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EFFECTS OF FASCIA-ORIENTED TRAINING PROGRAM ON JOINT POSITION SENSE, FORCE SENSE, AND POSTURAL CONTROL OF DANCERS

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Abstract:

Introduction: The successful execution of dance elements demands exceptionally high levels of proprioceptive acuity. The fascial system contains significantly more mechanoreceptors than the muscular system and plays a crucial role in proprioceptive acuity. However, traditional dance training primarily focuses on the muscular system while neglecting the fascia. The aim of this study was to investigate the effectiveness of a fascia-oriented training program compared to a traditional one on dancers' joint position sense (JPS), force sense, and postural control.

Methods: A quasi-experimental, pretest-posttest control group design was used in this study. Thirty-four female semi-professional dancers (20.65 ± 2.33 years, contemporary dance) were randomly assigned to either the fascia-oriented training group (treatment group, 17 dancers) or the control group (traditional training, 17 dancers). The intervention lasted 6 weeks (3 sessions per week, each lasting 90 minutes). The lesson structure of the intervention group was the same as that of the control group, except for the fascia-oriented training program (15 minutes per session). Before and after the intervention, the dancers performed the angle reproduction test (shoulder and knee JPS test), the force-matching test, and the single-leg test (total excursion of the center of pressure, ellipse sway area).

Results: The findings of the study indicated that the treatment group displayed better JPS compared to the traditional training program. No significant differences were observed regarding force sense and postural control.

Conclusion: The fascia-oriented training program has a positive effect on JPS, which can enhance dancers' performance and reduce the risk of injury.

Introduction

The term proprioception refers to the information received from the body regarding the position and movement of the body in space. Proprioceptive information enables an individual to be aware of the position of the limbs (joint position sense) and their movement without visual feedback. Other important components of proprioceptive information are force sense (the perception of the amount of applied force) and the sense of postural control [1]. Proprioceptive

information plays a crucial role in coordinating the complex dance movements of body parts relative to each other (execution of complex choreography) and maintaining proper postural control [2]. Moreover, proprioceptive acuity is important for reducing the likelihood of placing joints in high-risk positions during jumps and landings (e.g. ankle/knee joints) [3]. Proprioceptive acuity improves with increasing age (e.g., young adults perform better than children) and with the proper training stimulation [4]. Children who do not receive appropriate training stimuli show lower proprioception than those who do [5]. Therefore, it is important for dancers to develop appropriate training procedures to improve proprioception.

The performance of dance movements demands exceptional flexibility. For this reason, static stretching (SS) is an integral part of dance training. However, recent studies reported that SS may have a negative impact on proprioceptive acuity [6]. For example, Oskouei et al. [7] reported that SS negatively affected knee JPS of football players, while Smajla et al. [6] observed reduced force sense in physically active, non-competitive young adult athletes. Further research by Martínez-Jiménez et al. [8] demonstrated that intermittent stretching produced better balance outcomes compared to continuous stretching in healthy adults. It is assumed that SS reduces muscle-tendon unit stiffness, affecting muscle-spindle receptors and Golgi-tendon organs [9], which are the main receptors for proprioceptive information. Furthermore, various studies have demonstrated that besides proprioceptive information, prolonged SS impairs strength, power, sprint, and jumping ability [9–11].

To counteract the negative effects of SS on strength and proprioception, it is suggested to combine SS and DS activities in warm-up routines [12]. However, the relevant research results are inconclusive. Some studies have reported that combined stretching protocols reduce the harmful effects of SS [13] while others have found no performance benefits following combined protocols [14]. Regarding dance, the few studies that have investigated the effects of combined stretching protocol reported improvements in vertical jump and balance [15,16]. Common stretching routines in dance training are based on combined stretching protocols [16]. Despite an extensive literature review, no studies were found that investigated the long-term effects of combined stretching training (static and dynamic stretching) on JPS and force sense in dance classes.

Fascia is a widespread tensional network throughout the body that surrounds all muscles and organs [17]. Due to the extremely large number of sensory receptors, estimated to be 10 times more than those in the muscular system, fascia plays a key role in body perception (proprioception) [17]. An unhealthy (non-elastic and non-resilient) fascia leads to decreased proprioceptive information and increased risk of injury (e.g. decreased postural control) [18]. Recent research shows that fascia adapts to the motor loads a person is exposed to [18]. Moreover, traditional static and dynamic stretching, commonly used in training, targets only the muscular system and not the fascia [19]. Evidence shows that repetitive monotonous stress on muscle groups during training (e.g. dancers performing the same dance moves repeatedly) is beneficial for muscle performance, but negatively affects fascial elasticity and resilience [17]. On the other hand, researchers suggest specific training principles that can improve the health of fascial network [17]. For example, Myers [19] recommends that hand rubbing and moving the skin tissues enhance fascial proprioception, while Schleip and Müller [17] suggest smooth and soft bouncing movements, such as hopping and soft landings, to improve the fascial system. Therefore, a focused training program of the fascial network could enhance proprioceptive acuity and reduce the risk of injury.

Recently, researchers have identified specific training principles that address the health of the fascial system [17]. The purpose of this study was to investigate the effects of a fascia-oriented training approach on joint position sense, force sense, and postural control in dancers. It was hypothesized that participation in a training program designed to improve the health of the fascial system would lead to improvements in proprioception compared to a traditional dance training program.

Material and Methods

Sample Characteristics

The sample size for the study was determined using G*Power software (version 3.1) [20]. The calculation parameters included an effect size (f) of 0.25, an alpha (α) of 0.05, and a power of 0.8. Based on G*Power's calculations, the optimal sample size was set at 28 dancers. To account for potential dropouts, the estimated number of participants was increased by 10%. A total of 34 semi-professional female dancers, aged 20.65 ± 2.33 years, voluntarily expressed interest in participating in the study. Inclusion criteria for participation in the study were: (a) regular engagement in dance training for at least three years, and (b) absence of acute musculoskeletal injuries, as self-reported by the dancers. Dancers were randomly assigned to either the treatment group (17 dancers, aged 21.12 ± 2.34 years)

or the control group (17 dancers, aged 20.18±2.29 years). Participants were also instructed to refrain from taking nutritional supplements and engaging in other physical activities (e.g., additional stretching sessions or strength training) during the study period. The study followed the ethical guidelines of the Aristotle University of Thessaloniki, and written informed consent was obtained from all participants. All procedures were conducted in accordance with the Declaration of Helsinki.

Procedure

A quasi-experimental pretest-posttest control group design was used in this study. The duration of the intervention was 6 weeks, with 3 sessions per week, each lasting 90 minutes. The structure of the treatment group’s session was the same as that of the control group, except for a 15-minute period of fascia training program (FTP) [21]. During this period, the treatment group performed the FTP (15 min), and the control group performed technique exercises (traditional dance session structure, Table 1). The FTP exercises aimed to replicate dance movements while following the fascia training principles outlined by Schleip and Müller [17] and Myers [19]. The training principles and the content of the program are presented in Table 2.

Table 1. Treatment protocols for both dance groups.

Phase	Time	Intervention Group	Control Group
1. Warm-Up	10-12 min	2-3 min of moderate-intensity jogging. 8-9 min of SS and DS exercises (quadriceps, hamstring, hip adductors, upper body). Each muscle received 30 sec of SS and 10-12 repetitions of DS [22].	
2. Special Treatment	15 min	Fascia training program. The training content of the program is presented in Table 2.	Dance preparation focused on technical skills.
3. Technique Drills	10-20 min	Practicing the refinement and mastering (precision) of technical skills of dance, e.g., plies, tendus, pirouettes, extensions, chasses, leaps, rolls.	
4. Choreography (phrases and sequences)	30-40 min	Practicing dance sequences, which combine various dance elements, e.g. jumps, turns, and floor work.	
5. Cool Down	10-12 min	Gentle movements and stretches to cool down the body and reduce muscle tension.	

Table 2. Fascia training principles of the intervention.

Fascia training principles: • Counter-movement preparation. The dancers entered a state of pre-tension before executing the main movement. For instance, the preparatory movement before a pirouette, where the dancer prepares the body with an opposite movement. • The Ninja principle (quiet and smooth moving). They performed silent jumps and controlled landings. • Pressure and Rehydration of the Fascia. Examples of tactile stimulation included using their hands to squeeze each arm, leg, the torso, back, and head (the whole body) [23,24]. They lightly tapped and smoothly brushed the different parts of their body. They also explored various other tactile movements such as scratching, rubbing, gentle pinching, and tapping. Myofascial self-massage with foam roller. • Variation of the dance movements and directing attention to fascia. The dance movements were performed with a wide variety in terms of energy (tension, weight, flow, easily stopped movements, powerful or gentle) tempo (slow, fast), and closed eyes [25]. For instance, begin by walking at a normal pace and gradually slow down until each step takes 12-15 seconds. Focus on which part of the foot touches the ground first, how weight shifts from one foot to the other, and how the muscle groups work together to maintain balance (fascia lines). Similar exercises were also practiced with eyes closed. • Fascia stretching to all directions. Gradual and controlled stretches typically performed in yoga (e.g. “Downward Dog”, “Bananasana”, “Reclined twist”). The exercises involved stretching the myofascial chains by pulling in multiple directions until reaching the final position. This type of stretching resembles the way a cat stretches after a nap (extending its body in various directions). The cat tenses and actively stretches by pressing its paws into the ground while simultaneously extending its body. An example is the supine Snow Angel exercise: the dancer is lying on the back with the arms on the side of the body and gently mimics a snow angel (slow steady load and holding the position). They increase the stretch by extending the elbow, wrist, and fingertips into the floor.
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Measurements

Measurements were taken before and after the six-week intervention. All experimental data collection was conducted in a quiet room. Shoulder and knee joint position sense (JPS) were assessed using the KFORCE Sens® electrogoniometer (Kinvent, France, <https://physio.kinvent.com>). The device provides real-time angle feedback on a tablet screen with an accuracy of 1° and a sampling rate of 75Hz. Measurements were taken from the dominant arm and leg.

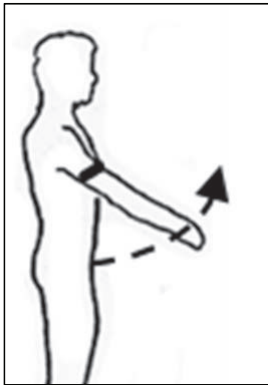


Figure 1. Shoulder Joint Position Sense (JPS) test

Active shoulder JPS test

Starting from a standing position with arms relaxed at their sides, participants were instructed to gradually flex their tested shoulders until they reached the target angle of 30° , as displayed on the tablet screen (Figure 1). Once the arm reached the target angle, participants were instructed to maintain the position for approximately 5 seconds and memorize it. They then returned to the starting position (arms relaxed at their sides). After a 5-second interval, they were asked to reproduce the target angle blindfolded. Once they felt they had reached the reference position, they indicated it to the examiner by saying "Here!" and the angle was recorded. The absolute difference between the target position and the replicated position was recorded as a JPS error. After a trial attempt, participants performed three test repetitions, with a three-second rest interval between each. The mean of the three trials was used for data analysis.



Figure 2. Standing knee flexion joint position sense (JPS) test

Active knee JPS test

The participants stood on a wooden platform (15 cm high) with their dominant leg hanging freely off the side (Figure 2). To maintain balance, they used the hand opposite to their dominant leg to hold onto the wall. Participants were instructed to slowly flex their dominant knee until they reached the target angle of 30° , which was displayed on the tablet screen. They were asked to memorize the target angle and returned to the initial position. Next, they were asked to reproduce the target angle. The measurement procedure was identical to that used for the shoulder JPS test. The mean of three trials was used for data analysis. Test-retest reliability had been previously established for shoulder and knee JPS with 11 dancers (shoulder ICC = .76, knee ICC = .70). The dancers involved in the reliability measurements were not included in the main study.

Force sense test

An electronic digital hand dynamometer was used for the hand grip force reproduction test (K-Grip, acquisition frequency 75 Hz, KINVENT, www.k-invent.com). While standing, the dancers were instructed to position their arms with the elbow bent at 90° . The target force level was set at 50% of the maximum voluntary contraction (MVC, grip strength). Participants were instructed to apply 50% of MVC (target force level) for three seconds and memorize the force they exerted (the force level was displayed on the screen). Then, they were instructed to reproduce the target force without any visual feedback. The absolute difference between the target force (50% of MVC) and the average of the three trials (without feedback), was used for the force sense test analysis. Test-retest reliability with 11 participants showed an acceptable ICC = .75. The dancers who participated in the reliability measurements were excluded from the main study.

Postural control

Single-leg postural control was assessed using a force platform (KINVENT, France, www.k-invent.com). The dependent variables were the total excursion of the Center of Pressure (CoP path length) and the ellipse sway area. The dancers were asked to stand as quietly as possible for 10 seconds on their dominant leg with the other leg flexed at

approximately 90°. After a trial application, participants performed three test repetitions, with a 30-second rest interval between trials. The best score of the three trials was used for analysis.

Statistical Analyses

The data were analyzed using a two-way repeated measures ANOVA design, with group (treatment vs. control) as the between-subject factor and time (pre vs. post) as the within-subject factor. Levene’s test was conducted to assess the homogeneity of variances. If the assumption of sphericity was violated, the Greenhouse-Geisser correction was applied. In cases where a significant interaction was found, follow-up univariate ANOVAs were performed to determine significant differences. Effect sizes of ANOVA are reported as partial eta square values (η_p^2). All statistical analyses were conducted using SPSS (version 28). Statistical significance was set at $p \leq .05$.

Results

Descriptive statistics of the dependent variables ($M \pm SD$) are presented in Table 3. There was no baseline difference between the two groups (shoulder JPS $F = .11, p = .73, \eta_p^2 = .004$, knee JPS $F = 1.25, p = .27, \eta_p^2 = .038$, force sense $F = .265, p = .61, \eta_p^2 = .008$, postural control $F = .098, p = .756, \eta_p^2 = .003$).

Table 3. Means and standard deviations of the dependent variables ($M \pm SD$)

	Treatment Group		Control Group	
	Pre	Post	Pre	Post
Shoulder JPS (cm)	3.64 ± 3.06	1.27 ± 1.09*	3.30 ± 2.58	2.98 ± 1.81
Knee JPS (cm)	3.65 ± 3.44	1.36 ± 1.16*	2.57 ± 2.00	2.37 ± 1.47
Force sense (Kg)	1.69 ± 1.17	1.41 ± 0.99	1.91 ± 1.33	1.90 ± .97
Path length (mm)	386.29 ± 107.05	359.10 ± 95.31	375.33 ± 96.65	352.12 ± 83.98
Ellipse area (mm²)	447.37 ± 151.45	393.24 ± 143.255	417.27 ± 174.59	425.27 ± 136.46

Notes. * significant difference between the two groups ($p < .05$)

Shoulder JPS

There was a borderline non-significant interaction between groups, with medium effect size and measurement time (pre and posttest) ($F = 3.86, p = .058, \eta_p^2 = .108$). By the end of the intervention, the treatment group performed significantly better than the control group ($F = 11.01, p = .002, \eta_p^2 = .256$).

Knee JPS

There was a significant interaction between group and measurement time ($F = 5.20, p = .029, \eta_p^2 = .140$). By the end of the intervention, the treatment group showed significantly better performance compared to the control group ($F = 4.86, p = .035, \eta_p^2 = .132$).

Force sense

There was no significant interaction between group and measurement time ($F = .39, p = .53, \eta_p^2 = .012$). Additionally, there was no significant difference between the two groups at the end of the intervention ($F = 2.13, p = .154, \eta_p^2 = .063$).

Postural control

There was no significant interaction in the total length of CoP and ellipse area ($F = .028, p = .86, \eta_p^2 = .001$ and $F = 1.52, p = .226, \eta_p^2 = .045$, respectively). Additionally, no significant difference was found between the two groups at the end of the intervention ($F = .051, p = .822, \eta_p^2 = .002$ and $F = .44, p = .509, \eta_p^2 = .014$, treatment and control, respectively).

Discussion

The aim of this study was to investigate the effectiveness of a fascia-oriented training program (FTP) compared to a traditional training program on dancers’ joint position sense, force sense, and postural control. The primary finding

of this study was that the treatment group displayed superior JPS compared to the control group at the end of the intervention. However, no significant differences were observed between the two groups in terms of force sense and postural control. Furthermore, in the intra-group comparisons, neither training program led to improvements in force sense or postural control.

Joint Position Sense

Accurate JPS is essential for high performance and reducing the risk of injuries. The observed improvement in JPS within the treatment group suggests that the FTP effectively improves the joint position reproduction accuracy. On the contrary, there were no significant improvements in the control group (traditional training). This result is consistent with previous studies reporting that JPS can be improved through proprioceptive exercise programs [26,27]. Specifically, Yoon et al. [26] found that an eight-week proprioceptive training program improved JPS of volleyball players (50 min per day, three times a week). In addition, Lin et al. [27] reported improved JPS of ballet dancers after a 6-week training program (one hour per day, 3 days per week). The difference between these studies and the present one is the duration of the fascia-oriented training unit. The 15-minute FTP in the present study was incorporated into the overall dance training program, immediately after the warm-up, whereas in the aforementioned studies, FTPs required an extended time of additional sessions (50–60 min session, 3 days per week) [26,27]. Semi-professional dancers usually train about 3–4 times a week, with each session lasting about 90 minutes. Moreover, semi-professional dancers take on extra jobs to cover their expenses, which require extra time. Therefore, for semi-professional dancers, it is challenging to find additional training hours per week for proprioceptive exercises due to the increased costs of training space and time. The advantage of the present study is the improvement of body position sense with significantly less training time compared to previous studies (the training program was incorporated in training sessions).

The improvement of JPS could be attributed to the effective stimulation of the fascial proprioceptive receptors. Connective tissue of fascia contains more receptors (such as Golgi tendon organs, Ruffini endings, and Pacinian corpuscles) than muscle tissue and plays a key role in JPS [28]. The FTP used in this study may have contributed to the release of adhesions and restrictions within the fascia that interfere with proprioceptive information, thereby improving the dancers' sense of joint position.

Force sense

In contrast to the improvements observed in joint position sense, this study found no significant difference at the end of the intervention between the treatment and control group in terms of force sense. According to previous research, force sense is not correlated with JPS [29]. Furthermore, previous studies with foam rolling have reported improvements in JPS but not in force sense [30,31]. This may be due to the fact that the information for the two senses comes from different types of mechanoreceptors and ways of processing the information in the central nervous system [1]. Muscle spindles are considered the primary receptors for JPS, whereas Golgi tendon organs are mainly associated with muscle force sense [32]. In general, it is recognized that the origin of the force sense is both central and peripheral [33]. The peripheral receptors detect changes in muscle tension and send this information to the central nervous system. The interpretation and response to the peripheral (afferent) information involve central processing. Two primary theories explain the potential mechanisms behind the tuning of force sense. In the first theory, called “the sense of effort”, the perception of force refers to the corollary discharges of motor commands in the sensory area of the cortex. The second theory, “the sense of force theory” proposes that perception is related to peripheral inputs (information from mechanoreceptors). While both theories are important for understanding how we perceive muscle force, evidence suggests that the “sense of effort” theory (central nervous system processing) has a greater impact than the “sense of force” theory (afferent information) [34]. Perhaps the exercises in the program of the present study were insufficient to improve the central nervous system processes. Future studies might consider incorporating more targeted exercises to enhance the sense of force [35].

In addition, the non-significant findings of the present study regarding the force sense could also be explained by the measurement method (hand grip). Fascia is a body-wide tensional network of tissue that functions in linked chains and its role in transmitting force during multi-joint movements is unquestionable [36]. Therefore, a force sense test involving long musculofascial chains and greater body-wide tension, compared to the hand-grip test used in the present study, might have produced different results. Future research should take this issue into account.

Postural control

The information provided by fascial receptors plays a crucial role in maintaining postural control [37,38]. The results of the present study indicated neutral effects of both traditional and proprioceptive training on dancers' postural con-

trol. These findings contrast with previous research reporting improvements in postural control following proprioceptive training [26,27]. The different findings regarding postural control may be attributed to variations in the content of the proprioceptive training programs. Studies reporting improvements in postural control after proprioceptive training incorporated balance training equipment (e.g. balance foam pad, balance beam) and specialized postural control exercises (e.g. single leg balance on a wobble board). For instance, Yoon et al. [26], incorporated exercises using BOSU balls and Gym balls (e.g. one-leg stance on BOSU ball). This suggests that the improvement of postural control may require specialized balance equipment and exercises.

Limitations

The main limitation of this study is its duration. The relatively short overall duration of the intervention (six weeks) may not have been sufficient to observe changes in force sense and postural control. Future research should examine longer intervention periods to determine whether ongoing fascia-oriented training programs yield significant improvements in these areas. The small sample size and the focus on female semi-professional female dancers are recognized as further limitations of this study.

Conclusions

A healthy fascia increases the quality of proprioceptive information and reduces the risk of injury [19]. Traditional dance training focuses mainly on the muscular system, often overlooking the fascia. The fascia-oriented program of the present study resulted in improved JPS compared to the traditional training. Therefore, the proposed fascia-oriented training program could be incorporated into the training program of dancers to enhance body awareness.

Practical Implications

The findings of the study highlight that incorporating a brief 15-minute fascia-oriented training program into regular dance sessions can effectively enhance dancers' JPS without requiring additional training time. This improvement in proprioceptive acuity may contribute to better performance accuracy and reduced risk of injury during complex dance movements. While the program appears promising for enhancing joint position sense, dance instructors should consider additional specialized balance training, which may still be necessary for the development of postural control. Notably, the training program can be easily integrated into existing dance routines, making it a practical solution for dance instructors and trainees.

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Informed consent statement: The participants were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

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