Balance Training in Modern Dancers: Proprioceptive-Neuromuscular Training vs Kinesio Taping

Article *in* Medical problems of performing artists · September 2018

DOI: 10.21091/mppa.2018.3022

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Article

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Proprioceptive-Neuromuscular Training vs Kinesio Taping

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Kinesio tape and proprioceptive exercises are both used for increasing balance in dancers. The purposes of this study were to: a) determine the acute effect of kinesio tape (KT) application on the ankle joint on balance performance, b) investigate the effects of an 8-week proprioceptive-neuromuscular (PN) training program on balance performance, and c) compare their effects vs modern dance technique classes alone. Thirty-three trained, university-level modern dance students (9 male, 24 female) were divided randomly into three groups: kinesio tape (KT, *n*=11), proprioceptive-neuromuscular (PN, *n*=11), or control (*n*=11). Static (turn-out *passé*-opened eyes/*relevé* and turn-out *passé*-closed eyes/flat foot), semi-dynamic (airplane), and dynamic balance (monopodalic-straight and -transverse in a turn-out *passé*-eyes opened/flat foot) tests were performed before and after the intervention. One day after pre-tests, KT mechanical correction technique was applied to the left ankle joint (supporting leg) in the KT group, and tests were repeated to determine the acute effect of KT. The PN group participated in an 8-week balance training program (2 days/wk, 60 min/day) involving exercises using stable and unstable surfaces. Significant improvements were observed for all static and dynamic balance tests in the PN group; semi-dynamic airplane and dynamic monopodalic-straight and transverse tests improved in the KT group; and only semi-dynamic airplane test scores changed significantly for the control group ($p<0.05$). Our findings suggest that with the exception of the semi-dynamic airplane test, both PN training and KT application were more effective at improving balance performance for modern dancers than modern dance technique classes alone.

Med Probl Perform Art 2018; 33(3):156–165.

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The authors declare no funding or conflicts of interest related to this study.

Supplemental material appears in the online version of this paper at https://doi.org/10.21091/mppa.2018.3022.

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https://doi.org/10.21091/mppa.2018.3022

Proprioception refers to awareness of the body and its limbs and their location as they move through space.[1] Proprioception mechanisms play essential roles in regulating balance by way of neuromuscular control.[2] Proprioception drills and balance exercises are often included as part of comprehensive neuromuscular training in dancers with the aim of optimizing performance, preventing injury, or providing rehabilitation.[3]

In addition to neuromuscular training programs, taping is a popular intervention thought to help prevent injuries. Elastic adhesive kinesio tapes (KT) are considered advantageous, as they allow full range of motion while still providing support.[4] While some studies have found that KT may provide improvement in muscle activity,[5] muscle strength,[6] isokinetic eccentric peak torque,[7] and force sense[8] and an increase in proprioceptive abilities in normal subjects, current evidence does not support the use of KT for treating musculoskeletal conditions.[9] Recent studies determined that KT may have limited potential to reduce pain in individuals with musculoskeletal injury[10] but did not facilitate muscle performance in healthy participants.[11] Although KT has been considered potentially beneficial in ballet dancers,[12] especially for controlling pronation and unstable ankles and in the care of some dance injuries, the effectiveness of KT taping is yet to be verified in dancers. In contrast to ballet dancers, modern dancers perform without shoes, and therefore, it may be helpful to determine the effect of KT on dancers' health and performance in this population.

Modern dance is an art form that combines aesthetic characteristics with physical abilities such as postural control and static and dynamic balance. Improvements in both static and dynamic balance levels, as well as enhanced dance efficiency, have been observed with training in experienced dancers.[13] However, modern dance is also characterized by the use of extreme positions that place stress on the musculoskeletal system, and ankle stability in particular is an important concern for successful performance of complex dance movements.[14]

To protect and strengthen the ankle region from injuries, preventative exercises might prove helpful, typically aimed at activating ideal neuromuscular control patterns as well as including joint stability exercises, balance training, proprioceptive training, plyometric (jump) exercises, and dance-specific skill training.[15] In addition, bandages or taping may be used to protect against injuries.[14] KT is thinner and more elastic than conventional tape, produces less mechanical restraint, and avoids the mobility restriction experienced with conventional methods.[16] It has been suggested that by permitting dancers to use bandaging and taping applications, teachers can promote safe and optimum performance.[12,17]

Identifying different factors that may affect the performance of the dancers is vital for protecting their health and improving the technical level of dancers. Some scientific studies have analyzed the effect of proprioception[5,18] and balance exercises[19] for ballet dancers; however, little is known about the effects of KT application[4] or proprioception and balance training in modern dancers. Evidence on KT use in dancers is conflicting, with Vinken et al.[20] finding that the application of elastic tape for healthy, active dancers may enhance parameters of postural control but also hamper other performance-related aspects. While some suggest KT may have potential health benefits in ballet dancers,[12] others have demonstrated that KT offers no force reduction effects at the knee or hip during the execution of ballet landings in turnout positions in adolescent dancers.[4] As the effects of KT may vary for different motor characteristics and different age groups the anatomical position and direction in which the bandage or tape is applied should reflect a specific goal.[12]

While KT use is increasing in popularity, current research is lacking regarding the use of KT and proprioceptive exercises as an effective option for increasing balance ability in modern dancers. Therefore, in light of the deficiencies in the existing literature, the aims of this study were: a) to determine the acute effect of KT application of the ankle joint on balance performance, b) to investigate the long-term effect of an 8-week proprioceptive-neuromuscular (PN) training program on balance performance, and c) to compare the effects of KT application, PN training, and modern dance technique classes to determine which method most improves balance performance in university-level modern dancers.

METHODS

Participants

This study was approved by Hacettepe University Institutional Ethics Committee (HEK 12/141-07) and was conducted in accordance with the Declaration of Helsinki policy on use of human participants. Before the study, all participants were informed of the purpose and risks of the study and gave their written informed consent.

The participants consisted of volunteer undergraduate students from the modern dance department. All modern dance department students were invited to participate in the research. Out of a total of 41 students in the department, 33 students (9 male, 24 female; aged 19 to 32 yrs, mean age 22.39 ± 3.13 yrs [SD]) met the selection criteria and enrolled in the study. The inclusion criteria were: age >18 yrs, practicing modern dance for at least 2 yrs, and participating in technique classes in ballet and modern dance for a minimum of 3 days/wk for 10 hrs/wk. Exclusion criteria included: upper or lower limb musculoskeletal injuries or any cardiovascular, metabolic, neurological or pulmonary complications (e.g., pneumonia or asthma) in the prior 12 wks, pregnancy, history of previous lower limb surgery, physiotherapy treatment in the past 6 mos, poor or fragile skin condition, or past skin reaction associated with use of adhesive tape. Eight dancers did not meet the criteria and were excluded. Each participant filled out a questionnaire on demographics, medical history, and training activity patterns prior to the study.

The study used a pretest-posttest randomized controlled experimental design with three groups. Random assignments were made by a data analyst and were concealed from all participants and study staff. Participants were randomly assigned (in a 1:1:1 ratio) via computer-generated randomly permuted blocks stratified by gender (male or female) and ages into three groups: proprioception neuromuscular group (PNG, n=11; 3 males, 8 females), kinesio tape group (KTG, n=11; 3 males, 8 females), and a control group (CG, n=11; 3 males, 8 females).

Experimental Protocol

All participants visited the laboratory three times and were measured on three occasions. The first visit served to familiarize them with the balance tests and training procedure. The second (pre-test) and third (post-test) visits served as the testing sessions. Anthropometric assessment and balance tests were taken in a single session at the same time of day (11:00–15:00) and under the same conditions. The tests were collected 48 hrs after the last physical training session to minimize the fatiguing effects of previous exercise. Participants avoided drinking or eating in the 3 hrs before measurements. Static (turn-out *passé*-opened eyes/*relevé* and turn-out *passé*-closed eyes/flatfoot), semi-dynamic (airplane test), and dynamic (monopodalic-straight and monopodalic-transverse) balance tests were performed and outcomes measured for all participants.

KTG participants were taped with KT (Kinesio Tex KTX-050, Tokyo, Japan) 1 day after the pre-test evaluations. The tape was applied on the supporting left ankle joint, covering the peroneal muscle group and lateral-medial malleolus with tape using the mechanical correction technique (see Methods, Kinesio Tape Application). The post-tests were repeated immediately after tape application in the KTG to determine the acute effect of KT.

After the pre-test evaluations, dancers in all three groups continued to take the same ballet and dance technique classes (including basic floor works, barre exercises, and center work) for a minimum of 3 hrs/day, 5 days/wk. In addition, the PNG participated in an 8-wk supervised training program (2 days/wk, 60 min/day). The KTG and CG continued only modern dance training and did not participate in any PN training. KT was not applied to the CG and PNG.

All baseline evaluations were carried out at the beginning of the research, and post-tests were performed at the end of the 8 wks for PNG and CG. None of the group participants had any experience in PN training or KT application.

Testing Procedures

Anthropometric Assessment

Body height and body mass were measured without shoes and in light clothing according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK).[21] Body mass index (BMI) was calculated with the formula: BMI = kg/m^2. The measures were taken by an ISAK-accredited researcher.

Balance Tests

Dancers did a standardized general warm-up protocol (10 min) before the balance measurements. All balance tests were performed in a randomized order for each subject to eliminate the effects of learning bias. One balance trial for each of the tests was allowed before the beginning of data collection. All participants were tested barefoot. One minute of rest was allowed between each test. The best values of each variable were used in the analysis of results.

Participants were instructed to use the dominant leg as the lifted leg. The dominant leg was determined by asking participants which leg they use in dance choreography.[22] The right leg was dominant and the left leg was the supporting leg in all participants. When a participant hopped, moved on the standing foot, touched the non-weight bearing foot to the ground, swayed the arms or body position, changed position of the leg, or opened his/her eyes, the test was terminated. The subjects were asked to raise their heel to highest heel-rise in a *relevé* position without losing balance. The supporting left ankle was in maximum flexion and the left hallux in maximum extension. A ballet teacher was present throughout the tests to ensure that the movements were performed correctly. The dancers were blinded to the results of the tests. Measurements were timed using a stopwatch (Technos, YP2151/8P, Brazile) that could accurately measure to 0.01 s.

Turn-out passé balance tests: Four standing balance tasks were chosen based on their varying difficulty and common use in previous literature for dancers.[23,24] Single-leg stance has been shown to be a reliable and valid measure of balance in various populations[25] and a frequently used marker of balance deficit.[26] The clinical test of single-leg stance assesses postural steadiness in a static position by a quantitative measurement, i.e., the number of seconds a person can maintain the one-leg stance position, thus implying that better postural steadiness would allow for longer standing on one leg.[27] The single-leg stance test is often used to determine static balance in dancers with *passé* balance position.[19,24] This test is preferred because it is one of the balance elements technically used by dancers. The actual form of this test is 90º flexion of hip and knee of the lifted leg.

The tests were performed in two different forms—eyes opened/*relevé* and eyes closed/flat foot (Fig. 1A and 1B)—and barefoot on a gym floor surface. The participants performed a turn-out *passé* (knee bent, hip abducted and external rotated, foot in a point position, toe touching the knee of the standing limb) by standing on one foot with open eyes and in a *relevé* position. During starting position, the dancers held the barre until they felt ready; they then left the barre and took up a classical first *port de bras* position of the upper extremity maintaining the *relevé* position and looking straight ahead. The participants held the position as long as possible (Fig. 1A). All participants also performed the static balance test with eyes-closed/flat foot under the same conditions (Fig. 1B). The static balance tests were performed three times on the supported leg as indicated in the previous literature.[28]

Airplane balance test: Semi-dynamic balance performance was determined by the airplane test.[24] The airplane test measures trunk control and dynamic lower-extremity alignment and has been found to be significantly predictive of point readiness. The test assesses the dancer's ability to maintain neutral alignment and center of mass over the base of support while doing complex movement.[24] The dancer starts by standing on one leg with the abducting arms in a horizontal position (Fig. 1C); the trunk is then pitched forward and the non-support leg is extended back, keeping the pelvis square to the ground. The participant performs five controlled *pliés* on the flat foot while horizontally adducting the arms to touch the fingertips to the floor (Fig. 1C). Dancers who demonstrate a pelvic drop, hip adduction or internal rotation, knee valgus, or foot pronation receive a failing grade. The correct number of movements was recorded for the analysis, and the test was repeated one time.

Monopodalic balance tests: The tests, modified for dancers,[21,22] were conducted barefooted in single-leg stance on a Libra balance board (Easytech, Prato, Italia) with postural control system. The dynamic balance tests were performed in two different planes, with the balance board placed straight (Fig. 1D) and transverse (Fig. 1E) planes, respectively.[29] In this experiment, the pattern line adopted was a sinusoid of amplitude 5° and frequency 10 cycles/min. The balance curve was r = 24 cm and the 6th difficulty degree (deviation from the pattern line ± 5°) applied.

Participants were asked to stand on the force plate and follow the instructions to perform a sequence of tasks. The tasks included single-leg standing on the supporting left leg with eyes open. The participants performed a turn-out *passé* with the upper extremities held in classical first *port de bras* position with open eyes and flat footed. The participants held the position as long as possible. The postural stability scores included the monopodalic-straight balance and the monopodalic-transverse balance stability scores. Participants had to remain in monopodalic stance on a tilting balance board observing a fixed point for a total of six tests (3 times straight and 3 times transverse directions)

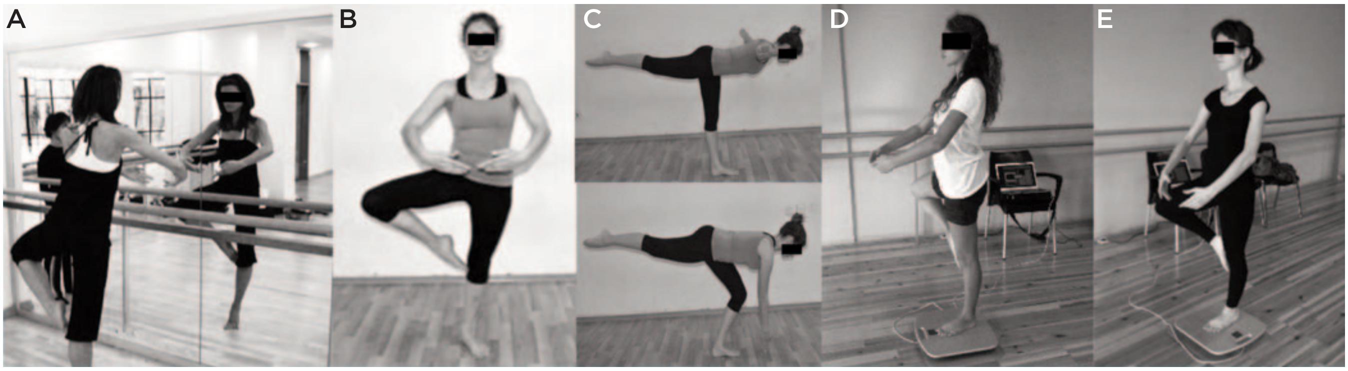

FIGURE 1. Balance tests in *passé* and airplane positions: A, *passé* (eyes opened/*relevé*); B, *passé* (eyes closed/flat foot); C, airplane; D, monopodalic-straight; E, monopodalic-transverse.

for the supporting limb (left leg), with the eyes fixed on a point set at 3 m at the height of the eyes, lasting 30 sec each, with intervals of 30 sec between each test.

Kinesio Tape Application

KT correction technique application was performed by the same physiotherapist who had received special training by an experienced certified instructor of the KT method. KT was applied to the left ankle joint including the distal part of the peroneal muscle group and lateral-medial malleolus. Mechanical correction aims to correct the positional errors between the articular surfaces caused by shortening of muscles or muscle spasms, thus addressing functional limitations.

The tape was applied to participants in a long sitting position. Two 50-cm-long, I-shaped strips were cut. The first strip was placed on the lateral leg at the distal part of peroneal muscle including the medial and lateral malleolus with a tension of 0%. Then, the tape was pulled from the sole of the lateral to the medial malleolus with a tension of 50%. The tape was pulled with original length from the medial part to the anterior part of the ankle in a diagonal way. The process was repeated with the other strip starting from the medial part of the ankle. After application on the ankle and heel, mechanical correction technique was created (Fig. 2A). After KT application to the KTG, the post-tests were repeated immediately (10 min later) to determine the acute effect of KT.

Proprioceptive-Neuromuscular Training

The progressive PN training program was based on previous investigations and observations from conditioning coaches and sports medicine professionals.[30,31] Before the experimental period, because none of the dancers had used unstable surfaces such as stability trainers or rocker boards, a familiarization session was conducted. In addition, a 1-wk preparatory pre-training period allowed participants to become accustomed to the resistance training and different exercises. After familiarization, the PNG followed a 60 min/day PN training program, twice a week (Tuesday and Friday), for 16 total sessions over 8 weeks. All exercises were performed barefoot to allow optimal proprioceptive input.[32,33]

PN training sessions consisted of three parts totaling 60 min: warm-up (10 min), main phase exercises (40–45 min), and cool-down (5–10 min). The dancers performed a regular warm-up, consisting of 3–5 min of walking and jogging and 3–5 min of dynamic movements.

The progressive overload approach was used to determine the content and quality of training. Participants progressed weekly in sets and/or resistance throughout the training period, with exercises gradually increasing in difficulty and load during the course of 8 wks. (Details of the specific exercises for each phase of training are available from the author.) The protocol was organized according to the methodology of circuit training; thus, the 10 to 12 exercises were consecutively repeated in the main phase of each training session, with the number of exercises selected based on the time limit (40–45 min). The PN exercises were aimed to develop balance ability, core stability, lower limb strength, and neuromuscular control at the same time.

The exercise program (40 min) consisted of balance exercises designed to challenge the visual (e.g., opened/closed eyes), vestibular (e.g., move head), somatosensory (e.g., stand on foam), and muscular (e.g., standing on one leg, bending body in different directions) systems.[34] Balance especially is skill specific, and training should use the same technical skills that are required during dance performance.[19] Thus, some balance exercises (e.g., *passé,* attitude, *arabesque, a la seconde, demi-plié* lateral flexions, airplane, airplane with trunk rotation, modified star excursion-*ronde*) used in dance were chosen and performed in different directions (e.g., forward, side, backward) and degrees (e.g., 45°, 90°, 135°).

All groups executed the same balance exercises in their technical lessons. Balance exercises were also supported with dynamic neuromuscular training components such as plyometrics, core strength, and resistance exercises. These multivariate exercises (superman, classic crunches, reverse sit-up, oblique sit-up, spiderman, back extension, plank, lateral lunch, push-up, single-leg hop, multidirectional hops, vertical jump, 180º jumps stick landing, etc.) included torso, legs, arms, and foot flexion, extension, and

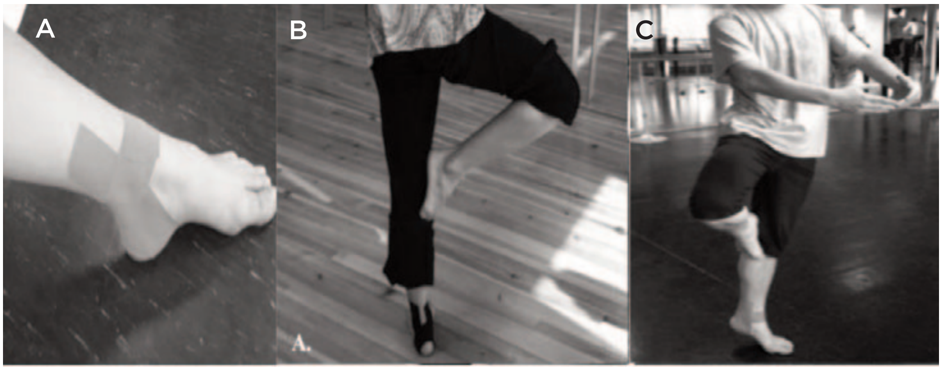

FIGURE 2. Balance tests in *passé* positions with kinesio tape: **A**, KT application; **B**, *passé* (eyes closed/flat foot) with KT; **C**, *passé* (eyes opened/*relevé*) with KT.

rotational strength maneuvers including eccentric, concentric, and isometric contractions on a stable or unstable surface (see Appendix 1 online).

Dynamic balance exercises progressed by altering the dancer's center of gravity through perturbations, adding external weight to the movement, or executing the movement with a single limb. In addition, this group performed exercises focused on maintaining dynamic stabilization, with movements designed to strengthen the core musculature. As this protocol progressed, the difficulty also increased by moving from stable surfaces to relatively unstable surfaces (Appendix 1) such as stability trainers or rocker boards. From week 1 to 4, the dancers worked with his/her own body weight. From week 5 onward, additional weight (400-g rhythmic gymnastics balls) was added to increase resistance to movements. The aim of these exercises was to improve the awareness and neuromuscular control of the hip, knee, and ankle muscles during standing, running, cutting, jumping, and landing tasks with simultaneous ball handling and with the gradual inclusion of exercises on unstable surfaces. -

The cool-down sessions lasted for 10 min and involved relaxation movements and light stretching exercises (10–12 s) of the major muscle groups.

Statistical Analysis

All data were analyzed using SPSS ver. 22 (IBM-SPSS, Inc., Armonk, NY, USA). Statistical significance was set at $p<0.05$. Means and standard deviations (SD) were calculated for all variables, and normality of sample distribution was assessed with the Shapiro-Wilk test.

Both test-retest reliability and inter-rater reliability of all balance tests were assessed with intraclass correlation ($ICC_{3,2}$) with a two-way mixed average measures model and absolute (i.e., within-individual) agreement. Mean difference between test sessions was set as a measure of absolute reliability. Zero lying in the 95% confidence interval (CI) of the mean difference can be seen as a criterion for absolute reliability, showing reasonable agreement between different measurements of a test. The 95% CIs were determined for all ICCs. As a general rule, an ICC >0.90 is considered high, 0.80 to 0.90 as moderate, and <0.80 as insufficient for physiological field tests. ICCs of at least 0.80 are acceptable for physical measures.[35]

The test-retest reliability from our laboratory for the turn-out *passé*-opened eyes/*relevé* (r=0.87, p=0.03), turn-out *passé*-closed eyes/flatfoot (r=0.86, p=0.03), airplane (r=0.91, p=0.002), monopodalic-straight (r=0.89, p=0.002), and monopodalic-transverse (r=0.86, p=0.002) for 20 subjects (10 male, 10 female) was measured 48 hours apart. The raters were blinded to the participant details and the tests were identified by a number only. The reliability analysis (Cronbach alpha) and intraclass correlation coefficients (ICCs) showed that these tests were highly reliable. The ICC coefficients (R) ranged from 0.86 to 0.91 with no significant differences (p>0.05) between mean values for balance tests.

Homogeneity of variance was assessed using Levene's test. The data were not found to be normally distributed and thus differences between groups were computed using a non-parametric Kruskal-Wallis one-way ANOVA test. When the ANOVA showed significant differences between groups, the Mann-Whitney U-test was used for pairwise comparisons between groups. The non-parametric Wilcoxon matched pairs signed-test was employed to assess the significance of the differences between the means of variables within groups.

Magnitude of treatment effects both within and between groups was estimated with Cohen's effect size (ES).[36] The within-group ES is defined as the difference between posttest mean and pretest mean divided by pretest SD. The between-group ES is defined as the difference between experimental group posttest mean and control group posttest mean divided by control group pretest SD.[36] In the present study, between-groups ES were estimated by differences between PNG–KTG, PNG–CG, and KTG–CG.

Rhea[36] proposed a new scale for determining the magnitude of ES (trivial, small, moderate, or large) in strength training research. In this classification, Rhea[36] took the training status of the participants into consideration by separating them into three groups: untrained (consistent training <1 yr), recreationally trained (consistent training

TABLE 1. Baseline Demographic Characteristics and Training Experience for the Dancer Groups

Variables	KTG	PNG	CG	χ^2	*p-Value*
Age (*yrs*)	22.18 ± 2.13 (19 – 26)	2.36 ± 4.65 2(19 – 32)	22.64 ± 2.61 (19 – 27)	1.91	0.38
Height (*cm*)	165.91 ± 8.64 (155 – 181)	167.64 ± 9.55 (153 – 186)	168.09 ± 7.35 (156 – 179)	0.77	0.68
Body mass (*kg*)	57.03 ± 6.91 (46.7 – 69.2)	57.94 ± 8.24 (48.0 – 71.0)	59.72 ± 7.87 (46.3 – 74.5)	0.81	0.67
BMI	20.75 ± 2.50 (46.7 – 69.2)	20.54 ± 1.44 (19.0 – 23.3)	21.10 ± 1.97 (17.7 – 23.9)	0.95	0.62
Length of training (*yrs*)	9.00 ± 4.58 (3 – 19)	8.36 ± 4.80 (2 – 18)	12.00 ± 7.51 (2 – 22)	1.39	0.50
Training hours/wk	33.1 ± 10.31 (17 – 50)	31.55 ± 13.15 (9 – 50)	25.91 ± 11.14 (8 – 40)	2.20	0.33
Training frequency/wk *(times)*	5.82 ± 0.98 (4 – 7)	5.64 ± 0.92 (5 – 7)	5.00 ± 1.26 (3 – 7)	2.55	0.28

Values are mean ± SD (range). The *p*-value was calculated by Kruskal-Wallis H test.

from 1–5 yr), and highly trained (consistent training of >5 yr). Because the dancers in this study had prior dance experience of at least 3 years, the scale for "recreationally trained" was selected for interpretation: trivial (ES, 0.35), small (ES, 0.35–0.80), moderate (ES, 0.80–1.50), and large (ES, 1.50). Additionally, the difference of the medians was given including their 95% CI.

RESULTS

Baseline Characteristics

Table 1 presents the baseline physical characteristics and training levels for the three groups. No differences were found between groups in age, height, body mass, BMI, training years, training hours per week, and training frequency per week. Balance variables for pre- and post-tests are reported in Table 2. The Kruskal-Wallis test showed no significant differences between all groups in terms of the baseline results of airplane, turn-out *passé* (opened eyes/*relevé*), turn-out *passé* (closed eyes/flat foot), monopodalic straight, and monopodalic transverse measurements (all $p>0.05$). Thus, the groups were found to be homogeneous in baseline measurements, and a post-hoc test was not needed.

Within-Group Differences

For pre- and post-test differences within groups, Wilcoxon results revealed significant differences for PNG in the airplane ($p<0.05$, large ES of 1.54), turn-out *passé*-opened eyes/*relevé* ($p<0.05$, large ES of 1.69), turn-out *passé*-closed eyes/flat foot ($p<0.05$, large ES of 8.10), monopodalic-straight ($p<0.05$, small ES of –0.62), and monopodalic-transverse ($p<0.05$, large ES of –1.56). For KTG, there were significant differences in the airplane ($p<0.05$, small ES of 0.53), monopodalic-straight ($p<0.05$, small ES of –0.49), and monopodalic-transverse ($p<0.05$, small ES of –0.74) balance performance; while for CG, there was a significant difference only in the airplane test ($p<0.05$, small ES of –0.66).

Between-Group Differences

Intra-group and inter-group comparisons of pre- and post-test variables are presented in Figure 3. Comparing pre- and post-tests (Table 2), Mann-Whitney U-test results revealed significant differences between PNG and KTG for airplane ($p<0.01$, small ES of 0.35, Fig. 3A) and turn-out *passé*-closed eyes/flat foot ($p<0.05$, moderate ES of 0.85, Fig. 3C), as PNG generated greater improvement than KTG.

There were significant differences between PNG and CG for airplane ($p<0.01$, moderate ES of 0.86, Fig. 3A), turn-out *passé*-open eyes/*relevé* ($p<0.05$, moderate ES of 0.63, Fig. 3B). Turn-out *passé*-closed eyes/flat foot ($p<0.05$, large ES of 2.40, Fig. 3C), monopodalic-straight ($p<0.05$, moderate ES of –1.42, Fig. 3D), and monopodalic-transverse ($p<0.05$, moderate ES of –1.40; Fig. 3E), as PNG generated greater improvement than CG. There were significant differences between KTG and CG for monopodalic-straight ($p<0.05$, moderate ES of –0.90, Fig. 3D) and monopodalic-transverse ($p<0.05$, moderate ES of 1.07), as KTG generated greater improvement than CG.

DISCUSSION

The results of this study revealed significant improvements in balance performance resulting from the long-term effect of the PN training program and the acute effect of KT application compared to controls. The main findings of the present study were that 8 weeks of additional PN training exercises (2 days/wk, 60 min/day) significantly increased the static and dynamic balance performance of university-level modern dancers. The results also suggest that KT application with a mechanical correction technique on the left ankle joint of the supporting leg may significantly increase semi-dynamic and dynamic balance performance. During an 8-week period, the traditional modern dance technique classes alone were not enough to improve the static and dynamic balance performance except for the semi-dynamic balance test.

TABLE 2. Performance Variables of Pre- and Post-Tests for Dancer Groups

Performance Variables	KTG (*n*=11) Pre-test	KTG (*n*=11) Post-test	PNG (*n*=11) Pre-test	PNG (*n*=11) Post-test	CG (*n*=11) Pre-test	CG (*n*=11) Post-test	Within-Group *p*-Value PNG	Within-Group *p*-Value KTG	Within-Group *p*-Value CG	Between-Groups *p*-Value PNG -KTG	Between-Groups *p*-Value PNG -CG	Between-Groups *p*-Value KTG -CG
Airplane (*n*)	3.27 ± 1.56 (0 – 5)	4.09 ± 1.38 (1 – 5)	2.18 ± 1.60 (0 – 5)	4.64 ± 0.67 (3 – 5)	2.45 ± 1.69 (0 – 5)	3.18 ± 1.54 (1 – 5)	0.005†	0.02*	0.02*	0.003†	0.003†	0.490
Turn-out passé (opened eyes/*relevé*) – (sec)	15.00 ± 10.59 (6 – 41)	15.36 ± 10.00 (5 – 38)	7.73 ± 5.27 (3 – 19)	16.64 ± 10.27 (5 – 35)	10.18 ± 10.16 (3 – 36)	10.27 ± 10.68 (1 – 39)	0.008†	0.61	0.89	0.110	0.012*	0.550
Turn-out *passé* (closed eyes/flat foot) (sec)	20.73 ± 18.05 (6 – 64)	37.36 ± 30.60 (6 – 98)	11.18 ± 5.13 (6 – 22)	52.73 ± 40.14 (13 – 152)	16.27 ± 11.75 (7 – 50)	24.55 ± 27.34 (4 – 100)	0.003†	0.06	0.29	0.040*	0.004†	0.340
Monopodalic straight (score)	3.91 ± 1.69 (2.0 – 7.0)	3.08 ± 1.32 (1.5 – 5.3)	2.85 ± 1.03 (1.3 – 4.8)	2.21 ± 0.45 (1.2 – 2.8)	3.75 ± 1.65 (2.2 – 8.1)	4.56 ± 1.60 (2.6 – 7.4)	0.021*	0.02*	0.06	0.620	0.003†	0.005†
Monopodalic transverse (score)	4.25 ± 1.42 (2.7 – 6.5)	3.20 ± 1.10 (1.6 – 5.3)	4.78 ± 1.30 (3.0 – 6.9)	2.75 ± 0.61 (1.7 – 3.7)	3.74 ± 1.34 (1.8 – 5.7)	4.63 ± 2.36 (2.4 – 9.8)	0.003†	0.02*	0.27	0.100	0.001†	0.030

Values given as mean ± SD (range). *p*-Values significant at $^*p<0.05$, $^†p<0.01$.

Proprioception[1,37] and balance outcomes[19] are controversial, with investigations done mostly in ballet dancers. Trained dancers exhibit perceptual and balance errors in quantitative testing.[38] Ballet training alone, however, without concurrent additional coordinative training, has been shown to not lead to improvements in ankle joint position sense or improved measures of balance within a 5-month period.[5] Similarly, the present study revealed that modern dance technique classes alone did not provide enough scope for multi-faceted balance enhancement. Our results indicate that long-term training or additional applications are needed to improve proprioception and its components in modern dancers. This may be due to the fact that dance training primarily focuses on skill acquisition and hence does not elicit significant improvements in specific fitness parameters.[39] Therefore, our study findings suggest the benefits of additional proprioception and balance training on modern dancers' balance performance.

The concept of training specificity would suggest that improvements in proprioception would be most effective with a training program that involves different types, forms, or variations of exercises.[37] In the current study, the combination of PN training, which progressed from low-intensity single-joint movements to high-intensity multi-joint movements on different surfaces (stable and unstable) and planes, resulted in meaningful improvement in the balance performance of university-level modern dancers. Another possible explanation for the improvement in balance performance might be that the PN program was designed to target the systems that control balance (i.e., visual, vestibular, somatosensory, muscular)[34] and response to gradually changing environmental conditions. The modification of the exercises by changing the arm position, opening and closing eyes, changing support stance, increasing or decreasing surface stability,[40] increasing or decreasing speed, adding unanticipated movements or perturbations, improving core strength, and adding specific skills are considered factors contributing to the development of balance performance.

Remarkably, our study also showed that in addition to the dance technique classes, the PN training was very effective for the development of versatility of balance ability, such as static, semi-dynamic, and dynamic balance performance. The increase of balance abilities could also be explained by use of unstable platforms. The results of the present study were also consistent with previous reports on balance training programs involving unstable surfaces,[41] which showed an improvement in static and dynamic balance abilities. Balance control on unstable support surface maintains muscular proprioceptive signals originating from the ankle and increases ankle evertor muscle activity.[42]

It has been reported previously that the postural control exhibited by dancers depends on the availability of visual information.[43] Dancers often train in front of mirrors and use visual landmarks,[5] which might foster increased visual dependency for dancers. In the present study, another important outcome was that no significant

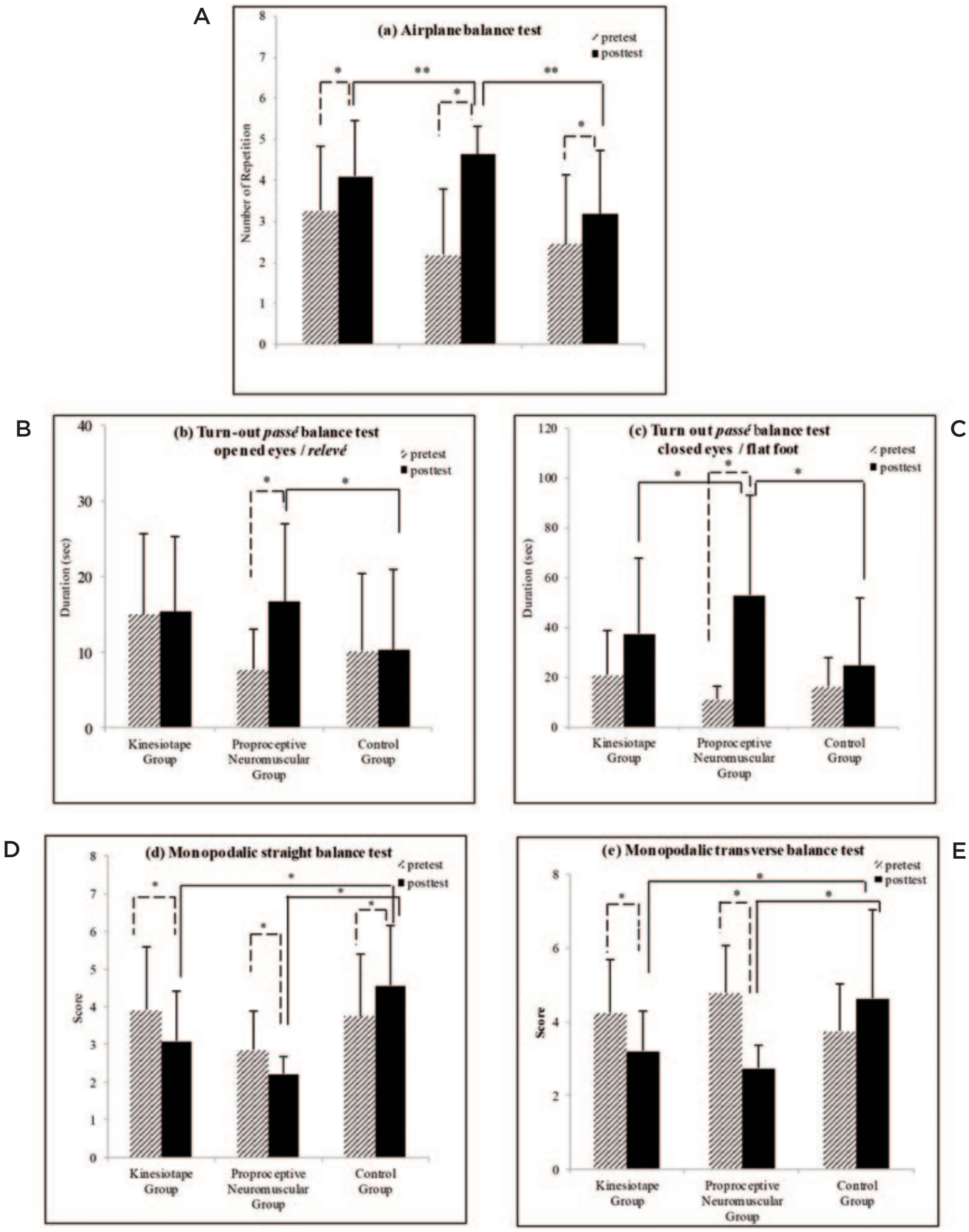

FIGURE 3. Differences of pre- and post-tests values within and between groups: **A**, airplane balance test; **B**, turn-out *passé* balance test with opened-eyes/*relevé*; **C**, turn out *passé* balance test with closed-eyes/flat foot; **D**, monopodalic-straight balance test; **E**, monopodalic-transverse balance test. *p*-Values significant at *$p<0.05$.

improvements were observed among the CG across all closed-eyes variations of the balance tests. This could be because training in dance technique develops specific modalities of balance that are not transferable to posture control in our test situations. Compared to other groups, PNG dancers showed a significant increase in all eyes-open and eyes-closed balance tests performance. These results indicate that dancers can be trained to adopt proprioceptive strategies to maintain static and dynamic balance, which consequently improves their balance performance. This opinion is consistent with the observations by Hutt and Redding.[19]

KT is widely used in clinical practice, but the current evidence does not support the use of this intervention.[9] In this study, an acute effect of KT application was shown by significant improvements in some semi-dynamic and dynamic balance tests. KT application on the supporting left ankle joint, covering the peroneal muscle group and lateral-medial malleolus with mechanical correction technique, might enhance dynamic support of the muscle and joints in the taped ankle. This application did not provide improvement in static balance, but better results were obtained in dynamic conditions. One reason for positive change in dynamic performance could be explained by the placebo effect; the dancers could be more confident once the ankle was taped because they believed that tape would secure and support the ankle area. Since the object of the present study was to investigate the short-term effects of KT, the results were valid for 10 minutes after application and not for any longer time period. Because of its elastic properties, KT does not limit functional performance and therefore might enhance functional stability through proprioception and muscle activation rather than through mechanical support.[44]

Our results do not agree with those of a previous study[45] which found that KT did not improve postural balance.[45] This difference can be explained by methodological approaches. Because of the use of diverse measurement systems and different durations in previous research,[46] comparison of the effects of KT is difficult. One may argue that the effect of KT is likely to be muscle-specific.[47] This hypothesis remains to be tested by proper studies comparing the effects of KT application on different body parts.

It is noteworthy that KT application led to a similar improvement in dynamic balance performance as an 8-week PN training. However, even though its facilitating effect on muscle activity seems to be proven, data regarding the capacity of KT to increase static balance performance are still controversial. Repeated applications or longer period of application might be necessary to obtain an improvement in static balance performance.

The ankle is a commonly injured joint for dancers[41] and KT application may facilitate short-term performance stability of the ankle joint in modern dancers. The effect of long-term use of the KT was not tested in this study, and therefore, the results of KT effects obtained in this study can only be valid for short-term applications, especially for dynamic balance performances.

The balance movements in our research were executed on one leg, and therefore, the performance benefits to modern dancers of applying KT on both anteroposterior and mediolateral stability may be important. Our findings differ from previous studies that maintain KT application increases anteroposterior but not mediolateral stability in neurological patients[48] and athletes.[49] Because the KT group could not be blinded, a placebo effect could account for the results.

There are some limitations to the study. Due to the small enrollment for modern dancers in the university, the number of participants was relatively low. With fewer male dancers, male and female participant numbers were unequal, and hence gender differences could not be analyzed.

Conclusions

This study provides important practical applications for dance medicine and science. The results indicate that long-term PN training (8-wk, 2 days/wk, 60 min/day) is effective at improving static, dynamic, and semi-dynamic balance performance for modern dancers. KT application also had acute effects for increasing both semi-dynamic airplane and dynamic monopodalic-straight and monopodalic-transverse test performances in modern dancers. Dance studio exercises alone do not provide enough stimuli to promote substantial enhancements in static and dynamic balance performance. In order to provide multidimensional balance enhancements, well-planned PN training should be added to technical dance training. Further investigations with larger sample sizes are necessary to explore the acute and chronic effects of PN training on different dance styles and KT applications to different body parts in dancers.

Acknowledgments: This research was conducted as a master's dissertation (DT). The authors thank the students of the Modern Dance Department, Mimar Sinan Fine Arts State University, and their teachers who volunteered to participate in this study. The author also thank Med. Dr. Jon Woo for his help with translation.

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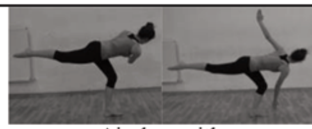
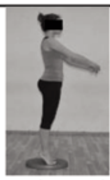
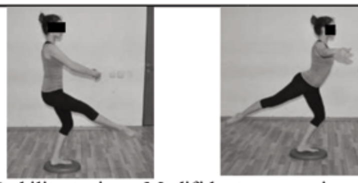
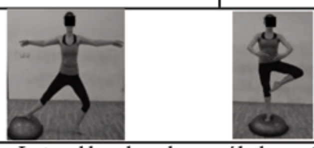
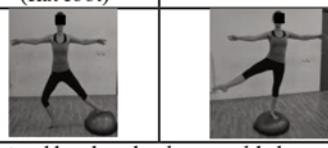
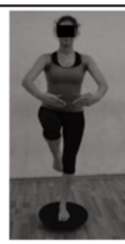
Accepted 16-Mar-2018
Published online 1-Sep-2018
https://doi.org/10.21091/mppa.2018.3022_

Supplemental material appears in the online version of this paper at https://doi.org/10.21091/mppa.2018.3022.

APPENDIX 1. Some of the Exercises for the PN Group

Exercises				
Floor exercises without apparatus	 Alternating Froggers (or Spidermans -front)	 Alternating Froggers (or Spidermans - side)	 Airplane with trunk rotation	
	 Prone positions - back extension -Y- -T- -W- -L-			
Stability trainer exercises	 Stability trainer – rise up and down (*relevé*)	 Stability trainer -Modifide star excursion -*Rondé*	 Stability trainer – *passé* balance (flat foot)	
BOSU exercises	 BOSU crunches or sit-up variations			
	 BOSU - *demi-plié* variation (*flatfoot*)	 BOSU - *demi-plié hold* (*relevé*)	 BOSU – *arabesqué* balance (flat foot)	 BOSU - *airplane* balance (*flatfoot*)
	 Lateral lunch and *passsé* balance (flat foot)	 Lateral lunch and *a la second* balance (flat foot)		
	 BOSU *turn-out passe* ps - ball catch (flatfoot)	 Stability trainer – BOSU (double footed jumps up – down)	 BOSU broad jump	
Rocker board and wobble board exercises	 Rocker board plunk isometric	 Prone bridging on elbows with single leg hip extension	 Rocker board *demi-plié* lateral flexion	 Wobble board paralel *passé* balance

*Unstable surfaces included stability trainers, rocker board, wobble board, and BOSU (both sides up balance trainer).