)	p=0.47 d=0.30

Vertical loading impulse (N*s)	200.27 (61.62)	208.11 (45.85)	p=0.73 d=0.14	200.51 (54.20)	208.02 (37.97)	p=0.70 d=0.16

*GRF=Ground Reaction Force; **VGRF=Vertical Ground Reaction Force.
***=Statistically Significant (p<0.05).

Survey data for anxiety: The results showed a statistically significant relationship between participating in Latin ballroom dancing and levels of, and experiences with, anxiety. Dancers, compared to non-dancers, in this study were more likely to have a probable anxiety disorder diagnosis with 58.3% of dancers having a probable anxiety disorder and 8.33% of non-dancers having a probable anxiety disorder (p=0.06, degrees of freedom "df"=1). However, this difference is likely not attributable to the number of hours spent dancing (p=0.81, df=1) (see Table 3).

Table 3. Relationship between hours spent training Latin ballroom and a provisional anxiety diagnosis.
Descriptives - How many hours a week do you participate in Latin ballroom dancing? (Average).

Anxiety Diagnosis	Number	Mean	Standard Deviation	Standard Error	Coefficient of Variation
None	7	9.79	5.28	1.994	0.54
Probable anxiety disorder	5	10.80	8.93	3.992	0.83

When asked how often they experienced anxiety symptoms immediately prior to, during, or immediately after a competition or performance, there was no difference illustrated between dancers with a probable anxiety disorder and dancers without a probable anxiety disorder (p=0.63, df=3) (see Table 4).

Table 4. Relationship between Latin ballroom competitions and provisional anxiety diagnosis.
How often in the past year have you experienced any of the symptoms in the anxiety section above as it related to competition or performance (immediately prior, during, or immediately afterwards)?

Anxiety Diagnosis		More than half the competitions/ performances	Nearly every competition/ performance	Never	Some, but less than half of the competitions/ performances	Total
None	Count	2.00	1.00	1.00	3.00	7.00
	% within row	28.57 %	14.29 %	14.29 %	42.86 %	100.00 %
	% of total	16.67 %	8.33 %	8.33 %	25.00 %	58.33 %
Probable anxiety disorder	Count	2.00	0.00	0.00	3.00	5.00
	% within row	40.00 %	0.00 %	0.00 %	60.00 %	100.00 %
	% of total	16.67 %	0.00 %	0.00 %	25.00%	41.67 %
Total	Count	4.00	1.00	1.00	6.00	12.00
	% within row	33.33 %	8.33 %	8.33 %	50.00 %	100.00 %
	% of total	33.33 %	8.33 %	8.33 %	50.00 %	100.00 %

There is, however, a trend for dancers to experience more anxiety symptoms during a rehearsal than non-dancers experience anxiety symptoms during a workout (p=0.09, df=3), but this result was not statistically significant (see Table 5).

Table 5. Dancers vs non-dancers and anxiety symptoms during rehearsals/workouts.

Contingency Tables

How often in the past 2 weeks have you experienced any of the symptoms in the anxiety section above during practice or rehearsal?

Latin or Non-Latin		More than half the sessions	Nearly every session	Not at all	Several times	Total
Latin	Count	1.00	1.00	4.00	6.00	12.00
	% within row	8.33 %	8.33 %	33.33 %	50.00 %	100.00 %
	% of total	4.17 %	4.17 %	16.67 %	25.00 %	50.00 %
Non-Latin	Count	0.00	0.00	10.00	2.00	12.00
	% within row	0.00 %	0.00 %	83.33 %	16.67 %	100.00 %
	% of total	0.00 %	0.00 %	41.67 %	8.33 %	50.00 %
Total	Count	1.00	1.00	14.00	8.00	24.00
	% within row	4.17 %	4.17 %	58.33 %	33.33 %	100.00 %
	% of total	4.17 %	4.17 %	58.33 %	33.33 %	100.00 %

Finally, there is no statistically significant difference between dancers and non-dancers experiencing anxiety symptoms in between rehearsals or workouts (p=0.53, df=3) (see Table 6).

Table 6. Dancers vs non-dancers and anxiety symptoms between rehearsals/workout.

Contingency Tables

How often in the past 2 weeks have you experienced any of the symptoms in the anxiety section above in between practices?

Latin or Non-Latin		Consistently	More than half the time	Not at all	Several times	Total
Latin	Count	0.00	1.00	3.00	8.00	12.00
	% within row	0.00 %	8.33 %	25.00 %	66.67 %	100.00 %
	% of total	0.00 %	4.17 %	12.50 %	33.33 %	50.00 %
Non-Latin	Count	1.00	1.00	5.00	5.00	12.00
	% within row	8.33 %	8.33 %	41.67 %	41.67 %	100.00 %
	% of total	4.17 %	4.17 %	20.83 %	20.83 %	50.00 %
Total	Count	1.00	2.00	8.00	13.00	24.00
	% within row	4.17 %	8.33 %	33.33 %	54.17 %	100.00 %
	% of total	4.17 %	8.33 %	33.33 %	54.17 %	100.00 %

Survey data for depression: There was no statistically significant difference between dancers and non-dancers and their likelihood of a depression diagnosis (p=0.16, df=3) (see Table 7).

Table 7. Latin vs non-dancers' likelihood of a provisional depression diagnosis.

Contingency Table

Depression Diagnosis		Latin	Non	Total
Mild depression	Count	4.00	4.00	8.00
	% within column	33.33 %	33.33 %	33.33 %
Minimal depression	Count	5.00	6.00	11.00
	% within column	41.67 %	50.00 %	45.83 %
Moderate depression	Count	3.00	0.00	3.00
	% within column	25.00 %	0.00 %	12.50 %
No depression	Count	0.00	2.00	2.00
	% within column	0.00 %	16.67 %	8.33 %
Total	Count	12.00	12.00	24.00
	% within column	100.00 %	100.00 %	100.00 %

There were no statistically significant differences found for Latin ballroom dancers' depression diagnosis and the number of hours danced per week (p=0.42, df=2) (see Table 8).

Table 8. Relationship between hours spent training Latin ballroom and a provisional depression diagnosis.
Descriptives - How many hours a week do you participate in Latin ballroom dancing? (Average).

Depression Diagnosis	N	Mean	Standard Deviation	Standard of Error	Coefficient of Variation
Mild depression	4	7.88	6.79	3.39	0.86
Minimal depression	5	9.40	4.04	1.81	0.43
Moderate depression	3	14.67	10.02	5.78	0.68

However, dancers were statistically more likely to experience depressive symptoms during rehearsal with 58.33% responding that they experienced symptoms of depression during practice or rehearsal "several times", with only 41.67% reporting "not at all", while 16.67% of non-dancers reported they experienced depressive symptoms during a workout "several times" and 83.33% reported "not at all" (p=0.03). Dancers were also statistically more likely to experience symptoms of depression in-between rehearsals or workouts with 58.33% of Latin dancers reporting they experienced symptoms of depression between rehearsals and only 16.67% of non-dancers reporting they experienced symptoms of depression between workouts (p=0.035). The data collected to assess the relationship between a depression diagnosis and competitions was inconclusive (see Table 9).

Table 9. Depression score and experiences of depression symptoms around competitions.
Contingency Tables

Depression Diagnosis		How often in the past year have you experienced any of the symptoms in the depression section above as it related to competition or performance (immediately prior, during, or immediately afterwards)?				
		More than half of the competitions/performances	Nearly all the competitions/performances	Never	Some, but less than half of the competitions/performances	Total
Mild depression	Count	0.00	0.00	2.00	2.00	4.00
	% within row	0.00 %	0.00 %	50.00 %	50.00 %	100.0 %
	% of total	0.00 %	0.00 %	16.67 %	16.67 %	33.33 %
Minimal depression	Count	0.00	0.00	2.00	3.00	5.00
	% within row	0.00 %	0.00 %	40.00 %	60.00 %	100.00 %
	% of total	0.00 %	0.00 %	16.67 %	25.00 %	41.67 %
Moderate depression	Count	1.00	1.00	0.00	1.00	3.00
	% within row	33.33 %	33.33 %	0.00 %	33.33 %	100.00 %
	% of total	8.33 %	8.33 %	0.00 %	8.33 %	25.00 %
No depression	Count	0.00	0.00	0.00	0.00	0.00
	% within row	N/A	N/A	N/A	N/A	N/A
	% of total	N/A	N/A	N/A	N/A	N/A
Total	Count	1.00	1.00	4.00	6.00	12.00
	% within row	8.33 %	8.33 %	33.33 %	50.00 %	100.00 %
	% of total	8.33 %	8.33 %	33.33 %	50.00 %	100.00 %

Survey data for self-perception of the impact of training on anxiety and depression: Latin ballroom dancers and non-dancers had statistically significant different responses to the questions on the survey that asked how they would explain their form of training affects their levels of both anxiety and depression. Among the dancers, 33.33% responded "It decreases and increases my feelings of anxiety depending on the situation", 8.33% responded "It helps to decrease my feeling of anxiety all of the time", 33.33% responded "It helps to decrease my feelings of anxiety some of the time", and 25.00% responded "It increases my feelings of anxiety some of the time". Among the non-dancers, 58.33% responded "It helps to decrease my feelings of anxiety all of the time" and the other 41.67% responded "It helps to decrease my feelings of anxiety some of the time". In summary, 58.33% of Latin ballroom dancers indicated that participating in Latin ballroom dancing increases their levels of anxiety to some degree and

100% of non-dancers indicated that regularly working out decreases their levels of anxiety (p=0.01). Regarding their responses to how Latin ballroom dancing affects their levels of depression, 41.67% of dancers responded that "It decreases and increases my feelings of depression depending on the situation", 41.67% responded "It helps to decrease my feeling of depression some of the time", and 16.67% responded "It helps to decrease my feelings of depression all of the time". Among the non-dancers, 8.33% responded that "It decreases and increases my feelings of depression depending on the situation", 8.33% responded "It has no effect", 50% responded "It helps to decrease my feelings of depression all of the time", and 33.33% responded "It helps to decrease my feelings of depression some of the time". In summary, most of the non-dancers reported that working out regularly decreases their depression and dancers are more likely to report that it is situational (p=0.005).

DISCUSSION

The purpose of this study was to analyze the impact of Latin ballroom dance training on gait biomechanics as well as levels of and experiences with anxiety and depression. It was hypothesized that Latin dancers would have significant differences from healthy non-dancers in gait biomechanics such as toe-in toe-out angles, frontal plane knee angles, peak braking forces, and percentage of gait spent in swing phase. It was additionally hypothesized that Latin ballroom dancers would have higher levels of anxiety and depression than non-dancers and be more likely to experience these symptoms during rehearsals and around competitions. It was also expected that the higher levels of anxiety would exacerbate the gait alterations.

The results of this study showed that Latin ballroom dance training has minimal effect on the factors of gait biomechanics measured; despite the dancers having higher levels of anxiety, the only statistically significant differences found were the absolute value difference between legs for peak braking impulse and the difference from left to right leg in peak braking ground reaction forces. The results also showed that Latin ballroom dancers had higher anxiety scores and were more likely to have a probable anxiety disorder diagnosis than non-dancers, but that they were not more likely to have a provisional depression diagnosis than non-dancers. However, these differences were not shown to be related to the number of hours an individual participated in Latin ballroom dance training per week or participation in competitions or performances. Latin dancers did show a tendency to experience more symptoms of anxiety during a rehearsal or practice than non-dancers experienced anxiety symptoms during a workout. They were also more likely to experience depressive symptoms during and in-between rehearsals or practices. Also, more dancers reported that their participation in Latin ballroom training increases their levels of anxiety and depression. Finally, the results of this study did not show that anxiety differences between Latin ballroom dancers and healthy non-dancers were a source of altered gait biomechanics. Higher levels of anxiety were not causing movement changes as would have been expected given previous studies' results.

There are various potential interpretations and explanations for the results found in the biomechanics data collected in this study. In Latin ballroom dancing, the left foot is known as

the "leading foot", where it usually is the one that steps forward first while the right foot is often the "breaking foot", where it initiates backwards movements. This might cause dancers to shift to their left foot and leg being their preferred limb, or the foot and leg that leads out in the voluntary motor action of walking (25), and potentially causing the left leg to be their dominant limb (20). This is one possible reason why the dancers had greater variation in peak breaking ground reaction forces, with the left foot having larger GRF than the right. It also might explain why non-dancers had larger absolute differences in breaking impulse. These foundational technique and movement patterns are used so often in Latin ballroom dancing that it is reasonable that there is some transference of them to gait and daily movements. It is important to note though that research is showing that healthy populations also have asymmetry, so this increased asymmetry found among dancers might not be harmful (11, 22). Additionally, contrary to the original hypotheses of this study as well as much of the research done previously on the impact dance training has on movement patterns, a very high portion of the data collected in this study showed that Latin ballroom dancers do not significantly differ in gait biomechanics when compared to recreational and healthy non-dancers. For example, since dancers did not have increased lateral-medial GRF, impulse, and time to peak of reaction forces in the heel contact phase, it can be assumed they do not have additional foot pronation (7). Pronation is one part of Latin ballroom technique used to increase hip rolling and movement during steps, so it can be concluded that Latin ballroom dancers using this technique in dance do not see transference of these movements into their gait.

The lack of these and other statistically significant differences in components of gait biomechanics between dancers and non-dancers indicates that Latin ballroom dancing has minimal effect on walking and will likely not impact variables associated with improper gait, such as joint health and risk of injury, either positively or negatively. One potential reason that the results of this study do not align with previous findings in research is the modality of dance training studied. Latin ballroom dance training has not been studied and is likely the explanation for why these findings differ from other research studies. One possible explanation for this is that Latin ballroom dancing contains multiple sub-categories of dances, such as samba or cha-cha, each with their own unique variations on technique. While the main techniques of toe leads, rolling of hips, and turn-out of Latin ballroom dancing can be found across all forms of Latin dances the smaller differences might have large enough variation to negate any long-term impact on gait biomechanics.

One potential application of the biomechanical data collected in this study is in clinical settings, such as when practitioners are considering dance as an intervention strategy to improve things such as balance, motor control, mobility, and risk of falling among older individuals. However, recognizing that Latin ballroom dance specifically has no impact on the gait biomechanics variables studied here is valuable information for knowing which form of dance intervention to use to help improve gait biomechanics. The lack of a relationship shown in this study would lead practitioners and clinicians to select an alternative intervention, but additional research on other biomechanical factors of gait is needed to further understand the relationship between Latin ballroom dancing and gait.

The data collected in this study indicates a relationship between Latin ballroom dancing and an individuals' experience with symptoms of anxiety and depression. While the results show a stronger relationship between regular participation in Latin dancing and anxiety, the data also has trends indicating a relationship to depression as well. Not only are dancers more likely than healthy non-dancers to have a probable anxiety disorder diagnosis, but they are also more likely to experience these symptoms during a rehearsal or practice. These relationships might be indicative that the pressures and expectations placed on dancers during rehearsals are increasing levels of anxiety and negatively impacting dancers. This could be a result of self-imposed stress, external expectations, and unhealthy competition between peers, as well as many other factors. Dancers also are likely to attribute their symptoms of anxiety to participation in Latin ballroom dancing. This study found that 58.3% of Latin ballroom dancers indicated that participating in Latin ballroom dancing increases their levels of anxiety to some degree, while 100% of non-dancers indicated that regularly working out decreases their levels of anxiety. Furthermore, the more hours an individual participated in Latin dancing did not have an impact on their likelihood of a provisional anxiety diagnosis. This illustrates that anxiety levels are not dependent on how much time they dedicate to training, performing, or competing, but are attributed to simply participating.

The results of this study do not show as strong of a relationship between Latin ballroom dancing and depression when compared to a healthy non-dancing sample. Dancers are not significantly more likely to receive a depression diagnosis than non-dancers, but they are more likely to experience depressive symptoms during and in between rehearsals. Therefore, while they reported experiencing more symptoms on a regular basis, they were not experiencing these symptoms to a level that impacted the likelihood or severity of a provisional depression diagnosis. Additionally, while there is indication of a trend that increasing the number of hours danced per week might increase the severity of a depression diagnosis, the standard deviations are large and not enough data is available to draw that conclusion. These results are showing hints of a relationship between Latin ballroom dancing and depression; however, the results found in this study are relatively inconclusive and additional research is needed to further understand it.

Therefore, the relationships between Latin ballroom dance training, anxiety, and depression are much more complicated than originally anticipated. The results found in this study show both statistically significant relationships and non-statistically significant trends indicating that participation in Latin ballroom dance increases the risk of someone struggling with symptoms of anxiety and depression, and therefore an increased likelihood of receiving a provisional diagnosis. While this is the first study to look at this relationship directly and additional research is necessary, it is important for dancers, parents, and coaches to be aware of these findings. Understanding the source of these symptoms as it relates to Latin ballroom dance training is essential for both prevention and treatment to promote wellness among dancers.
Even though it was reasonable to expect that the combination of dance training with higher levels of anxiety would cause significant changes in gait patterns, the data collected in this study does not support that idea. While the results of this study show that even though dancers had

higher levels of anxiety and were more likely to have a probable anxiety diagnosis, their gait was not altered significantly when compared to healthy non-dancers. When these results are looked at in the context of previous research findings, it can be theorized that Latin ballroom dance training negates any gait changes that might result from having anxiety. Instead of being compounded as was originally predicted, dance training and gait alterations caused by anxiety might actually counteract each other. While an anxiety diagnosis is never a positive thing, this study indicates that Latin ballroom dance training might be an effective way to neutralize or combat some of the negative physical effects of anxiety. However, since dancers had higher levels of anxiety and were more likely to have a probable anxiety diagnosis as a result of their training, the practical value of these potential benefits is debatable. Some potential explanations for this could be that only some of the same variables were measured in this study and the previous research studies. It could also be attributed to the results showing that dancers felt symptoms of anxiety most often during a rehearsal or practice and might not experience them consistently enough for it to alter their gait.

While the results of this study showed hints of a relationship between Latin ballroom dance training and depression, it is neither a strong nor clear enough connection to reasonably analyze the relationship between depression and gait among dancers; however, it is logical to theorize that the negative effects of depression on gait biomechanics could be counteracted by the dance training as was seen among dancers with anxiety.

Conclusion: Limitations to this study include a lack of information on injury history, a relatively small sample size, and the use of a self-reporting survey. The age of the participants is also a likely limitation. While none of the participants in this study had suffered a lower limb injury in the past 3 months, injuries they suffered prior to that might have an impact on gait biomechanics which was not accounted for in this study. The small sample size has an especially large impact on the psychological data and further information is needed to provide validation and reliability for the results found in this study. Furthermore, the nature of self-reporting in the survey could have led to inaccurate results regarding training history and psychological symptoms even though this study did everything possible to ensure anonymity and create an environment where participants did not feel external pressures or expectations to respond in a certain way. Lastly, the age group of participants in this study could be too young for any significant effects of dancing on gait, anxiety, or depression to manifest. It is possible that many more years of consistent dance training and/or a higher exposure of dance training per week is needed before any negative or positive consequences occur.

While there were many valuable and important findings in this study, additional research on the relationship between Latin ballroom dance, gait, anxiety, and depression is essential. For example, research on Latin ballroom dance's impact on gait can focus on other gait factors including, but not limited to, upper body biomechanics, postural dynamics, muscular activation, plantar pressure distributions, and timing of various peak forces or impulses during stance phase. The relationship between participation between Latin ballroom dance and psychological factors such as anxiety and depression also needs further research for validation and

clarification. Additional studies should include a larger sample size for more detailed, valid, and accurate data. It could also focus on dancers who participate in Latin ballroom recreationally and non-competitively versus dancers who dance more competitively or on a performance team. Research could also study the possibility that Latin ballroom dance training might negate the effects of anxiety on gait biomechanics to promote healthier movement.

It is commonly recognized that participation in physical exercise and activity has a positive impact on mental wellness, and there is great value in studying both the physical and mental impact of Latin ballroom dancing. Not only does studying both physical and mental aspects of dance participation provide a more comprehensive perspective on an individual's wellness, it allows for the study of how physical health and mental health relate to each other. The findings of this study showed minimal impact of Latin ballroom dancing on gait biomechanics, but likely increases levels of anxiety. Providing this more holistic perspective on Latin ballroom dancing allows practitioners, dance teachers, parents, and dancers to make educated decisions to promote health, safety, and wellness among dancers. Increasing awareness and understanding of short- and long-term results of participating in any activity, including Latin ballroom dancing, is an essential part of that process.

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