International Journal of EXERCISE SCIENCE

Original Research

Transversus Abdominis and Lumbar Multifidus Thickness Among Three Dance Positions in Argentine Tango Dancers

ELENI GOURIDOU†, ELEFTHERIOS KELLIS‡, ERMIONI KATARTZI‡, and NIKOLAOS KOFOTOLIS‡

Laboratory of Neuromechanics, Department of Physical Education and Sport Sciences at Serres, Aristotle University of Thessaloniki, Thessaloniki, GREECE

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 14(1): 473-485, 2021. Core muscle function is considered a risk factor for low back pain appearance in dancers. The purpose of this study was to examine the transversus abdominis and lumbar multifidus thickness among Argentine Tango dancers in different functional dance positions. A secondary purpose was to compare muscle thickness at rest and contraction between dancers and untrained participants. Ten trained dancers and ten untrained women aged 33.8 ± 6.09 years participated in this study. Using ultrasonography, the transversus abdominis and lumbar multifidus muscle thickness were measured at rest and during contraction in three different dance positions: Basic in Open embrace, Basic in Close embrace, and Volcada. The results showed a significant increase in muscle thickness during contraction compared to thickness at rest for both muscles ($p < 0.05$). The group of dancers showed a greater transversus abdominis thickness than the untrained group ($p < 0.05$). Further, transversus abdominal thickness progressively increased from Basic in Open embrace to Basic in Close embrace position, as well as from Basic in Close embrace to Volcada position in dancers ($p < 0.05$), while fewer changes between positions were found for the untrained group. Multifidus muscle thickness also differed between positions, but no group differences were observed ($p > 0.05$). Training exercises in these Argentine Tango positions may be beneficial for the performance and prevention of low back pain, especially in Argentine Tango dancers.

KEY WORDS: Core stability, trunk, low back pain, ultrasonography, exercise

INTRODUCTION

Many dancers frequently experience low back pain (LBP) (42). In particular, lumbar spine injuries are the second most frequent in these athletes (17). Among others, the particular style and the technical requirements of each dance appear to influence its frequency. Lower back injury rate seems to be higher in professional ballet, jazz and street dancers compared to those engaged in social dances such as Ballroom (12, 29).

Research has shown that LBP is associated with lower levels of trunk stability compared with pain-free trainees (16, 38, 39). The main stabilizing muscles in the lumbar and pelvic region include the transversus abdominis (TrA) and the lumbar multifidus (LM), as their activation onset contributes to the stability of lumbar spine in unexpected load conditions (20, 34). When the trunk stability is altered by reactive forces due to sudden limb movement, the TrA is the first trunk muscle that is activated and it is accompanied by co-activation of the antagonist LM (20, 21). The stabilizing role of deep abdominal muscles and their association with intra-abdominal pressure, contributes to postural control and spinal stability, during functional activities (19).

Recent studies focused on core muscle function by assessing changes in deep abdominal and back paraspinal muscle thickness at rest and contraction using ultrasound (US) imaging (18, 24, 33, 22). The use of ultrasound provides an indication of muscle contraction, as changes in muscle thickness from rest to contraction are related to changes in electromyographic activity (32). Further, there is evidence that individuals with LBP present with smaller TrA contraction thickness compared with pain-free population (14). Core stabilization training, including exercises with abdominal drawing-in maneuver (ADIM), seems to be effective for rehabilitation and performance enhancement in athletes, dancers, and patients with LBP by increasing muscle strength and improving spinal stability and postural control (25, 40, 45). Exercises involving ADIM increase intra-abdominal pressure by pulling the abdominal wall through contraction of TrA and oblique abdominals (9). Cresswell et al. (9) found that during isometric contraction from the standing position, there is a consistent association between the increase of TrA muscle thickness, intra-abdominal pressure, and force production to minimize joint loads in habitual activity adults. Intra-abdominal pressure and/or muscle thickness is increased during physical activity depending on its intensity (11).

Argentine tango is a type of dance which is followed systematically by a part of the general population, owing to its important social and psychological benefits for the participants (43). Today, hundreds of thousands of participants gather in landscaped halls, dancing to the sounds of tango music worldwide. According to van Alphen (44), Argentine Tango is an improvised dance where the communication and the coordination between the two partners' bodies practically coexist. The Leader, usually a male dancer, sets the "foundations" of the dance and the Follower, usually a female dancer, communicates feedback with steps, pivots, turns and pauses for embellishments even in inclined positions. Technical requirements include the alignment of the body, chest contact and the transfer of body mass to the metatarsals for both partners, in their effort to maintain static and dynamic balance. The complex balance tasks in heel raise position increase the demand for higher technical and physical performance requirement in Followers.

An increase in core muscle activation represents a strategy to maintain postural stability and balance which are challenged by an external perturbation (5). This may assist in preventing LBP as well as in performing exercise with correct technique (23, 31). Dancing is a demanding physical activity and dancers must be properly trained to avoid injuries (28). Despite regular exercise, deep spinal muscle strength and lumbar motor control are often inadequate in some dancers when performing core stability exercise associated with LBP appearance (3, 39). Argentine Tango involves a variety of unique dance postures and it has been used as a dance therapy intervention for the treatment of gait and balance impairments in individuals with neurological disorders (8). This type of exercise has been recommended as a beneficial activity for posture and gait by Tango therapists, who propose that Argentine Tango possibly strengthens the core muscles (26). However, changes in thickness of TrA and LM in Argentine Tango dancers are currently unknown.

The purpose of the present study was to investigate TrA and LM muscle recruitment during three functional dance positions. A secondary purpose was to compare muscle thickness levels of TrA and LM between Argentine Tango dancers and non-dancers. The three dance positions were selected, as they place different basic postural demands during training and are representative of Argentine Tango dance. Evaluating the amount of change in muscle contraction in functional positions could add information for the design of appropriate training programs for Argentine Tango dancers that could prevent injuries and improve performance. In addition, estimation of TrA and LM thickness in healthy adults, who choose this exercise as leisure activity, could represent the effect of Argentine Tango dance-related tasks in core muscle behavior and function. Our primary hypothesis was that performance of ADIM maneuver from various Argentine Tango positions would increase TrA and LM thickness. The second hypothesis was that dancers would have greater changes in TrA and LM thickness compared to untrained participants.

METHODS

Participants

The necessary sample size to achieve statistical power was calculated using G-power (v.3.1.9.4, University Kiel, Kiel, Germany). Based on previous research using the same experimental protocol, group differences in thickness more than 0.17 ± 0.58 mm for the TrA and 1.2 ± 3.95 mm for the LM can be attributed to influence of an independent variable (22). Such differences correspond to an effect size of approximately 0.30. Hence, for the analysis of variance (ANOVA) global effect on muscle thickness, the following inputs were provided: number of groups = 2, effect size = 0.30 (medium effect), power = 0.80, type 1 error = 5%. This model yielded a total sample size of 18 participants.

Twenty women (age: 33.80 ± 6.09, weight: 53.4 ±3 kg, height: 164 ± 5 cm, BMI: 19.97 ± 1.03) participated voluntary in this study. Ten of them were nationally competitive level athletes from the same team, with dance experience five to eleven years and sport dancing experience between one and four years. The control group included ten sedentary women who did not participate in any physical activity for at least the previous twelve months. Participant characteristics are demonstrated in Table 1. All participants were declared healthy with no current or previous injuries in the lumbar spine and/or the limbs and gave their written informed consent. The protocol was approved by the University Ethics Board. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (35).

Protocol

Measurement equipment: An Aloka SSD 3500 ultrasound (Aloka inc Japan, frequency 15 MHZ) device with an 60mm-10MHz linear transducer was used for the measurement of TrA and LM muscle thickness, during three functional dance positions.

Procedure: Prior to testing, participants performed a 15-minute familiarization and warm up. Specifically, individuals were given a demonstration of ADIM first from the supine, then from the standing position, and in each of the three dancing positions of the main protocol. They were then asked to perform a minimum of five efforts in each testing condition. In all trial measurements, participants had visual contact with the ultrasound screen and verbal feedback of the score to understand TrA activation by performing maximum exhalation. To ensure similar performance of participants the following procedure was followed. Participants first performed several familiarization trials by performing ADIM contractions in each dance position. They received standardized instructions regarding performance of each contraction. The experimenter calculated US muscle thickness immediately after each trial and asked for an additional trial, if needed.

The selected functional dance positions were performed according to the "Terminology of Argentine Tango for Tango Therapy" and the instructions described in the book "Argentine Tango, A Guide to Basics and Beyond (Part 1)" (Figure 1) (6, 27). In the first "Basic in Open Embrace" or Basic position, the body weight was distributed among the foot. Partners were in their axis and the lower body was 20 cm apart. In the second "Basic in Close Embrace" or Pyramid position, the participants started from the basic position in Open embrace and then transferred their weight to metatarsals and their axis in front of their toes on exhalation, maintaining their static and dynamic balance. In the third position ("Volcada"), the distance between partners increased by half a foot by marking the floor. From a heel-raising position the participant leaned forward and fell out of her axis, while performing isometric contraction of the upper extremities and selective activation of the TrA muscle. At the end of the effort the partners were balanced on a common axis without altering the initial position and distance of their arms. The participants were instructed to "push back as if you want to return to your starting position". In each of the three dancing positions, upon contraction, subjects were asked to draw in their abdomen by performing maximal exhalation and hold this contraction without moving the spine or the pelvis. Each attempt lasted about ten seconds. Verbal feedback was provided continuously to maintain the abdominal draw. In case of wrong dance position or movement of the spine, the effort was repeated. All dancing movements were performed with the same partner.

Ultrasound measurements: Ultrasound measurements consisted of thickness measurements taken from the TrA and the LM (a) at rest from Base position in Open embrace (Rest), (b) performing ADIM from Base position in Open embrace (Basic), (c) performing ADIM from Base position in Close embrace (Pyramid), and (d) performing ADIM in Volcada position.

Ultrasound probe positions were first identified and marked on the skin. For the measurements of TrA muscle thickness, the transducer was positioned on the abdominal wall

along a line midway between the inferior angle of the rib cage and the iliac crest. Via ultrasound image, the distance between the upper and lower line of the muscle fascia at the middle of the image was measured following the Hides et al. protocol (18). Regarding LM, the transducer was positioned longitudinally along the vertical column until the L4/5 zygapophyseal joint could be identified. For muscle thickness value, the distance between the spinous process of the 4th lumbar vertebrae and the subcutaneous tissue was measured (24). For the resting measures, participants were guided to breathe normally and US images from each muscle were recorded at the end of exhalation. In the dancing positions, the US probe was applied immediately after the participant has initiated the ADIM. Three measurements from the TrA and LM were then taken in each dance position. Using the ultrasound manufacturer software, the muscle thickness at rest (mm), muscle thickness at contraction (mm), and the differences as a percentage change were calculated. Three measurements for each functional position were taken when ADIM was performed and the best was selected. In total, four measurements were assessed for each muscle at rest and during ADIM in each of the three dance positions. The efficacy of ultrasound evaluation of TrA and LM thickness in standing position during functional tasks to assess muscle contraction has been previously documented (15). Ultrasound provides a two-dimensional cross-section of muscle in each condition. EMG activation of deep musculature is difficult to measure unless an invasive procedure is used. Muscle thickness is relatively easy to measure under in vivo conditions and it is correlated to EMG activation (32).
ZZXCCCCXCZ

Figure 1. Measurement positions: Basic in Open embrace, Basic in Close embrace (Pyramid), Volcada (from left to right).

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics 25 for Windows. Independent t-tests were used to compare the anthropometric characteristics and resting thickness between groups. Test for normality (Shapiro-Wilks test) and sphericity (Mauchly's Sphericity test) were performed, correcting the *F*-value (Greenhouse-Geisser) when violated. For data analysis, analysis of variance with repeated measurements (2x4 repeated measures) was undertaken separately. When significant interactions of variables were identified (group x position), paired samples t-tests and independent samples t-tests were followed (Bonferroni post-hoc). The percent difference in muscle thickness between rest and contraction was calculated by the formula [(thickness at contraction – thickness at rest) / thickness at rest] x 100. Non-parametric Friedman test for the TrA percentage change differences between positions was performed. For LM percentage change differences, an analysis of variance (2x3 repeated measures) was used. The level of significance was set at $p < 0.05$. Partial eta squared indicating a "small", "medium", and "large" effect size were 0.01, 0.06, and 0.14 respectively (2). Effect sizes indicating a "small", "medium", and "large" effect size were 0.20, 0.50, and 0.80 respectively (7).

RESULTS

There were no differences in age (t = 1.3, df = 18, p = 0.2), height (t = 1.1, df = 10.4, p = 0.3), weight (t = 0.7, df = 18, p = 0.5) and BMI (t = 0.8, df = 11.6, p = 0.4) between groups (Table 1). Similarly, at baseline, no statistically significant differences in the resting thickness of TrA (t =0.25, df = 18, p = 0.805) and LM (t =0.05, df = 18, p = 0.59) were found between groups (Table 2).

Table 1. Participant characteristics.

	Dancers (n = 10)	Controls (n = 10)	p	Total (n = 20)
Age	35.50 ± 5.82	32.10 ± 6.18	0.2	33.8 ± 6.09
High (cm)	165 ± 2	162 ± 8	0.3	164 ± 5
Weight (kg)	53.90 ± 2.18	52.90 ± 3.70	0.5	53.4 ± 3
BMI (kg/m2)	19.78 ± 0.53	20.15 ± 1.38	0.4	19.97 ± 1.03

Mean (±SD) and p-value are shown BMI= body mass index.

TrA muscle thickness: The analysis of variance showed that the dance position x group interaction (F (3.54) = 8.79, p = 0.000, partial eta squared = 0.328) and the main effect of dance position on TrA muscle thickness (F (3.54) = 148.006, p = 0.000, partial eta squared = 0.892) were statistically significant. After Bonferroni correction, the dancers showed significantly greater TrA contraction thickness than non-athletes in the Basic (t = 3.009, p = 0.008, d = 1.04), Pyramid (t = 5.707, p = 0.000, d = 1.3) and Volcada position (t = 6.293, p = 0.000, d = 1.32) (Table 2). In within-group comparisons, statistically significant differences were observed between rest and the three ADIM conditions for both groups (p = 0.000). The group of dancers presented a progressively increase in muscle thickness from rest to Basic (t = 8.964, df = 9, p = 0.000, d = 2.35), from Basic to Pyramid (t = 3.709, df = 9, p = 0.005, d = 0.9) and from Pyramid to Volcada condition (t = 4.513, df = 9, p = 0.001, d = 0.53). In controls, muscle thickness increased only from rest to Basic condition (t = 10.633, df = 9, p = 0.000, d = 1.24). In this group, no differences between Basic and Pyramid as well as between Pyramid and Volcada were found (p > 0.05).

LM muscle thickness: The analysis of variance showed that the effect of condition in LM muscle thickness was statistically significant (F (1.732.54) = 153.48, p = 0.00, partial eta squared = 0.895), but not the interaction condition x group (F (1.732.54) = 2,508, p = 0.104, partial eta squared = 0.122). For both groups, changes in muscle thickness were found between rest, Basic, Pyramid and Volcada condition (Table 2).

Table 2. Mean± SD values of muscles size (mm) at rest and during contraction in both groups.

Conditions	TRAD	TRAC	*p*	ES	LMD	LMC	ES
Rest	3.8±0.75	3.87±0.47	0.805	0.15	26.1±3.74	25.12±4.36	0.22
Basic	6.15±0.99^	5.11±0.45^	0.008*	2.31	27.68±3.74^	26.44±4.34^	0.29
Pyramid	7.05±0.56^	5.75±0.46^	0.000*	2.83	29.35±3.29^	27.31±3.72^	0.55
Volcada	7.58±0.39^	6.26±0.54^	0.000*	2.44	30.66±3.78^	29.04±4.02^	0.40

TRAD= transversus abdominis (dancers), TRAC = transversus abdominis (control), LMD= lumbar multifidus (dancers), LMC= lumbar multifidus (control), Controls ES=Effect size.
* Significant difference between groups; ^ Significant difference between rest and contraction conditions.

Percentage change of TrA thickness: The Friedman test showed that the percent change of TrA muscle thickness was affected by the dance position for dancers (p = 0.000) and matched controls (p = 0.002). The changes were grater in dancers compared with non-athletes in all measurement conditions (Table 3). In within-group comparisons (Wilcoxon test), dancers showed an increase between Basic-Pyramid (p = 0.005) and Pyramid-Volcada position (p = 0.005). In the control group, the TrA percentage change was found to be insignificant between Basic-Pyramid (p = 0.017) and Pyramid-Volcada position (p = 0.075).

Percentage change of LM thickness: The analysis of variance for percentage change of LM thickness showed that the effect of position on percentage change was statistically significant (F (1.414.36) = 72.477, p = 0.000, eta partial squared = 0.801) but not the interaction group x position (F (1.414.36) = 1.206, p = 0.301, partial eta squared = 0.063). Both groups showed differences in the percentage change between Basic, Pyramid and Volcada position (Table 3).

Table 3. Mean ± SD of % change in muscle thickness during contraction in 3 positions for both groups.

Conditions	TRAD	TRAC	*p*	ES	LMD	LMC	ES
Basic	55.15±30.51	33.80±10.84	0.001*	1.97	6.04±2.03	5.43±2.03	0.30
Pyramid	81.00±36.57^	47.40±25.18	0.003*	1.33	12.82±4.41^	9.39±5.34^	0.64
Volcada	91.20±44.27^	65.30±16.24	0.009*	1.59	17.72±4.38^	16.34±6.79^	0.20

* Significant difference between groups; ^ Significant difference between positions.

DISCUSSION

The main findings of this study were: 1. TrA and LM muscle thickness was greater in all dancing contraction conditions relative to thickness at rest for all groups, 2. thickness of TrA but not LM was clearly higher in dancers than untrained participants and, 3. TrA muscle behavior varied between groups during these exercises. To our knowledge, this is the first study which evaluated TrA and LM thickness at rest and contraction in Argentine Tango dancers.

A variety of exercises that recruit the TrA and LM muscles from the supine, prone, or quadruple positions have been proposed in the literature (4, 10). In this study, we found that contraction of the deep abdominal and spinal muscles from the three Argentine Tango dancing positions also significantly increased their thickness in all participants, thus confirm our primary hypothesis (Table 2). We also noted that thickness differed between dancing positions. The gradual increase in thickness from the Basic to the Pyramid and then to the Volcada dance position could be due to a greater demand for trunk stability. This may be due to narrowing of the base of support as well as an increase of the external resistance from the Basic to the Volcada position. According to Panjabi (36), the interaction of the active (contractile), passive (non-contractile), and nervous system serves to maintain the mechanical stability of the lumbar spine under normal load. As external load increases, muscle activation is greater to minimize passive pressure (36). Studies have also shown that greater and sudden perturbations from the upper or lower limbs, such as the ones which take place when performing Pyramid or Volcada exercises, may increase pre-activation and magnitude of activation of the deep abdominal and spinal muscles (20, 21, 34). It is also possible that co-contraction of all muscles during each dancing position might have increased intra-abdominal pressure, which also contributes to postural control and spinal stability (9, 19). Consequently, based on these results we could intimate that Argentine Tango seems to have a positive effect in TrA and LM muscle thickness, and through that, on lumbar stability even for novice participants.

The second hypothesis was that dancers would have greater changes in TrA and LM thickness compared to untrained participants. While the controls showed a general increase in thickness of both muscles from rest to each dancing position, the dancers increased progressively and significantly TrA contraction thickness from Basic to Pyramid and from Pyramid to Volcada positions (Table 3). As muscle thickness may indicate muscle activation, these findings could be translated into a stronger and stable core for dancers compared with sedentary women (32, 33). The higher ability of the dancers to better recruit the TrA in more demanding dance positions may be reflect differences in neural control between the two groups (5). Our experimental design does not allow conclusions as to whether previous training experience of dancers allowed them to better co-contract the TrA and the LM when performing contractions from a more demanding dancing position. Nevertheless, it appears that dancers manage to better recruit their TrA which may provide them with greater lumbar stability and postural control (23, 31).

Chatfield et al (5) used EMG signals during a forward step passing from plié fondu position and found that beginner dancers had less abdominal muscle activation and vertical posture than experts. In our study TrA, but not LM activation, was clearly higher in dancers than untrained participants. The lower TrA contraction thickness in the untrained group in the Pyramid position could explain why some novice dancers find it difficult or inconvenient to stand in this position and prefer to dance in Open embrace. Qualitatively, we observed that when dancing in a Pyramid position, novice dancers usually flex their torso due to the increased compressive forces which are produced in this position performing a technically wrong dance posture (1). Dynamic control of the spine is achieved by sufficient trunk muscle co-activation and neuromuscular control in upright positions (37). On the other hand, the lack of lumbopelvic stability gives a high prevalence of injuries in lumbar spine and low extremities (38). Instructors could take this information into consideration when designing training programs by ensuring that athletes improve core muscle strength and spinal motor control, before progressing from the Open to Closed embrace position. Moreover, considering the potential benefits of co-activation in joint injury prevention and treatment, as well in performance, the specific Tango postures might have implications in rehabilitation (23, 25, 31, 40, 45). A recent study in post-stroke patients aged 18-60 years indicated that a combination of Argentine Tango therapy and a standard 45-minute rehabilitation program is more advantageous for improving postural balance compared with a conventional rehabilitation program (13). Further investigations are required to examine the beneficial influence of Argentine tango exercises as a therapeutic intervention for individuals with postural stability problems.

The absolute and percentage change in thickness of the TrA were higher in dancers in all dancing positions compared with control participants, whereas no group differences were found in rest thickness (Tables 2 and 3). As already explained, there are no previous studies which examined thickness in this particular sport. Nevertheless, our findings are in line with those by Linek et al. (30), who found that physically active adolescents, including dancers, had similar TrA resting thickness but a greater contraction thickness than adolescents with no regular physical activity. In contrast, national Olympic style female weightlifters had a significantly thicker absolute resting TrA thickness than non-athletes (41). Differences in sport and type of training may account for these contrasted findings. In the present study, Argentine Tango dance routine among female athletes appears to result in greater muscle thickness during contraction than non-athletes, but not in preferential hypertrophy of the TrA (as reflected in rest TrA). This indicates that dancers display a greater capacity to contract their TrA in each dancing position than controls. As dancers are systematically trained in performing in these dance positions, this is an expected finding. However, it is reasonable to suggest that greater TrA thickness represents a characteristic of basic Argentine Tango dance exercises.

In all contraction conditions, participants increased the TrA and LM thickness compared to thickness at rest. This evidence may indicate that Argentine Tango could have a positive effect on core stabilization even for novice participants. The higher levels of TrA muscle thickness for the dancers may be due to the specialized training that complies with the technical requirements of this dance. Future studies, comparing Tango athletes with those participating in other sports as well as male athletes could provide a better indication of relative effectiveness of Argentine Tango exercise for core stability in healthy individual. Research also confirmed that regular exercise has a significant impact on the ability of healthy individuals to perform selective activation and greater contraction of the TrA than sedentary individuals (33). In view of our findings, the greater values in TrA muscle thickness among dancers compared with no physical activity women could indicate that Argentine Tango as regular exercise may have a positive effect on TrA and lumbar stability. Notably, it is important to acknowledge that Argentine Tango dancers were more familiar in these exercises. In addition, the short ADIM training was based on visual and verbal biofeedback. However, the differences in TrA muscle thickness, which were observed between experienced and non-dancers, was able to present a positive correlation between muscle recruitment and exercise experience. If muscle thickness can be an indicator of muscle function or activity, Argentine Tango exercise could be suggested as core training contributing to the spinal stability and the postural control in standing. Nevertheless, we must emphasize that in this study participants performed the movements barefoot, while during training and competitions athletes wear 8-cm high-heeled professional dance shoes. This clearly resulted in a body posture which is different from the real dancing conditions, especially in the Basic dancing position. Additional studies examining participants who wear high heel shoes could provide additional information about the effectiveness of such exercises for core muscle contraction. Finally, Tango dancers usually assume a unipedal standing position while preparing their next step. Bipedal stance is frequently used during familiarization exercises in training. In this study, measurements were made in bipedal stance position to prevent injuries in non-athletes. Similarly, at the Pyramid and Volcada positions partners usually have their chest in contact. Instead, we used modified positions which are used for familiarization training, especially by less skillful dancers.

Performance of abdominal hollowing maneuvers from three Argentine Tango dancing positions resulted in a greater contraction thickness of two core muscles of the trunk, especially the transversus abdominis. Systematically trained Argentine Tango dancers displayed greater core muscle thickness than untrained individuals. The acute increase in core muscle thickness provide preliminary evidence that participation in Argentine Tango can have a positive influence on core stability but chronic effects of such exercises have yet to be determined.

REFERENCES

1. Bergmark A. Stability of the lumbar spine. A study in mechanical engineering. Acta Orthop Scand Suppl 230: 1-54, 1989.

2. Bernards JR, Sato K, Haff GG, Bazyler CD. Current research and statistical practices in sport science and a need for change. Sports (Basel) 5(4): 87, 2017.

3. Bobály VK, Makai A, Kiss G, Markus M, Lepenye KE, Simon-Ugron Á, Járomi M. Core muscle assessment of dancers. Studia UBB Educatio Artis Gymn LXI(2): 31-47, 2016.

4. Chanthapetch P, Kanlayanaphotporn R, Gaogasigam C, Chiradejnant A. Abdominal muscle activity during abdominal hollowing in four starting positions. Man Ther 14(6): 642-646, 2009.

5. Chatfield JS, Krasnow HD, Herman A, Blessing G. A descriptive analysis of kinematic and electromyographic relationships of the core during forward stepping in beginning and expert dancers. J Dance Med Sci 11(3): 76-84, 2007.

6. Chatzigeorgiou S, Dragatsi V. Argentine Tango, A guide to Basics and Beyond (Part 1). Brighton: The International Dance Teachers' Association; 2009.

7. Cohen J. Statistical power analysis for the behavioral sciences. New York, NY: Routledge; 1988.

8. Collebrusco L, Di Tocco G, Bellanti A. Tango-Therapy: An alternative approach in early rehabilitation of multiple sclerosis. Open J Ther Rehabil 6(3): 85-93, 2018.

9. Cresswell AG, Grundström H, Thorstensson A. Observations on intra-abdominal pressure and patterns of abdominal intra-muscular activity in man. Acta Physiol Scand 144(4): 409-418, 1992.

10. Dafkou K, Kellis E, Ellinoudis A, Sahinis C. The effect of additional external resistance on inter-set changes in abdominal muscle thickness during bridging exercise. J Sports Sci Med 19(1): 102–111, 2020.

11. Dietze-Hermosa M, Hitchcock R, Nygaard IE, Shaw JM. Intra-abdominal pressure and pelvic floor health: Should we be thinking about this relationship differently? Female Pelvic Med Reconstr Surg 26(7): 409-414, 2020.

12. Diogo MA, Ribas GG, Skare TL. Frequency of pain and eating disorders among professional and amateur dancers. Sao Paulo Med J 134(6): 501-507, 2016.

13. Dursun E, Yalcin S, Gokbel T, Karacan C, Dursun BM, Akarsu M, Dursun N. Evaluation of dance therapy effects on gait pattern in patients with previous cerebrovascular events: Randomized study results from a single center. Edorium J Disabil Rehabil 2: 124–130, 2016.

14. Ferreira PH, Ferreira ML, Hodges PW. Changes in recruitment of the abdominal muscles in people with low back pain: ultrasound measurement of muscle activity. Spine (Phila Pa 1976) 29(22): 2560–2566, 2004.

15. Gibbon KC, Debuse D, Hibbs A, Caplan N. Reliability and precision of sonography of the lumbar multifidus and transversus abdominis during dynamic activities. J Ultrasound Med 36(3): 571-581, 2017.

16. Gildea JE, Hides JA, Hodges PW. Morphology of the abdominal muscles in ballet dancers with and without low back pain: a magnetic resonance imaging study. J Sci Med Sport 17(5): 452-456, 2014.

17. Gottschlich ML, Young CC. Spine injuries in dancers. Curr Sports Med Rep 10(1): 40-44, 2011.

18. Hides JA, Miokovic T, Belavý DL, Stanton WR, Richardson CA. Ultrasound imaging assessment of abdominal muscle function during drawing-in of the abdominal wall: an intrarater reliability study. J Orthop Sports Phys Ther 37(8): 480-486, 2007.

19. Hodges PW, Gandevia SC. Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm. J Appl Physiol 89(3): 967-976, 2000.

20. Hodges PW, Richardson CA. Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. Exp Brain Res 114(2): 362-370, 1997.

21. Hodges PW, Richardson CA. Contraction of the abdominal muscles associated with movement of the lower limb. Phys Ther 77(2): 132-142, 1997.

22. Kellis E, Ellinoudis A, Intziegianni K, Kofotolis N. Muscle thickness during core stability exercises in children and adults. J Hum Kinet 71(1): 131–144, 2020.

23. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Med 36(3): 189-198, 2006.

24. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther 12(2): 161-166, 2007.

25. Kofotolis N, Kellis E, Vlachopoulos SP, Gouitas I, Theodorakis Y. Effects of Pilates and trunk strengthening exercises on health-related quality of life in women with chronic low back pain. J Back Musculoskelet Rehabil 29(4): 649-659, 2016.

26. Koh Y, Hur Y, Kim SI, Ha WC, Noh G. Tango gait for tango therapy: Functional anatomical characteristics of tango gait ('Tango Gaitology'). J Tango 1(2): 33-47, 2019.

27. Koh Y, Hur Y, Noh G. Terminology of argentine tango for tango therapy. J Tango 1(1): 7-17, 2019.

28. Koutedakis Y, Jamurtas A. The dancer as a performing athlete: physiological considerations. Sports Med 34(10): 651-661, 2004.

29. Kuisis SM, Camacho T, Kruger PE, Camacho AL. Self-reported incidence of injuries among ballroom dancers. Afr J Phys Health Educ Recreat Dance 18(1): 107-119, 2012.

30. Linek P, Saulicz E, Wolny T, Myśliwiec A. Assessment of the abdominal muscles at rest and during abdominal drawing-in manoeuvre in adolescent physically active girls: A case-control study. J Sport Health Sci 6(1): 118-124, 2017.

31. McGill SM, Grenier S, Kavcic N, Cholewicki J. Coordination of muscle activity to assure stability of the lumbar spine. J Electromyogr Kinesiol 13(4): 353-359, 2003.

32. McMeeken JM, Beith ID, Newham DJ, Milligan P, Critchley DJ. The relationship between EMG and change in thickness of transversus abdominis. Clin Biomech (Bristol, Avon) 19(4): 337-342, 2004.

33. Moon JH, Hong SM, Kim CW, Shin YA. Comparison of deep and superficial abdominal muscle activity between experienced Pilates and resistance exercise instructors and controls during stabilization exercise. J Exerc Rehabil 11(3): 161-168, 2015.

34. Moseley GL, Hodges PW, Gandevia SC. External Perturbation of the trunk in standing humans differentially activates components of the medial back muscles. J Physiol 547(2): 581–587, 2003.

35. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

36. Panjabi MM. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. J Spinal Disord 5(4): 390-396, 1992.

37. Reeves NP, Cholewicki J, van Dieën JH, Kawchuk G, Hodges PW. Are stability and instability relevant concepts for back pain? J Orthop Sports Phys Ther 49(6): 415-424, 2019.

38. Rickman AM, Ambegaonkar JP, Cortes N. Core stability: implications for dance injuries. Med Probl Perform Art 27(3): 159-164, 2012.

39. Roussel N, De Kooning M, Schutt A, Mottram S, Truijen S, Nijs J, Daenen L. Motor control and low back pain in dancers. Int J Sports Med 34(2): 138-143, 2013.

40. Saeterbakken AH, van den Tillaar R, Seiler S. Effect of core stability training on throwing velocity in female handball players. J Strength Cond Res 25(3): 712-718, 2011.

41. Sitilertpisan P, Pirunsan U, Puangmali A, Ratanapinunchai J, Kiatwattanacharoen S, Neamin H, Laskin JJ. Comparison of lateral abdominal muscle thickness between weightlifters and matched controls. Phys Ther Sport 12(4): 171-174, 2011.

42. Swain CTV, Bradshaw EJ, Ekegren CL, Whyte DG. The Epidemiology of Low back pain and injury in dance: A Systematic Review. J Orthop Sports Phys Ther 49(4): 239-252, 2019.

43. Targhetta R, Nalpas B, Pascal P. Argentine tango: Another behavioral addiction? J Behav Addict 2(3): 179-186, 2013.

44. van Alphen F. Tango and enactivism: first steps in exploring the dynamics and experience of interaction. Integr Psychol Behav Sci 48(3): 322-331, 2014.

45. Watson T, Graning J, McPherson S, Carter E, Edwards J, Melcher I, Burgess T. Dance, balance and core muscle performance measures are improved following a 9-week core stabilization training program among competitive collegiate dancers. Int J Sports Phys Ther 12(1): 25-41, 2017.