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RESEARCH ARTICLE

Professional Ballet Dancers' Balance Ability and Psychological Traits and States: A Longitudinal Pilot Study

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Abstract:

Introduction:

Professional dancers are committed to dancing despite their injuries and mood changes. Therefore, dancers' balance ability should be evaluated as an objective indicator of the quality of their dance/dancing ability.

Objective:

We aimed to examine the relationship between the balance ability of professional ballet dancers and their psychological traits and states by serotonin polymorphism, using pressure and center of gravity sensors.

Methods:

Five female professional dancers participated in this three-month longitudinal pilot study. The dancers' stress status was assessed each month on three conditional days to gauge stress conditions. Before and after their standard warm-up exercises, the dancers' center of gravity was assessed while standing and posing in ballet-specific positions, and psychological questionnaire surveys were conducted to assess the level of anxiety and objective stress. After all observations were completed, serotonin polymorphism was analyzed as one of the psychological traits.

Results:

All participants possessed the s/s-type (short type) serotonin transporter gene promoter polymorphism, indicating high sensitivity to stress. Their average trait anxiety score was 50.80±8.47. However, all participants were able to be calm, had no injuries, and maintained a stable center of gravity throughout the study period.

Conclusion:

Throughout the study, from ordinary practice to the time of the approaching ballet performance, the participants maintained stable balance ability regardless of their psychological traits and states of mind. It is unlikely that reactions to stress and psychological traits affected professional dancers' physicality. Thus, continuous assessment of the balance between mental and physical aspects enhances performance management.

Keywords: Balance ability, Sway of the center of gravity, Psychological traits, Psychological states, Anxiety, Professional dancer.

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1. INTRODUCTION

Professional ballet dancers generally have one or more major stage performances every year and spend the rest of their days practicing. Since the dancers seek to express "beauty" and "art" through their performances, highly imaginative physical expressions and abilities are required. Further, they must continue to perform despite facing various stress factors.

During the period of memorizing the choreography, dancers begin to face increasing psychological stress. This stress is often contingent on earning a role in the cast as well as the demands of the assigned role. Additionally, the stress of

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memorizing the choreography and receiving instructions from special teachers weighs on the dancers. The rehearsal period before a performance entails long practice hours to perfect the choreography. As a result, this is a period characterized by high physical stress, culminating in increased mental and physical fatigue [1, 2].

Professional dancers are committed to dancing despite their injuries and mood changes. It is possible to evaluate dancers' balance ability as an objective indicator of the quality of their dance/dancing ability. While the evaluation of this indicator involves an examination of various complex, intertwined factors, it is assessed mainly by the sway of the center of gravity, which measures the performance itself. Ballet is a unique dance in which the dancer must continuously maintain their balance, despite actualizing precarious positions to support their postures. In the first five positions for ballet movements, dancers must turn both their legs out to 180 degrees (one is in the coronal plane, the other in the sagittal position). The fifth position is called the starting point of movement. In this position, one leg from the "turned out" position is placed parallel and in front of the other leg in a standing position as if to make the toe of one foot touch the heel of the opposite foot. The basic positions in ballet differ entirely from the ordinary standing postures of laypeople. The sixth position is an exception: the dancer places both feet together, with the knees and the toes turned forward.

To maintain these basic positions, a dancer needs the ability to maintain a physical equilibrium between multiple joints and muscle groups with respect to their environment, with a critical focus on balance. This balancing ability comprises (a) static balance, or the ability to maintain body posture in physical movements not involving shifts in body position, that is, stabilizing the center of gravity and suppressing sway, and (b) dynamic balance, or the ability to maintain posture while engaging in physical movements [3, 4]. However, physical stressors, such as injury and fatigue may result in the disruption of this balance. Furthermore, this disruption may result from psychological stressors arising from the practice routine, casting for the dance, increased practice sessions, and stress during the period leading up to the stage performance. Dancers are often left to manage the stress on their own, which affects their psychological traits and states of mind.

Ballet dancers are required to create unique and artistic physical expressions, regardless of long durations of physical and/or mental stress. Consequently, balance ability should be evaluated as an objective indicator linked directly to the dance. Especially professional dancers must be committed to dancing despite their injuries and mood changes. Therefore, in this study, we aimed to examine the relationship between the balance ability of professional ballet dancers and their psychological traits and states by serotonin polymorphism, using pressure and center of gravity sensors. We measured two of the six basic positions and one-leg balance, all of which are unique to ballet, to investigate whether professional ballet dancers can maintain balance ability over time in basic ballet positions and the standing position.

2. MATERIALS AND METHODS

We analyzed the serotonin transporter gene promoter polymorphism (5-HTTLPR), wherein the differences in the activation of the amygdala, observed by magnetic resonance imaging, are related to trait anxiety—a psychological trait related to affect and emotions. Further, we evaluated the relationship between balance ability and psychological traits in professional dancers. The combination of this polymorphism (5-HTTLPR) consists of gene types s/s, s/l, and l/l. Compared with individuals who possess "l"-type (long-type) genes, those who possess "s"-type (short-type) genes show a strong correlation with stress sensitivity. Hence, possessing the s-type gene is a genetic factor that increases susceptibility to depression [5]. Thus, objective psychological traits based on the 5-HTTLPR genetic types may affect a person's state of mind and influence individual performance, depending on the stress conditions. Considering the rigorous training of professional ballet dancers, the differences between professional and non-professional dancers may be reflected more strongly by their social and environmental (occupational) factors than their 5-HTTLPR genetic types [6]. Therefore, the physical stability of professional ballet dancers may not reflect their state of mind.

2.1. Participants

We recruited five female professional ballet dancers aged 29.2 ± 4.7 years (who began learning ballet at 3–7 years of age) with 21–27 years of experience (Table **1**). The dancers are award-winning professional stage artists who have participated in international performances and continue their practice and stage activities while teaching students at ballet schools. They practice five to six days a week at a professional ballet company.

Table 1. Participants' physical characteristics.

-	Age	Height	Body Weight		Whole Body Muscle Mass		Body Mass Index	
ID	(yrs.)	(cm)	Pre	Post	Pre	Post	Pre	Post
			(kg)	(kg)	(kg)	(kg)	(kg/m^2)	(kg/m^2)
A	22	168	50.75	48.70	38.10	37.75	18.0	17.3
B	26	161	50.65	49.40	36.15	36.40	19.5	19.1
C	35	168	51.80	51.15	37.95	38.45	18.4	18.1
D	31	160	52.90	52.05	38.05	37.60	20.7	20.3
E	31	156	42.35	41.80	32.95	33.90	17.4	17.2

2.2. Measurement Method

A stabilometer (Gravicorder) was used to study the participants' ability to balance [7]. A sway of the center of gravity is often used to evaluate a body's static posture-retaining function; it has also been used to assess the postures of ballet dancers [8, 9]. We evaluated static posture by having the participant retain a standing posture, and then evaluated the amplitude (sways) of the intersection point between the ground and the line descending vertically from the body's center of gravity to the ground [7, 10].

Before and after the dancers' daily warm-up exercises, which consist of an introductory barre lesson and a center lesson, we measured the sway of the center of gravity and other items in both the standing posture and basic ballet postures. On the days of evaluation, we first determined the period for assessing psychological factors, or the stress condition: (a) an ordinary practice day (10 weeks before a performance), (b) a rehearsal day (7 weeks before a performance), and (c) a day before the performance (any day during the week immediately before a performance).

The supplemental explanation indicates that in the participants' daily schedule, approximately three hours in the morning are devoted to warm-up, while the afternoon is spent on voluntary practice and a run-through rehearsal. These warm-up exercises are universally practiced in ballet. Of these, a barre lesson (consisting of about 10 items) is conducted using either a horizontal barre, installed around the walls of a training room, or a moveable-style barre, meant for learning basic leg movements, and the body axis. This is because the classical ballet technique demands vertical body positioning on the axis gravity. Next, a center lesson (consisting of about 10 items) is performed on the floor after a barre lesson, without holding on to anything for support, to practice positions, poses, and other items accompanying bodily shifts and movements. Both are basic lessons performed by dancers of all ages regardless of their technical skill level.

To investigate the participants' psychological state in the period leading up to performance day, coupled with medical consultations (medical checkups) by a physician once every two weeks, a self-administered questionnaire survey was conducted both before and after the three stress condition days. After all chronological observations were completed, we analyzed 5-HTTLPR as one of the dancers' psychological traits.

2.3. Assessment of Postures

The following four types of postures (six postures in total) were assessed (Fig. **1**) six times, both before and after daily warm-up exercises on the three stress condition days: (1) standing position, (2) first position, (3) fifth position (left leg front and right leg front), and (4) unipedal standing on the axis foot (left and right axes). The assessments were performed after explaining the content to the participants and ensuring that they understood the measurement procedures on the measurement stand. They were instructed to face forward and stand still in a posture with optimal stabilization. To make the conditions as natural as possible, we used no visual indices. Measurements were performed barefoot with both arms hanging down.

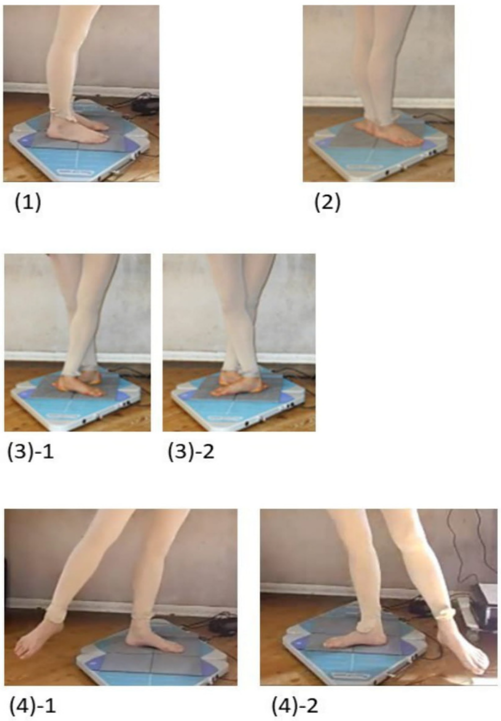

Fig. (1). Four types of six postures: (1) Standing position, (2) First position, (3) Fifth position (l. left leg front, 2. right leg front), and (4) Unipedal standing (1. left axes, 2. right axes).

First, to measure the sway of the center of gravity at the center of the base of support, we waited for the initial transient body sway to subside, and then measured the sway of the center of gravity for 30 seconds. Next, the participants held a posture wherein they could maintain stability under the various conditions of the basic posture. During measurement, participants were instructed to look straight ahead at the wall. They were asked not to change the base of the support. Before starting the subsequent trial, an interval of 1−2 minutes was provided to eliminate the body's memory of the sway. Throughout the process, if a participant was not able to take an appropriate posture per the instructions, a ballet instructor was assigned to check and correct the posture. Measurements were then made by experts well-versed in using the equipment. The participants were asked to keep their legs in the positions they perceived matched those used in ordinary ballet lessons. The arms, meanwhile, took an "under-position": the elbows were bent slightly, and the arms hung down as if to gently draw an oval shape.

2.4. Evaluation Items

In devising the equipment, we combined the plate-style leg load measurement devices Twin Gravicorder GP-6000 and Predas MD-1000 (Anima Co., Ltd., Tokyo, Japan). Using accurate load values, we simultaneously measured pressure distribution and corrected it automatically. The device features two plates that detect the sway of the center of gravity. The plantar pressure's force applied vertically while in the upright position is detected by a converter, and the sway of the center of pressure (COP) is output via changes in electrical signals. Each measurement value was recorded automatically as numerical figures and graphs. The sampling frequency was set at 50 ms (20 Hz). The device can dually measure the weight-bearing volume and sway of the center of gravity in each leg.

To evaluate postural sways, we employed the chronological data of the COP calculated by this device. As the basic postures in ballet use unique positioning, we focused on the parameters outlined below to investigate the stability factor.

(1) Weight-bearing and positional balance: The overall balance while standing on both legs or one leg. This indicates whether the dancers have an average balancing ability.

(2) Total trajectory length: The total moving distance of the center of gravity, which indicates the stability of the body sway.

(3) Outer circumference area: The trajectory's outer area or the area that surrounds the outer periphery of the sway, which is effective for the evaluation of equilibrium training.

(4) Practical value area: The area of a circle using the root mean square as the radius; the square root of a mean square. This area eliminates outlier values. A decrease in the sway distance from the center indicates the stability of the sway itself.

2.5. Psychological Investigation

The self-administered questionnaires described below were used to study differences and chronological changes in the participants' psychological traits and states before and after practice. The State-Trait Anxiety Inventory (STAI), comprising 40 items (20 items each for the State and Trait subscales) rated on a four-point scale, evaluates the degree of anxiety as an emotional state (S-Anxiety) and individual differences in anxiety-proneness as a personality trait (T-Anxiety) [11]. Objective stress (mood and condition) at a particular time was measured using a three-point scale (3: "good"; 2: "average"; 1: "poor").

Additionally, the dancers self-reported their injuries, pain, and whether they had received a medical checkup from their doctor.

2.6. Analysis of 5-HTTLPR Polymorphisms

We analyzed 5-HTTLPR polymorphisms (s/s, s/l, and l/l), which are considered objective indicators of psychological traits that reveal individual differences, especially regarding stress sensitivity [12]. We used a swab (Swab- γ, Eiken Chemical Co., Ltd.) to collect the participants' oral mucosa and extracted DNA with the QIAamp DNA mini-kit (Qiagen, Germany). Then, primers were set, and genetic polymorphisms were analyzed using a polymerase chain reaction (PCR) (as described by Yatabe *et al*.) [6].

2.7. Statistical Analysis

To study period-based within-participant changes, a corresponding Friedman test and the Wilcoxon signed-rank test were used. To study relationships, Spearman's rank correlation coefficients were calculated. SPSS for Windows (24.0 J, IBM Japan) was used for statistical processing, and the level of significance was set below 5%.

3. RESULTS

We recorded the participants' physical characteristics before and after the three-month study period (Table **1**). Each participant's body weight and body mass index (BMI) decreased, while muscle mass varied, either increasing or decreasing. Considering the general criteria for obesity and thinness, the weight and BMI of the participants ranged between underweight (BMI <18.5 [kg/m^2]) and average weight (BMI: 18.5–25 [kg/m^2]) at the time of the study. Their muscle ratio was considerably high (>30%).

3.1. Sway of the Center of Gravity

We first considered the changes in the sway of the center of gravity occurring over time. The total trajectory length of the COP shows the extent of the sway of the center of gravity the longer the distance, the greater the sway. Our results showed that the total trajectory length remained unchanged or decreased gradually, then stabilized. The balance between the two-leg position and single-leg load was stable, and the outer circumference area surrounded by the COP's total trajectory length was observed only in unipedal standing on one axis leg (right). The results of the measurements of various postures are discussed in the following subsections.

3.2. Standing Position

No significant differences in balance were observed in the standing position considering the total trajectory length, outer circumference area, and practical value area. No significant changes were observed throughout the study period, and the values remained stable (*ps* = 0.915, 0.998, 0.528; all n.s.) (Fig. **2**).

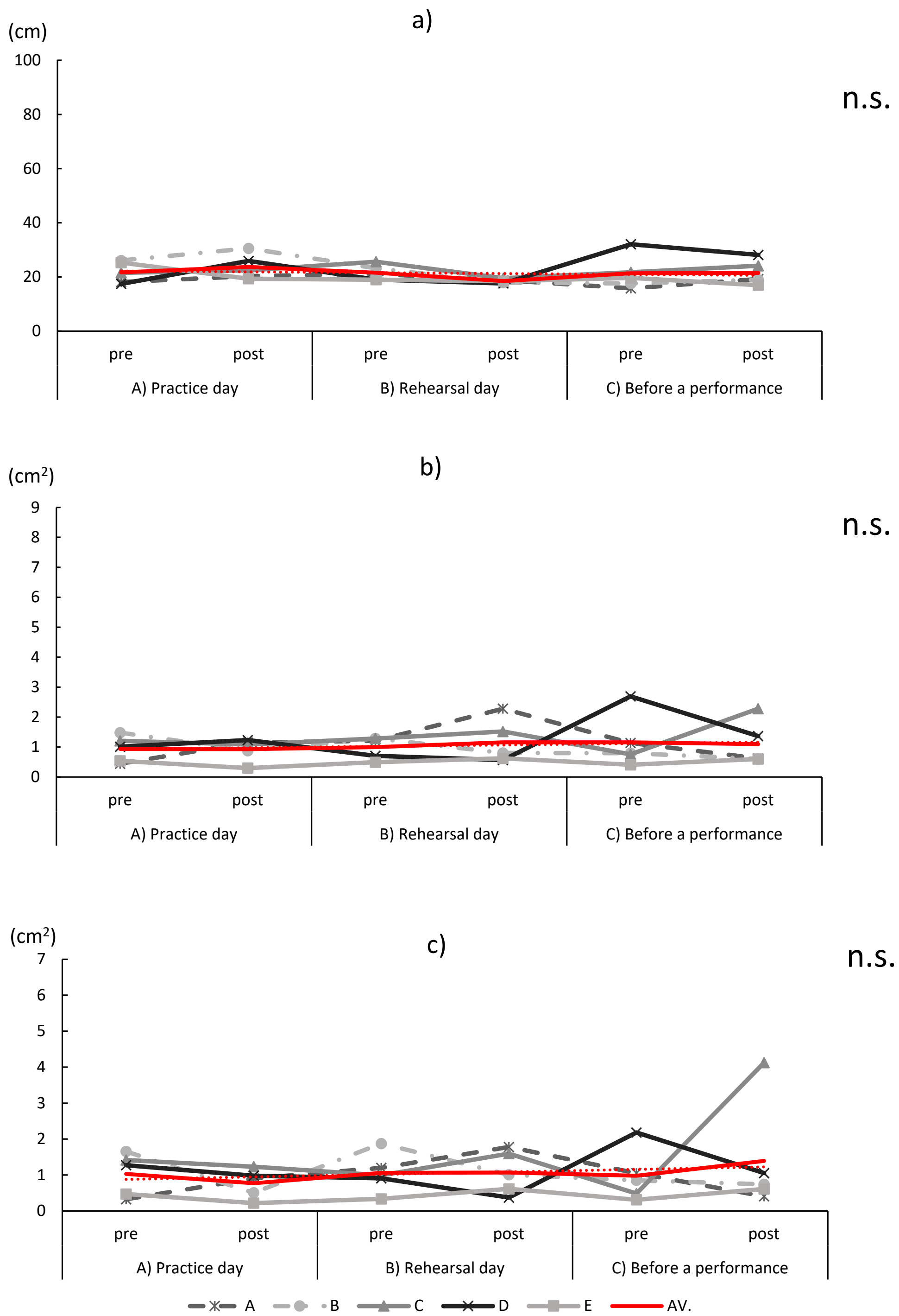

Fig. (2). Standing position; **a**) Total trajectory length, **b**) Outer circumference area, **c**) Effective value area.

3.3. First position

In the first position, a significant difference was observed in total trajectory length, which showed a gradual decline (*p* <0.01). The outer circumference area and practical value area showed no significant differences and remained stable (*ps* = 0.606, 0.639; n.s.) (Fig. **3**).

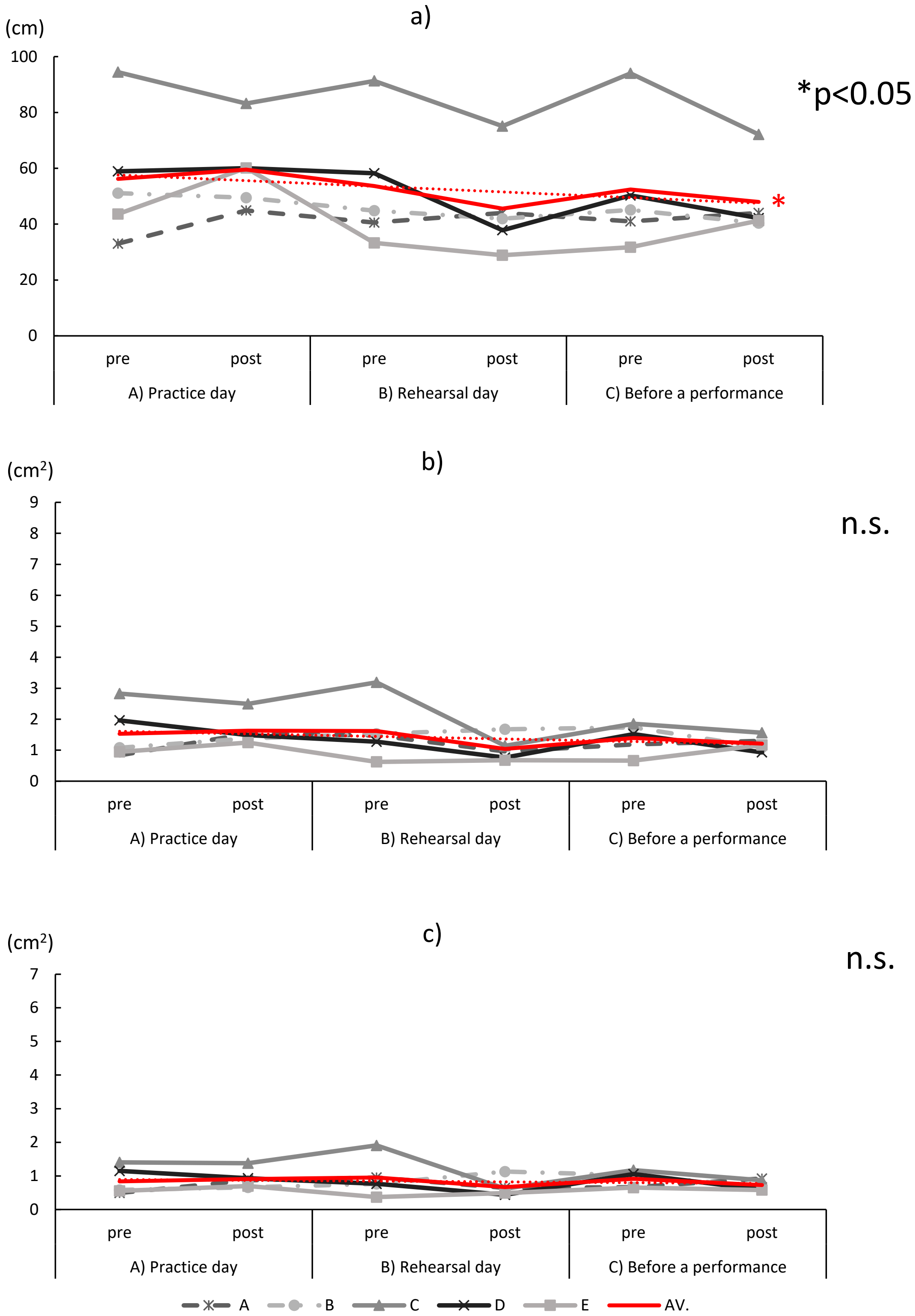

Fig. (3). First position; **a**) Total trajectory length, **b**) Outer circumference area, **c**) Effective value area

3.4. Fifth Position

In the "left foot front" fifth position, the total trajectory length showed a significant difference, but decreased gradually during the study period (p <0.05). Although the outer circumference area and practical value area showed slight variations during the study period, there were no significant differences (ps = 0.971, 0.979; n.s.).

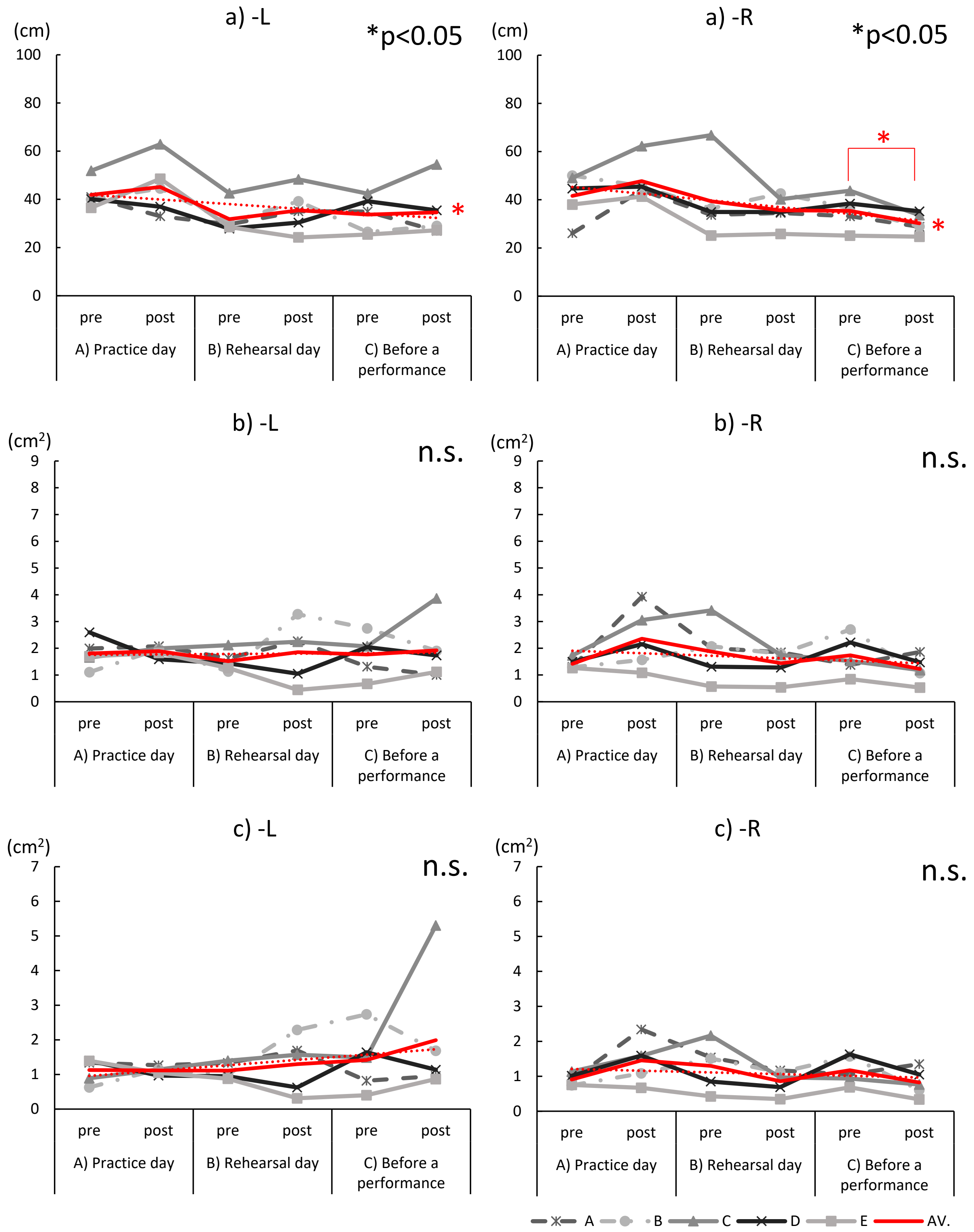

Fig. (4). Fifth position [left leg front(L), and right leg front(R)]; **a**) Total trajectory length, **b**) Outer circumference area, **c**) Effective value area.

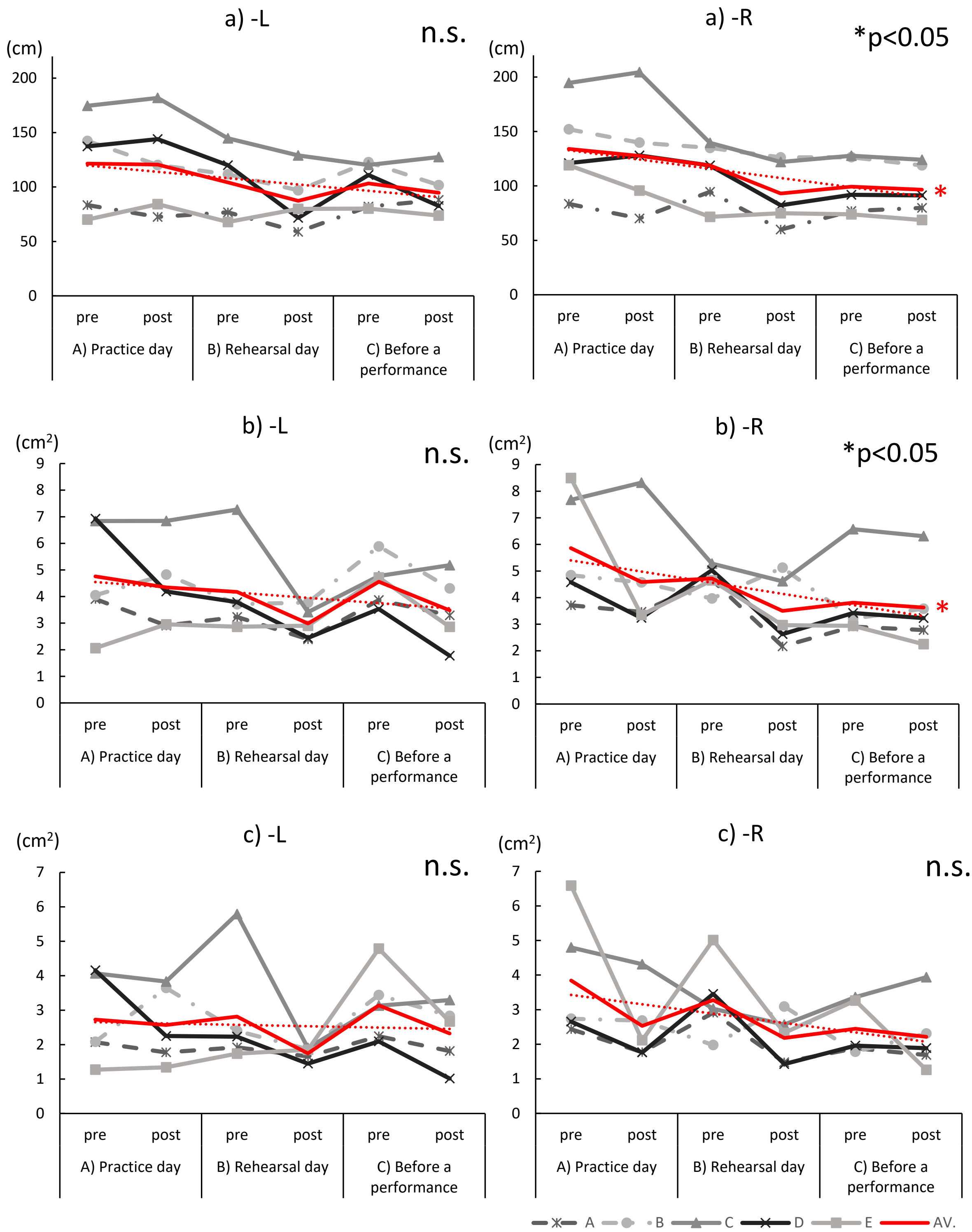

Fig. (5). Unipedal standing [left axes(L), and right axes(R)]; **a)** Total trajectory length, **b** Outer circumference area, **c)** Effective value area.

In the “right foot front” fifth position, the total trajectory length showed a significant difference but stabilized gradually during the study period (*p* <0.03). The only significant difference observed in this position in a before-and-after comparison was on the day before a performance (*p* <0.05). Physical stress often increases on the day immediately before a performance. However, the total trajectory length first decreased significantly, then improved. Although no significant differences were observed, variations increased gradually for the outer circumference area and the practical value area (*p*s = 0.185, 0.234; n.s.) (Fig. **4**).

3.5. Unipedal Standing (on the axis leg)

In unipedal standing using the left leg as the axis, no significant differences were observed in total trajectory length or the outer circumference area (*p*s = 0.152, 0.252). Furthermore, although no significant differences were observed, the practical value area consistently decreased after practice, perhaps owing to centripetal force; the variations decreased as well ($p = 0.303$). In unipedal standing using the right leg as the axis, significant differences were observed in total trajectory length and the outer circumference area, which stabilized gradually during the study period ($p < 0.01$, $p < 0.05$). The practical value area decreased gradually, although no significant differences were observed ($p = 0.109$) (Fig. **5**).

3.6. Psychological Evaluations

Based on the STAI, on average, the participants showed slightly high trait anxiety (50.80 ± 8.47 points) prior to the study, but tested calmer than usual throughout the study period. Before the research started, their state anxiety was recorded at 48.20 ± 4.21 points. Participants' anxiety increased on the day of rehearsal after the cast had been selected, and on the day immediately before a performance. State anxiety increased slightly during periods (b) and (c). However, throughout the study period, no significant fluctuations were observed, and participants were able to approach the day of performance in a calm state. Only chronic knee and ankle pain were self-reported (Table **2**); however, neither was classified as moderate or severe pain during the medical checkup. Measurements before warm-ups on a performance day showed a slightly higher state anxiety score (53.2 ± 10.80); however, there were no injuries, and the performance ended safely.

Regarding the relationship between psychological traits and states and the sway of the center of gravity (total trajectory length), no significant relationships were observed with trait anxiety; however, numerous significant correlations were observed with state anxiety on the day before a performance. An unstable element was established, either mentally or physically, and subsequently, a correlation was observed. Specifically, a correlation was observed with state anxiety scores in (1) the standing position prior to a lesson ($r = 1.000$, $p < 0.001$) and (2) the fifth position (right, front) after a lesson ($r = 0.900$, $p < 0.037$). Additionally, a correlation was observed between state anxiety scores after a lesson and the following: (1) first position, (2) fifth position (right, front) prior to a lesson (rs = 0.900, *ps* < 0.037), (3) fifth position (left, front) prior to a lesson ($r = 1.000$, $p < 0.01$), and (4) standing position after a lesson ($r = 0.900$, $p < 0.037$).

3.7. 5-HTTLPR

In the analysis of 5-HTTLPR genetic polymorphism, all participants possessed gene type s/s, and none had gene types s/l or l/l. All participants were assumed to be sensitive to stress, indicating a tendency for their mood to become unstable under conditions that produce psychological stress. Evaluations of their subjective mood and condition additionally showed a slight downward trend as the performance day approached. In sum, both their mood and condition tended to be evaluated as poor. However, these changes were not significant and individual differences were observed, accounting for the daily increases and decreases under stressful conditions, as indicated in Table **2**.

No correlation was observed between these subjective evaluations and the sway of the center of gravity in each measured position. Thus, it is unlikely that the dancers' reactions to psychological stress affected their physicality.

Table 2. STAI scores and objective stress on each condition day.

Condition Date		**Before Research**	**a) Practice Day**		**b) Rehearsal Day**		**c) Before a Performance**		***p***	**Performance day**		***p***
			Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**		**Pre**	**Post**	
STAI (pt.)	Trait-A	50.80 (8.47)	45.80 (4.15)	46.20 (3.27)	47.40 (8.76)	46.20 (7.43)	45.00 (4.47)	44.00 (4.00)	0.884 n.s.$^{\#}$	45.60 (4.51)	41.20 (4.49)	0.697 n.s.$^{\&}$
	p	-	1.000 n.s.$^{\$}$		0.357 n.s.$^{\$}$		0.414 n.s.$^{\$}$			0.273 n.s. $^{\$}$		
	State-A	48.20 (4.21)	45.80 (5.36)	45.60 (4.98)	51.60 (10.41)	49.20 (10.18)	46.80 (7.98)	50.40 (7.77)	0.369 n.s.$^{\#}$	53.20 (10.80)	45.80 (19.52)	0.323 n.s. $^{\&}$
	p	-	0.684 n.s.$^{\$}$		0.131 n.s.$^{\$}$		0.176 n.s.$^{\$}$			0.343 n.s $^{\$}$		
Objective Stress	Condition	-	2.00 (0.00)	1.80 (0.45)	1.40 (0.55)	1.60 (0.89)	1.80 (0.45)	1.60 (0.55)	0.388 n.s.†	2.20 (0.45)	2.00 (0.71)	0.491 n.s.§
	Mood	-	2.20 (0.45)	2.20 (1.10)	1.60 (0.55)	2.00 (0.71)	2.00 (0.00)	1.80 (0.45)	0.343 n.s.†	1.60 (0.55)	1.60 (0.89)	0.391 n.s.§
Pain	Yes(n)	E(1)	B,C(2)	E(1)	E(1)	E(1)	A,D,E(3)	A,D,E(3)		A,D,E(3)	A,C,D,E(4)	

$^{\$}$ pre vs. post, all n.s.; $^{\#}$ all six times, all n.s.; $^{\&}$ all eight times, all n.s.
†Change of condition and mood from a) to c), all n.s.; §from a) to performance day, all n.s.
STAI: State-Trait Anxiety Inventory.

4. DISCUSSION

This study aimed to examine the relationship between the balance ability of professional ballet dancers and their psychological traits and states by serotonin polymorphism, using pressure and center of gravity sensors. The dancers' stress status was assessed each month on three conditional days to gauge stress conditions. Before and after their standard warm-up exercises, the dancers' center of gravity was assessed while standing and posing in ballet-specific positions, and psychological questionnaire surveys were conducted to assess their level of anxiety and objective stress. All participants possessed the s/s-type serotonin transporter gene promoter polymorphism, indicating high sensitivity to stress. Their average trait anxiety score was 50.80±8.47. However, all participants were able to be calm, had no injuries, and maintained a stable center of gravity throughout the study period.

Ballet dancers tend to have greater muscle mass compared with ordinary people [13]. Nevertheless, in ballet, injuries and impairments increase during the period prior to a performance, and psychological stress is liable to worsen. In athletes, the higher their level of competition, the more outstanding their balance ability [14]. The results of our study revealed individual differences in psychological stress and mental/physical states of the dancers. Although major injuries or impairments did not occur in the days leading up to a performance, subjective psychological reactions toward performing showed a negative trend; however, no significant differences were observed overall.

All participants had s/s-type 5-HTTLPR genetic polymorphism. As a genetic factor, this indicates greater susceptibility to stress. Some participants experienced increased state anxiety approaching performance day. Although a correlation was observed between subjective mental states and physical balance ability, the level of state anxiety was not severe enough to disrupt balance ability. No relationships strong enough to hinder a performance were observed. In this case, we believe the environmental factor of extensive experience played a significant role. Once ballet dancers become professionals, they can better control their mental and physical states [15]. This coincides with the "experience value," cited by individuals in a ballet company report [16].

Previous research on professional ballet dancers and elite student dancers found a relationship between mood and 5-HTTLPR genetic polymorphism at different experience values depending on the dancers' stress periods [6]. This suggests that mental states of student dancers aiming to become professional dancers can be moderately predicted through identified patterns by investigating their psychological traits, genetic polymorphism, and other factors. However, it is difficult to make such predictions for professional dancers. It is possible that professional dancers are calmer owing to their age, experience, and lower need for daily practice, among other environmental factors. It can be assumed that ballet dancers who routinely practice for excessively long hours may eventually experience unstable emotions under a variety of stress conditions. As per the results of this study, having endured rigorous training for many years, professional ballet dancers' stable physical ability may not reflect their level of psychological stress. The differences between professional and non-professional dancers' occupational factors may be more strongly reflected in their performance than their 5-HTTLPR genetic types [6]. Notably, professional dancers' training overrides their psychological duress as it establishes the conditioning of the mind as the superior element to baseline neuroses.

Although we anticipated that the professional dancers in our study would be either type s/l or type l/l, they were all type s/s. Professional dancers are not selected based on their genetic polymorphisms, and their sense of balance is gained through repeated practice as well as balance and technique refinements. Accordingly, their ability to balance is stabilized and maintained without being affected by daily physical and mental stress. A recent report showed no distinct difference in a dancer's center of gravity, even after suffering a stage-II ankle injury. The dancer's abilities and skills remained intact after the ankle sprain and required no rehabilitation (*i.e*., the treatment consisted of bandaging the affected site for two weeks) [17]. Similarly, in our study, no dancers aggravated their injuries or suffered impairments.

In this study, the participants' balance ability was average and hassle-free on all condition dates, and the sway of their center of gravity remained stable throughout the study period. Past studies comparing junior dancers with elite dancers, and high-anxiety individuals with low-anxiety individuals, showed that the elite group had a significantly shorter length and smaller area of body sway [18]. Further, athletes possess superior balance compared with the general population; the higher the athletes' level of competition, the more outstanding their ability to balance, based on their somatic and vestibular sensations [19]. However, according to previous studies, in the static standing posture, the non-ballet group had a shorter trajectory length of the sway of the center of gravity than the ballet group, whereas the ballet group showed greater stability in the demi-pointe position, which requires the use of ballet shoes, than in the standing position with their eyes open [8, 9]. According to our results, a longer total trajectory length was observed in the first position, but the area was smaller and more stable than in the standing position, especially on the day before a performance.

Since the size of the sway of the COP does not necessarily signify poor balance, and a postural sway is non-linear in shape and has an unsteady nature depending on the individual [20], we were able to verify within-participant stability through posture. Balance is a physical ability attained through appropriate postural adjustments; it indicates that a person is placing their body's centroidal line within a fixed base of support. As the performance day approaches, a dancer's physical fatigue is expected to increase. However, here, the participants gradually became more stable.

Conversely, changes in the center of gravity were observed in specific postures. In the fifth position with the right foot front, the left leg becomes the axis leg, and the right leg is placed directly in front of it. In this position, the axis leg is more fatigued. Considering this, we judged the centripetal force to be unstable. However, the results showed that the dancer was less stable before practice, leading us to assume that regular practice helped maintain stability and physical balance. Moreover, while standing unipedal on the axis leg, many dancers preferred to use their left leg as the axis. However, even standing unipedal using the right leg as the axis eventually led to more stability. Although ballet dancers claim to have a favorite axis leg, they undergo training using both legs. Regarding performance maintenance, no influence of the right or left leg was observed.

Considering psychological aspects, professional ballet dancers tend to suffer injuries and impediments prior to a performance, which worsens their psychological stress [1]. In our study, although some injuries and pain were reported in the days leading up to a performance, they were not classified as moderate or severe. Hence, the dancers' objective mental states did not undergo significant changes. Furthermore, there was no correlation between dancers' trait/state anxiety and the sway of their center of gravity on ordinary practice days. Although psychological stress increased prior to a performance, it was confirmed that the dancers maintained basic postures' balance ability and stability of the sway of their center of gravity.

The 5-HTTLPR polymorphisms account for a portion of the dancers' emotional factors. It was believed possible to maintain performance power simply by having no injuries or impediments, or not aggravating them if they did arise, and routinely paying attention to individuals who display high anxiety. Generally, individuals under pressure tend to undergo various psychological changes, such as directing their attention to internal foci and developing anxiety. Thus, changes were assumed to occur in the sway of the center of gravity in the horizontal and front-back direction and in the outer circumference area reflecting such [21]. However, no significant changes were observed in the outer circumference area in each position during the period leading up to the performance day when stress and pressure increased. The ability to balance was maintained, regardless of physical and psychological stress. Further, although the use of the right leg as the axis while standing in a unipedal position significantly decreased over time, it was still stable, despite being the reverse dominant leg for all participants who were left-footed (or two-footed).

Thus, this study confirmed that ballet dancers maintain the balance of basic positions and stability of the sway of their center of gravity despite individual differences in objective psychological evaluations. Our findings suggest that professional ballet dancers can adjust their level of stress and thus maintain the physical ability to pursue the expression of beauty.

4.1. Limitations of this Study

However, once their injuries reach a particular stage (according to a stage classification), the dancers face difficulty achieving balance in challenging ballet positions. They are more likely to lose balance, no longer maintaining the positions unique to ballet. To prevent injuries and accidents during practice and the actual performance, it is necessary to employ medical management on a routine basis. Further, the sway of the center of gravity should be included in ballet dancers' health management routines. Since maintaining balance is crucial to a dancer, we hope that the evaluation of both static and dynamic balance becomes a widespread practice. Accordingly, it is necessary to conduct studies focusing on dynamic fluctuation properties. Furthermore, it is necessary to analyze the power spectrum to identify the mechanism of postural adjustments in each position. Scholars must consider conducting more detailed investigations with larger sample sizes, including surveys of injuries and impairments and their relationships with physical states (physiological function) over time.

CONCLUSION

This study was conducted with five professional ballet dancers to examine their ability to balance by the sway of their center of gravity, and the relationship between their balance ability and psychological traits and states. This investigation was conducted over three months. Throughout this period, from ordinary practice days to the time of approaching a stage ballet performance, the participants maintained stable balance ability regardless of their psychological traits and states of mind. Since no correlation was observed between the sway of the center of gravity and psychological evaluations, it is unlikely that their reactions to stress and their psychological traits affected professional dancers' physicality. While mental aspects, such as psychological sensitivity, might be easily disturbed, professional dancers' dance movements had little effect on their bodies.

However, the load on the lower limbs of a dancer is extreme, due to increased training before a performance, causing physical and mental fatigue. Therefore, by constantly assessing the balance between mental and physical aspects, in addition to psychological traits, such as gene polymorphisms, it may be possible to maintain and manage dancers' performance optimally.

LIST OF ABBREVIATIONS

COP	=	Center of Pressure
PCR	=	Polymerase Chain Reaction
BMI	=	Body Mass Index
5-HTTLPR	=	Serotonin Transporter Gene Promoter Polymorphism

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by St. Marianna University School of Medicine's Bioethics Committee (No. 1844, Gene 80). All participants provided informed consent in writing.

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. All the humans were used in accordance Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Authors sought permission for the publication of non-individually identifiable data.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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CONFLICT OF INTEREST

The authors report that there are no competing interests to declare.

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