European Journal of Physical Education and Sport Science
ISSN: 2501 - 1235
ISSN-L: 2501 - 1235
Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.3692663

Volume 6 │ Issue 2 │ 2020

EFFECTS OF A PLYOMETRIC SUPPLEMENTAL TRAINING ON VERTICAL JUMP HEIGHT AND AESTHETIC JUMPING ABILITY IN ADOLESCENT FEMALE DANCERS

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Abstract:
Dance is an artistic discipline that requires precision, artistry, grace, strength and power. Previous studies indicate that plyometric training has positive effects on fitness performance measures in ballet and modern dancers. However, many dancers are wary of engaging in supplementary training out of fear of excessive muscle hypertrophy that could change the aesthetics of body appearance, technique and general, dance artistry. Therefore, the purpose of this study was to investigate the effects of an 8-week supplementary plyometric intervention on vertical jump height, aesthetic jumping ability and anthropometric measures in female contemporary dancers. Sixteen females (12-18 years) were randomly assigned to an 8-week experimental group (EG, n=8) that performed a supplementary plyometric training twice a week or a control group (CG, n=8) that continued regular dance regimen. At baseline and after 8 weeks all participants were tested on the subjective aesthetic jumping ability, anthropometrics and vertical jump. The EG group showed significant ($p<0.05$) improvements in the subjective ability to hang suspended in the air during a jump (+21.4%) and the subjective jump height (+43.3%) following the intervention. Also, a significant 'Time x Group' interaction was found for countermovement jump and countermovement jump free arms ($p<0.05$), with the EG that showed significant improvements of 36.8% and 47.9%, respectively. No significant changes were seen in the CG for all measures from pre- to post-testing. There were no significant changes in any group for body weight and body fat. Our findings suggested that an 8-week supplementary plyometric training program twice a week had a significantly beneficial effect on both physical fitness indices and aesthetic jumping

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ability for female contemporary dancers. Therefore, it is suggested that the way a dancer is trained needs to be reviewed and the concept of supplementary training must be deepened.

Keywords: contemporary dance; body fat; stretch-shortening cycle

1. Introduction

Dance is an artistic discipline that requires precision, artistry, grace, strength and power. All forms of dance are mentally and physically rigorous. Dancers in both ballet and modern dance endlessly practice and drill basic movements, combinations, variations/choreography, and partner work. Previous research indicates that both ballet and modern dancers are fit compared to sedentary controls (Koutedakis & Jamurtas, 2004). Despite these above-average fitness levels, dancers do not always measure as physiologically robust as age-matched sports athletes (Koutedakis & Jamurtas, 2004; Koutedakis, Stavropoulos-Kalinoglou, & Metsios, 2005). There is also no consensus on the physiological or fitness requirements of ballet and modern dance. Twitchett, Koutedakis, and Wyon (2009) reported that scientific evidence examining the strength, power and agility demands of ballet and modern dance is lacking. Although most dance training requires rigorous physical exercise and has been found to enhance physiological parameters, it is not fully known if dancers would benefit from supplementary training (Koutedakis & Jamurtas, 2004; Koutedakis et al., 2005; Twitchett et al., 2009). However, some dancers engage in forms of supplementary training such as strength and plyometric training (Koutedakis et al., 2005).

Plyometric training has both been found to be effective in enhancing sports performance in young and adult athletes (Fischetti, Vilardi, Cataldi, & Greco, 2018; Markovic, Jukic, Milanovic, & Metikos, 2007; Martel, Harmer, Logan, & Parker, 2005; Matavulj, Kukolj, Ugarkovic, Tihanyi, & Jaric, 2001). It has been suggested that the main requirement necessary for dancers is a large reserve of power required for explosive jumps and high elevation, which lasts just a few seconds, energized by phosphocreatine (Koutedakis & Jamurtas, 2004). Plyometric training has been positively associated with vertical jump height in other athletic populations and it is expected that similar physiological mechanisms are responsible for the positive effect on vertical and subjective jump height in dancers (Markovic et al., 2007; Martel et al., 2005; Matavuli et al., 2001; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005). Indeed, Brown, Wells, Schade, Smith, and Fehling (2007) found that plyometric training regime positively enhanced vertical jump height as well as the subjective dance performance. There is a plethora of easily learned and time-efficient plyometric regimens. Additionally, the equipment required for plyometric training such as exercise steps, boxes and free weights, medicine balls or kettlebells is generally available for private purchase or at a gym (Girard, Koenig, & Village, 2015).

It must be known that many dancers have been traditionally wary of engaging in supplementary plyometric training out of fear of excessive muscle hypertrophy that could change the aesthetics of body appearance, technique and general, dance artistry (Koutedakis & Sharp, 2004). However, in some studies that measured thigh/calf girth or body fat, pre-and post-intervention, there was no significant change in any anthropometric measures (Angioi, 2012; Brown et al., 2007; Koutedakis et al., 2007; Twitchett, 2011). This information could positively affect dancers by decreasing hesitation in engaging in supplementary plyometric training. Nevertheless, classical ballet is still dictated largely by artistic and aesthetic principles, and ballet teachers, choreographers, and artistic directors appear reticent to include regular supplemental training into a dancers' schedule. Although it has been hypothesized that increased physical fitness, there are still concerns that supplemental training will affect the aesthetics of classical ballet dancers and their performance.

So, previous studies broadly indicate that plyometric training methods generally have positive effects on fitness performance measures in ballet and modern dancers (Chmelar et al., 1988; Harley et al., 2002; Koutedakis et al., 2007; Padfield, Eisenman, Luetkemeier, & Fitt, 1993). However, there is a paucity of data regarding the effectiveness of supplementary conditioning training on aesthetic competence and fitness levels in contemporary dance. To our knowledge, only one study has investigated via appropriately designed interventions the effects of increased fitness levels on selected aspects of contemporary dance. These available data suggest that increases in muscular strength and power have beneficial effects on jump ability (Brown et al., 2007). For this reason, it is necessary to further investigate the effects of supplemental conditioning training on contemporary dance performance. Furthermore, plyometric regimes do not negatively appear to affect the dancer's anthropometric measures (Angioi, 2012; Brown et al., 2007; Koutedakis et al., 2007; Twitchett, 2011). However, many of these studies had small sample sizes, heterogeneity of interventions and referred to adult dancers only.

Therefore, the purpose of this study was to investigate the effects of a plyometric training program on the functional dance performance in adolescent female dancers. We hypothesized that an 8-week supplementary plyometric intervention would promote great gains on selected fitness-related parameters, such as lower body muscular power, and aesthetic jumping ability in female contemporary dancers. Furthermore, we do not expect any change in anthropometric measures.

2. Material and Methods

2.1 Participants

This study used an experimental, controlled, repeated measures design. Sixteen female contemporary dancers between the ages of 12 and 18 years volunteered to participate in this study. All subjects were concurrently enrolled in at least one intermediate-advanced or advanced dance technique class. An a priori power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) with an assumed type I error of 0.05 and a type II error rate of 0.20 (80%

statistical power) was calculated for measures of fitness performance and revealed that 8 participants per group would be sufficient to observe medium 'Time x Group' interaction effects. Due to limited subject availability, only female dancers participated. After baseline testing, participants were assigned to a plyometric training group (EG) or a control group (CG) using a pre-test matched-pairs approach.

Participants were ranked according to their baseline age, paired, and randomly allocated to either the EG (n = 8; age: 15.0 ± 2.3 years; BMI: 23.4 ± 4.2 kg·m^{-2}; practice: 9.6 ± 2.8 years) or CG (n = 8; age: 14.3 ± 1.3 years; BMI: 20.2 ± 1.4 kg·m^{-2}; practice: 6.6 ± 4.5 years). This approach reduces the bias associated with randomization because it decreases the likelihood of differences between study groups at baseline. Furthermore, this approach takes into account the effect of biological maturation in the subjects studied. Dancers were excluded from the study if: 1) they presented a confirmed injury and/or eating disorder, or 2) they were undertaking other forms of sports activities. Each of the inclusion criteria was determined by responses to a specifically modified medical questionnaire (Par-Q). A parent/guardian provided a signature of consent before participation and after full verbal and written explanation of the data collection procedures, and in the case of those 18-year-old, consent was provided by the participant. The study was conducted in accordance with the Declaration of Helsinki. All participants were recruited from a local dance school in April 2019 and the study was conducted from May to June 2019.

2.2 Procedures and Measures

Testing was completed in three sessions in the following order: 1) subjective dance evaluation, 2) anthropometry and 3) lower body power assessment. A minimum of two days separated each testing sessions. Pre- and post-testing sessions occurred within one week before and after the eight-week intervention period.

A. Subjective Dance Evaluation

A subjective dance evaluation was used to examine the effects of the plyometric training program on aesthetic jumping ability. This subjective evaluation is the same that has been developed and used by Brown et al. (2007). However, in our study, the inter-rater reliability was assessed to check the strength of agreement between scores given by the judges. Two experienced female dance teachers with at least seven years' experience assessed four aspects of petit allegro technique: ballon (defined as the dancers ability to hang suspended in the air during a jump), height of the jumps, the ability to point the feet in the air, and the dancer's overall jumping ability (defined as the dancer's ability to create an aesthetically pleasing jump). For each aspect, the experienced members evaluated the subjects on a 5-point scale: 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent. The dance combination that was evaluated in each case was 16 measures long and consisted of the following steps: échappé close fifth, échappé close fifth, échappé close right leg coupé derrière, coupé assemblé dessous, glissade jeté dessus, temps levé, temps levé, jeté dessus, assemblé dessus, entrechat quatre. Subjects were instructed to wear dance clothing with the feet visible. After a self-directed warm-up, the subjects were taught the jump combination and they have been given time to practice it. Each subject entered the studio individually and performed the combination once. One of the evaluators kept the beat throughout the combination and attempted to keep the tempo constant for each subject. The evaluators were blind to the group designation of each subject and to the content of the training programs. The scores for each subject by each evaluator were averaged for each aspect of jumping. A very good interobserver agreement was reported for ballon, jump height and overall ability, k = 0.89, 0.92 and 0.90, respectively, whereas a good agreement was reported for feet point, k = 0.78.

B. Anthropometric Measurements

To assess possible changes in body composition with the imposed intervention, anthropometric measurements were obtained. *Bodyweight* was measured to the nearest tenth of a kilogram using a Tanita® digital scales. *Percent body fat* was determined using the skinfold method and calculated by following two-site (triceps and calf) prediction equation referred to white girls aged 6-17 years: [%BF = 0.610(∑2SKF) + 5.1] (Slaughter et al., 1988). All measurements were taken on the right side of the body and to ensure the reliability of the measurement, the same experienced technicians performed all skinfold measurements on the same subjects. The gauge was read to the closest 0.2 mm using a Harpenden (Baty International, Burgess Hill, United Kingdom) calliper. The measurements were taken at each skinfold site in 2 rotations. If any of the measurements differed by more than 1 mm, a third measurement was taken and the mean value was used to determine the sum of skinfold (SKF).

C. Vertical Jump

The Vertical jump was performed through the 1) Squat jump, 2) countermovement jump and 3) countermovement jump free arms tests, and the jump height was measured using an App installed on an iPhone 5 s (Apple Inc., USA), named "My Jump" and validated by Balsalobre-Fernández, Glaister, and Lockey (2015). This app was designed for analysing vertical jumps to allow the calculation of the time (in ms) between two frames selected by the user and subsequently to calculate the height of the jump using the equation described in the literature (Bosco, Luhtanen, & Komi, 1983): $h = t^2 \times 1.22625$, with h being the jump height in metres and t being the flight time of the jump in seconds. The participants completed a standard 10-min warm-up composed of jogging, lower-body dynamic stretches and vertical jumps. Then the *squat jump test* was performed from a starting position in which the participants' knees were at a 90-degree knee angle, without allowing any countermovement. The participants' hands were kept on their hips, thus avoiding any arm swing. The subjects were required to jump as high as possible, without performing a countermovement (pre-stretch), and to land at the same point of take-off. They were also required to rebound with straight legs when landing to avoid knee bending and alteration of measurements. The *countermovement jump test* started with a fast-downward movement to approximately a 90° knee flexion immediately followed by a quick upward vertical movement, as high as possible for the subject, all in one sequence. The test was performed with hands-on-hips. Whereas during the *countermovement jump free arms test* the use of the arms during take-off was allowed. Each participant was given three trials, which were separated by 1-minute intervals, to complete their highest jump. The highest jump in the trials was recorded as the dependent variable and used in subsequent analyses. The intraclass correlation coefficient for the three Vertical Jump tests has been ranged between 0.85 and 0.93 reporting a reliability from good to high.

2.3 Plyometric Training

Dancers in the experimental group participated in supplementary plyometric training protocols twice a week. If the subjects were not warm from a dance class before the training session, they either jogged or cycled at a low intensity for five minutes. Each training session lasted from 30 to 45 minutes and there was a minimum of one recovery day between sessions. All training sessions were supervised by research assistants graduates in the Sport Sciences and experts on plyometric training. The control group was asked to participate in no additional training beyond the regular dance regimen.

The plyometric training protocol involved 3 sets of 8 repetitions of 4 exercises for a total of 96 "touches" per session. A touch is defined as a jump or a foot contact with the ground. All subjects were treated as novices to plyometric training and were therefore prescribed four exercises of low to medium intensity with a low volume of total touches. The plyometric exercises were performed in the following order: depth jumps, step-ups, box jumps, and "froggies". There was a one-minute active recovery period between sets during which the subjects walked around casually. During *depth jumps*, subjects stepped off a box, landed into a squat with thighs parallel to the ground, and then jumped as quickly as possible to a maximum vertical height. During *step-ups*, the subjects stood with the left foot on the ground and the right foot on the top of the box. The subject fully extended the right leg and jumped to a maximal height and landed with the same leg. One set was considered 8 repetitions on the right leg followed immediately by 8 repetitions on the left leg. *Box jumps* consisted of a two-footed countermovement hop from the floor to the top of a box. The subjects would step off the box and repeat. *"Froggies"* were a two-footed maximal horizontal hop similar to a standing long jump. The jumps were sequential and commenced with a countermovement. Intensity and height increased every four sessions. Intensity was defined as how explosively the jumps were executed. The researcher visually monitored changes in intensity and gave the subjects encouragement and feedback to ensure proper effort. The first week focused on keeping a low intensity to familiarize the subjects with plyometrics and reinforce the proper form. For depth jumps, step-ups, and box jumps the box height started at 15 cm. At the eighth training session, the box height was increased 5 cm. For the final four sessions, the intensity was progressed by making the jumps more explosive. When the box height increased the subjects were instructed to reduce the intensity for at least one training session. As the subjects acclimated to the new height, the intensity would be resumed by making the jumps more explosive. Froggies were progressed solely by increasing the explosiveness of the jumps. Froggies were performed at a low intensity for the first and second weeks, a medium intensity for the third and fourth weeks, and were done at a high intensity for the last four weeks.

2.4 Statistical Analyses

All analyses were performed using SAS JMP® Statistics (Version <14.1>, SAS Institute Inc., Cary, NC, USA, 2018), and the data are presented as group mean values and standard deviations. A multivariate analysis of variance (MANOVA) was used to detect differences between the study groups in all baseline measures. A Mann–Whitney U test was performed to search differences between the groups in the baseline subjective dance evaluation and compare the differences pre-post intervention. Also, a Wilcoxon signed-rank test was used to identify the significant changes within the groups in the subjective dance evaluation scores after 8-weeks of training. An analysis of variance (ANOVA) was used to determine the interaction between the two independent variables of training (pre/post; within-subjects factor) and group (EG and CG; between-subjects factors) on the continuous dependent variables. When 'Time x Group' interactions reached the level of significance, group-specific post hoc tests (i.e., paired t-tests) were conducted to identify the significant comparisons. Percentage changes were calculated as [(post-training value – pretraining value)/pretraining value] x 100.

The reliabilities of the Vertical jump measurements were assessed using intraclass correlation coefficients; scores from 0.8 to 0.9 were considered as good, while values above > 0.9 were considered as high (Vincent & Weir, 2012). Instead, the inter-rater agreement, for the scores given by the two experienced dance teachers on the aesthetic jumping ability, was calculated using a weighted Cohen's Kappa; values of 0.8 or above indicated a very good strength of agreement and values between 0.6 and 0.8 represented a good strength of agreement (Altman, 1991). We accepted $p < 0.05$ as our criterion of statistical significance, whether a positive or a negative difference was seen (i.e., a 2-tailed test was adopted).

3. Results

All participants received the treatment conditions as allocated. Sixteen subjects completed the training program, and none reported any training-related injury. The plyometric training group and control group did not differ significantly at baseline either in anthropometric characteristics, fitness measures and subjective dance evaluation ($p > 0.05$).

The plyometric training group significantly improved the subjective ability to hang suspended in the air during a jump (21.4%, $p = 0.031$) and the subjective jump height (43.3%, $p = 0.016$), whereas no difference ($p > 0.05$) was observed from pre- to post-testing in the ability to point the feet while jumping and to create an aesthetically pleasing jump. No significant changes were seen in the control group for any subjective variable from pre- to post-testing ($p > 0.05$).

There were no significant changes in any group for body weight and body fat ($p > 0.05$). Significant main effects for 'time' were observed on squat jump and countermovement jump free arms, $F_{1,14} = 11.9$ and 49.4, respectively, $p < 0.01$. The plyometric training group showed a significant increase in vertical jump height from pre- to post-testing for squat jump (52.7%, $p = 0.0049$) and countermovement jump free arms (47.9%, $p < 0.001$), whereas the control group showed no changes in the same variables after 8 weeks.

Significant 'Time x Group' interaction was found for both countermovement jumps, the one with the hands-on-hips and the one with the free arms, $F_{1,14} = 6.2$ and 36.3, respectively, $p < 0.05$, with the plyometric training group that showed significantly greater improvements in the countermovement jump (36.8%, $p < 0.001$) and countermovement jump free arms than control group. There were no significant interaction effects between groups for the squat jump, $F_{1,14} = 1.6$, $p > 0.05$. Pre- and post-intervention results for all outcome measures are presented in Table 1.

Table 1: Changes in subjective dance evaluation scores, anthropometric measures and vertical jump height after 8 weeks. Data presented as mean ± SD

	EG (n = 8)			CG (n = 8)		
Variables	**Pre**	**Post**	**Δ**	**Pre**	**Post**	**Δ**
Subjective Dance Evaluation (score)						
Ballon	2.8 ± 0.5	3.4 ± 0.7*†	0.6	2.8 ± 0.7	3.0 ± 0.8	0.2
Jump height	3.0 ± 0.8	4.3 ± 0.9*†	1.3	2.9 ± 0.8	3.3 ± 1.0	0.4
Feet point	3.5 ± 1.2	3.6 ± 1.2	0.1	3.6 ± 0.7	3.8 ± 0.7	0.2
Overall ability	3.1 ± 0.6	3.6 ± 0.5	0.5	3.1 ± 0.6	3.4 ± 0.5	0.3
Anthropometry						
Body Weight (kg)	58.2 ± 14.9	58.9 ± 14.8	0.7	50.3 ± 3.6	50.2 ± 3.9	-0.1
% Body Fat	25.0 ± 11.5	25.0 ± 8.5	0.0	19.2 ± 7.8	18.0 ± 8.0	-1.2
Vertical jump (cm)						
Squat jump	5.5 ± 1.6	8.4 ± 3.4*	2.9	7.4 ± 2.3	8.7 ± 3.7	1.3
Countermovement jump	7.6 ± 2.8	9.4 ± 2.5*†	2.8	7.5 ± 2.4	7.3 ± 2.7	-0.2
Countermovement jump free arms	7.3 ± 1.4	10.8 ± 2.4*†	3.5	7.1 ± 1.5	7.3 ± 2.1	0.2

Score range: 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent. EG = Experimental group (plyometric training); CG = Control group (regular dance regimen). Δ = individual absolute change. *Significantly different from baseline ($p < 0.05$). †Significant effect of the plyometric training program ($p < 0.05$).

4. Discussion

Dance training is a long process of physical, intellectual, and psychological preparation, through physical exercise, often beginning in childhood and continuing until retirement. Fitness programs, supplementary to traditional dance classes, have only recently been considered as a part of this process; it may be suggested that this cross-training has generally been avoided thus far because of tradition and a reluctance to follow principles associated with the sport. However, it is known that combined and multilateral training methods in a conditioning program aimed at maximizing fitness performance in youth (Fischetti & Greco, 2017; Fischetti et al., 2018). Therefore, the present randomized controlled study aimed to examine the effects of an 8-week supplementary plyometric intervention on fitness-related parameters and aesthetic jumping ability in female contemporary dancers. The main result for the conditioning group was that supplementary exercise training significantly increased selected fitness components (lower body muscular power) with simultaneous increases in the aesthetic jumping ability of the dancers, without causing any changes in anthropometric measures.

Previously published data revealed that plyometric training methods have positive effects on fitness performance measures in ballet and modern dancers (Chmelar et al., 1988; Harley et al., 2002; Koutedakis et al., 2007; Padfield, Eisenman, Luetkemeier, & Fitt, 1993). Furthermore, a study of Brown et al. (2007) demonstrated the effects of 6-weeks of plyometric training versus traditional strength training on power and aesthetic jumping ability in collegiate dancers. The functional outcomes of interest were vertical jump height and an aesthetic jump assessment, which consisted of an evaluation by three dance faculty members using a standard rubric of dance technique. The results indicated that the plyometric group significantly increased the vertical jump height and improved the subjective dance evaluation for subjective jump height. No significant changes were observed for these outcome measures in the control group. So, given that extreme neuromuscular control is required to create aesthetically pleasing jumps, it is plausible that supplementary training geared toward improving the power of the musculature required for jumping may improve aesthetics.

Our findings confirm these previous data, suggesting that the aesthetic jumping ability of dancers benefits from enhanced physical fitness levels such as lower body muscular power. In present study, the plyometric training group showed a significant increase in vertical jump height from pre- to post-testing for squat jump (+52.7%, $p < 0.01$), countermovement jump (+36.8%, $p < 0.001$) and countermovement jump free arms (+47.9%, $p < 0.001$), whereas control group showed no changes in the same variables after 8 weeks. However, there were no significant interaction effects between groups for the squat jump test meaning no effect of the plyometric training program for this measured variable. This could be likely due to adaptations from the plyometric exercises used in this study, that is a specific activation of the stretch reflex and the series elastic components of the involved musculature. While the squat jump is performed without allowing any countermovement, instead the countermovement jump starts with a fast-downward movement immediately followed by a quick upward vertical movement, as high as possible. The stretching forces that occur during movement, give rise to eccentric muscle contractions with the resulting stored elastic energy, which contributes to an increase in strength in subsequent concentric contractions. This mechanism is known as the Stretch-Shortening Cycle (Komi, 2003), and is explicated in the squat with countermovement (Bosco, Tarkka, & Komi, 1982). Instead, the enhance in the squat jump could be due to growth and biological maturation process of muscle strength that increases significantly during ages 12 to 16 (Meylan et al., 2014). The control group exhibited no changes in any variables after the eight-week monitoring period. This suggests that short-term dance training alone is insufficient to improve strength, power, or jumping ability in this population. Similar results have been repeatedly demonstrated in previous investigations (Grossman & Wilmerding, 2000; Koutedakis & Sharp, 2004).

In a systematic review of Girard et al. (2015) was broadly indicate that strength and plyometric training methods generally have positive effects on functional performance measures such as jump-height or subjective, aesthetic performance in elite ballet and modern dancers. Furthermore, strength and plyometric regimes from trials did not negatively affect the dancer's anthropometric measures. This review supports our previous finding mentioned above and also that supplementary plyometric training no affects the dancer's anthropometric measures as has been demonstrated in other previous studies (Angioi, 2012; Brown et al., 2007; Koutedakis et al., 2007; Twitchett, 2011). However, in the present study was used the skinfold measurements which are generally considered the least accurate (Yannakoulia, Keramopoulos, Tsakalakos, & Antonia-Leda, 2000). But a study found that skinfold measurements were positively correlated with both BIA and DXA measurements demonstrating their effectiveness (Eliakim, Ish-Shalom, Giladi, Falk, & Constantini, 2000). Also, this study had a large sample size (n = 59 female) and was conducted on adolescent (age 14–17 years) dancers, as in our research.

A major limitation of the present study is related to the subjective dance evaluation on aesthetic jumping ability. Although a high level of agreement was demonstrated between the two judges and the coding was deemed reliable, which means that the qualitative research displayed rigour, the results should be treated with extreme caution. Also, our findings were limited to 12-18-years-old female contemporary dancers. Another threat to external validity is the small sample size, that may cause a decreased of the statistical power and a greater risk for a Type II error. So, larger randomised controlled studies, with a continued focus on specific dance disciplines of ballet and modern dance, are needed to ascertain which dance disciplines will benefit from specific plyometric training intervention.

5. Conclusion

In summary, an 8-week supplementary plyometric training program twice a week had a significantly beneficial effect on both physical fitness indices and aesthetic jumping ability for female contemporary dancers. Therefore, the novel findings of the study suggest that supplementary training is required to prepare dancers for the increased demands of functional dance performance. Furthermore, it should be highlighted that performance gains were achieved without any occurrence of musculoskeletal injury. This demonstrates the importance of being trained by graduates in the Sport Sciences and experts on plyometric training to prevent musculoskeletal injury which is very common among athletes who participate in conditioning programs (Greco, Settimo, & Fischetti, 2018). In future studies, more multidisciplinary scientific research is needed on the different forms of dance and dance training. Also, it is suggested that the way a dancer is trained needs to be reviewed and the concept of supplementary training must be deepened.

Funding
No sources of funding were used to assist in the preparation of this manuscript.

Conflicts of interest
The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' contribution
Mariateresa De Leonardis designed the study, collected data and wrote the manuscript. Gianpiero Greco carried out the statistical analysis, interpreted the data, wrote and revised the manuscript. Both authors contributed intellectually to the manuscript, and have read the manuscript and approved the submission.

References

Altman, D. G. (1991). *Practical statistics for medical research*. London: Chapman & Hall. p. 404.
Angioi, M. (2012). Effects of supplemental training on fitness and aesthetic competence parameters in contemporary dance: a randomised controlled trial. *Medical problems of performing artists*, *27*(1), 3-8.
Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of Sports Sciences*, *33*(15), 1574-1579.
Bosco, C., Luhtanen, P., & Komi, P. V. (1983). A simple method for measurement of mechanical power in jumping. *European journal of applied physiology and occupational physiology*, *50*(2), 273-282.
Bosco, C., Tarkka, I., & Komi, P. V. (1982). Effect of elastic energy and myoelectrical potentiation of triceps surae during stretch-shortening cycle exercise. *International Journal of Sports Medicine*, *3*, 137–140.
Brown, A. C., Wells, T. J., Schade, M. L., Smith, D. L., & Fehling, P. C. (2007). Effects of plyometric training versus traditional weight training on strength, power, and aesthetic jumping ability in female collegiate dancers. *Journal of dance medicine & science*, *11*(2), 38-44.
Chmelar, R. D., Schultz, B. B., Ruhling, R. O., Shepherd, T. A., Zupan, M. F., & Fitt, S. S. (1988). A physiologic profile comparing levels and styles of female dancers. *The Physician and sports medicine*, *16*(7), 87-96.
Eliakim, A., Ish-Shalom, S., Giladi, A., Falk, B., & Constantini, N. (2000). Assessment of body composition in ballet dancers: Correlation among anthropometric measurements, bio-electrical impedance analysis, and dual-energy X-ray absorptiometry. *International journal of sports medicine*, *21*(08), 598-601.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Fischetti, F., & Greco, G. (2017). Multilateral methods in Physical Education improve physical capacity and motor skills performance of the youth. *Journal of Physical Education and Sport, 17*(3), 2160-2168.

Fischetti, F., Vilardi, A., Cataldi, S., & Greco, G. (2018). Effects of Plyometric Training Program on Speed and Explosive Strength of the Lower Limbs in Young Athletes. *Journal of Physical Education and Sport, 18*(4), 2476-2482.

Girard, J., Koenig, K., & Village, D. (2015). The effect of strength and plyometric training on functional dance performance in elite ballet and modern dancers. *Physical Therapy Reviews*, *20*(4), 233-240.

Greco, G., Settimo, M., & Fischetti, F. (2018). Relationship between the correct running technique and lower back well-being perceived by the practitioner. *Journal of Physical Education and Sport, 18*(3), 1796-1800.

Grossman, G., & Wilmerding, M. (2000). The effect of conditioning on the height of dancer's extension in a la seconde. *Journal of dance medicine & science*, *4*(4), 117-121.

Harley, Y. X., Gibson, A. S. C., Harley, E. H., Lambert, M. I., Vaughan, C. L., & Noakes, T. D. (2002). Quadriceps strength and jumping efficiency in dancers. *Journal of dance medicine & science*, *6*(3), 87-94.

Komi, P. V. (2003). Stretch-shortening cycle. *Strength and power in sport, 2*, 184-202.

Koutedakis, Y., & Jamurtas, A. (2004). The dancer as a performing athlete. *Sports medicine*, *34*(10), 651-661.

Koutedakis, Y., & Sharp, N. C. (2004). Thigh-muscles strength training, dance exercise, dynamometry, and anthropometry in professional ballerinas. *Journal of strength and conditioning research*, *18*(4), 714-718.

Koutedakis, Y., Hukam, H., Metsios, G., Nevill, A., Giakas, G., Jamurtas, A., & Myszkewycz, L. (2007). The effects of three months of aerobic and strength training on selected performance-and fitness-related parameters in modern dance students. *The Journal of Strength & Conditioning Research*, *21*(3), 808-812.

Koutedakis, Y., Stavropoulos-Kalinoglou, A., & Metsios, G. (2005). The significance of muscular strength in dance. *Journal of dance medicine & science*, *9*(1), 29-34.

Markovic, G., Jukic, I., Milanovic, D., & Metikos, D. (2007). Effects of sprint and plyometric training on muscle function and athletic performance. *The Journal of Strength & Conditioning Research*, *21*(2), 543-549.

Martel, G. F., Harmer, M. L., Logan, J. M., & Parker, C. B. (2005). Aquatic plyometric training increases vertical jump in female volleyball players. *Medicine and science in sports and exercise, 37*(10), 1814-1819.

Matavulj, D., Kukolj, M., Ugarkovic, D., Tihanyi, J., & Jaric, S. (2001). Effects of plyometric training on jumping performance in junior basketball players. *Journal of Sports Medicine & Physical Fitness, 41*, 159–164.

Meylan, C. M. P., Cronin, J. B., Oliver, J. L., Hopkins, W. G., & Contreras, B. (2014). The effect of maturation on adaptations to strength training and detraining in 11–15-year-olds. *Scandinavian journal of medicine & science in sports, 24*(3), e156-e164.

Padfield, J. A., Eisenman, P. A., Luetkemeier, M. J., & Fitt, S. S. (1993). Physiological profiles of performing and recreational early adolescent female dancers. *Pediatric Exercise Science*, *5*(1), 51-59.

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van Loan, M. D., & Bemben, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology, 60*, 709-723.

Tricoli, V., Lamas, L., Carnevale, R., & Ugrinowitsch, C. (2005). Short-term effects on lower-body functional power development: weightlifting vs. vertical jump training programs. *The Journal of Strength & Conditioning Research*, *19*(2), 433-437.

Twitchett, E. A. (2011). Do increases in selected fitness parameters affect the aesthetic aspects of classical ballet performance? *Medical problems of performing artists*, *26*(1), 35-38.

Twitchett, E. A., Koutedakis, Y., & Wyon, M. A. (2009). Physiological fitness and professional classical ballet performance: a brief review. *The Journal of Strength & Conditioning Research*, *23*(9), 2732-2740.

Vincent, W., & Weir, J. P. (2012). *Statistics in Kinesiology* (4th Ed). Champaign, IL: Human Kinetics.

Yannakoulia, M., Keramopoulos, A., Tsakalakos, N., & Antonia-Leda, M. (2000). Body composition in dancers: the bioelectrical impedance method. *Medicine and science in sports and exercise*, *32*(1), 228-234.