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Effect of supplementary physical training on vertical jump height in professional ballet dancers

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Complete List of Authors:	Escobar-Alvarez, Juan; University of the West of Scotland - Ayr Campus, School of Health and Life Sciences; UP CIFI2D, CIFI2D-Center of Research, Education, Innovation and Intervention in Sport. University of Porto; South Essex College, Faculty of Higher Education Jiménez-Reyes, Pedro; Universidad Rey Juan Carlos, Centre for Sport Studies, Rey Juan Carlos University, Madrid, Spain Conceição, Filipe; UP LABIOMEP, LABIOMEP, Porto Biomechanics Laboratory. University of Porto; UP CIFI2D, CIFI2D-Center of Research, Education, Innovation and Intervention in Sport, Faculty of Sports. University of Porto Fuentes, Juan P.; Universidad de Extremadura, Facultad de Ciencias del Deporte
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Effect of supplementary physical training on vertical jump height in professional ballet dancers

Running head: Plyometric vs Combined training in ballet dancers

Abstract

Dancers require many specific dance skills of a ballistic nature. Therefore, the design of supplementary training to improve the strength of the lower limbs and jump height is a relevant area of research. The purpose of this study was (i) to compare the effect of plyometric training (PT) vs combined training (CTr) on countermovement jump (CMJ), squat jump (SJ) and *sauté* in first position (*sauté*) height; and (ii) to observe whether changes on CMJ and SJ are associated with changes in *sauté* in female and male dancers. Eighty-one classical professional ballet dancers (41 females and 40 males, age=22.9±3.7years, body mass-BM=59.7±8.6Kg, height=167.4±7.3cm) from two different dance companies were divided into a control group and 2 experimental groups: PT and CTr. All groups followed their common routine of training regarding classes and rehearsal practice, while the experimental groups added 2 sessions (1hour per session) for 9 weeks of supplementary training. Significant increases (medium to large effect size) in CMJ, SJ and *sauté* height were found in the pre- vs post-test comparisons for both experimental groups. Significant, very large correlations were found between the magnitude of improvement in *sauté* and the magnitude of improvement in CMJ and SJ. Plyometric and combined training programs are effective ways to improve jumping ability in professional female and male ballet dancers. The improvement in CMJ and SJ has a good transference on *sauté* performance. These findings support the use of traditional training methods to improve jump height in specific and non specific ballet jumping ability.

Key Words: Performance, Exercise Fitness, Strength, Training

INTRODUCTION

Ballet is an artistic discipline that requires both male and female dancers to perform many unilateral and bilateral jumps. Therefore, jumping ability has been identified as an important part of dance performance, giving dancers a longer time to implement technical skills during the flight stage of the leap [1–4]. A previous study has compared the number of jumps in female (5.29+4.97 jumps per minute) and male (4.68+4.98 jumps per minute) ballet dancers, reporting significant differences between them [5]. The prescription of supplementary training aimed to improve jump height [2,6–9], however, is not as commonplace in ballet as it is in sports.

It has been suggested that in ballet, male dancers are more focused on supplementary weight training, while females undertake more cardiovascular exercise [7]. One of the reasons for this, has been the assumption that dancers are concerned (particularly in females) about increasing muscle mass and its impact on the aesthetic component of dance. However, a recent study with a mixed genre of professional dancers (19 ballet dancers included) has concluded that the dancers' perception is to not be afraid of muscle hypertrophy, which is a more prevalent preconception in dance teachers [10].

Due to the physical demands and physiological responses observed in professional ballet [11], designing optimal training programs for dancers is a relevant area of research. Recent investigations have suggested that due to the high number of jumps, *pliés*, and lifts, managing training loads and recovery may be a focus for strategies seeking to optimize dancer health and wellbeing [11]. Therefore, ballet companies need to provide dancers with supplementary physical training [11]. The implementation of training principles (i.e. periodization and progressive overload) would also benefit dancers' health and wellbeing [11,12]. Different methods of training such as plyometrics (PT) [2], whole-body vibration [13–16], traditional strength training [2,13] and individualized training based on force-velocity profiling during jumping [17] have reported a positive effect on jumping ability in elite ballet and modern dancers [18,19]. However, most of the studies have been conducted with female participants. A recent systematic review of the kinetic and kinematic parameters in ballet jumping concluded that only 4 out of 29 articles investigated male ballet dancers, identifying a gap in the literature [19].

Dance choreography routinely demands several types of jumps, including standard actions such as countermovement jumps (CMJ) or squat jumps (SJ) and ballet-specific jumps such as the *sauté* in first position (*sauté*) [20]. *Sauté* is one of the most common ballet jumps, which can be defined as a CMJ that is performed with an external rotation of the lower limbs and the heels together, known as turnout [21]. Investigations have reported the differences between CMJ and SJ in comparison with *sauté* [22,23]. However, to the best of our knowledge, investigations have not observed the effect of supplementary training to improve jump height (CMJ and SJ), and its effect on a specific dance skill like the *sauté*.

Some other specific dance jumps have been studied. Blanco and colleagues found large to very large associations between grand jeté leap height and CMJ and drop jump in ballet dancers with different skill levels, suggesting a relationship between ballet specific and non-specific jumps in this population [24]. This may support the use of traditional training methods such as plyometrics or combined training (Ctr) [25] to improve ballet specific jumps. Moreover, recent findings suggest that supplementary training can have positive outcomes on ballet specific jumps [26]. As a consequence, performance in specific dance jumps that are vertically orientated and with an external rotation of the lower limbs, such as *sauté*, may be enhanced through training programs based on improving CMJ or SJ.

The current literature reveals a lack of studies observing the effect of vertical jump training (CMJ and SJ) on specific dance skills based on leaping. In addition to this, investigations observing the effect of supplementary physical training on male dancers are very limited [19]. Therefore, the purpose of this study was (i) to compare the effect of two common methods of supplementary training (PT, CTr) on CMJ, SJ and *sauté* height; and (ii) to observe whether changes in CMJ and SJ were associated with changes in *sauté* after nine weeks of physical supplementary training in female and male dancers.

METHODS

Subjects

Eighty-one (41 females-F and 40 males-M) professional classical ballet dancers from 2 different dance companies (38 and 43 dancers each) participated in this study (age=22.9±3.7years, body mass-BM=59.7±8.6Kg, height=167.4±7.3cm). All the participants had more than 12 years' experience (training volume of 13±3.5 hours per week) and were informed of the benefits and risks of the investigation through a structured consent form and a Physical Activity Readiness Questionnaire (PAR-Q). This study was approved by the Research Ethics Board of ***removed for peer-reviewed*** in agreement with the Declaration of Helsinki.

Procedures

All subjects were asked to meet for two sessions one week before any training intervention (Pre-test week). Participants performed the same standardized warm-up both days, consisting of 5 minutes' jogging, dynamic stretching, a range of movement exercises based on specific dance actions, and preparatory jumps in countermovement, squat, and *sauté* in first position (unilateral and bilateral jumps). Body mass (BM) in kg and height (cm) were measured using a Tanita SC-330 (TANITA Corporation, Itabashi-ku Tokyo, Japan), and an aluminium stadiometer (Seca 713 model, Postfach, Germany) respectively. Knee flexion was standardised to 90 degrees during the CMJ and SJ. CMJ height (cm), SJ height (cm) and *sauté* height (cm) were measured, selecting the best performance of 3 trials (2 min intra-set and 5 min for inter-set recovery) using a contact platform size A-1 (Chronojump Boscosystem®) [27]. The Chronojump contact platform calculates the jump height based on flight time. Data were inputted into Microsoft excel prior to statistical analysis.

First testing Session (Tuesday): The first session was planned to collect participants' BM, height and CMJ. All the participants performed the CMJ barefoot, and two observers (one on either side of the subject) provided feedback about the starting height of 90° (knee flexion) for the squat during jump performance. If one of the observers disagreed with the 90° (knee flexion) squat, the trial was invalidated and was repeated.

Second testing session (Friday): The second session was aimed to collect SJ height and *sauté* height. The methods for SJ were consistent with that of the CMJ and the participants were informed to hold for 3 seconds the squat position previous jumping.

All the participants performed the jumps barefoot. Two observers (one on either side of the subject) provided feedback about the starting height of 90° (knee flexion) squat during SJ performance. If one of the observers disagreed with the 90° (knee flexion) squat, the trial was invalidated and was repeated.

One week after the first testing session (Tuesday), participants were divided into a control group (CG) (14 females and 12 males) and 2 different experimental groups, corresponding to PT (15 females and 11 males) and CTr (12 females and 17 males). All the groups performed their usual training routine with regard to classes and rehearsal practice (34.2±4 hours). The experimental groups (PT and CTr) added 2 sessions (1 hour per session) of supplementary training per week, for 9 weeks (Tuesdays and Fridays). It was decided to have at least 48 hours between complementary training sessions for fatigue management, since these sessions were added in the early stage of the season. All the sessions were supervised by certified strength and conditioning (S&C) coaches. The training programs implemented for the PT and CTr groups can be seen in Table 1. Recovery periods of 2 and 5 minutes were set for intra and inter-set exercises, respectively. Due to the height and jumping differences between female and male dancers, the box heights were set at 40cm (F-40) and 50cm (M50) respectively. Participants were asked to meet the week after the end of the training intervention for the post-test measurements, following the same procedures used in the pre-test week.

Table 1 here

Statistical Analysis

All statistical analyses were conducted using the Statistical Package for Social Sciences (IBM SPSS version 27.0; SPSS, Chicago, IL, USA) and presented as means ± SD. Normal distribution for the study variables was observed with the Shapiro-Wilk Test. Two (one per each sex) two-way analysis of variance (ANOVA) (3group x 2time) with Bonferroni adjustment and level of significance set at $p \leq 0.05$ was used for inter- and intra-group comparisons within sex. The magnitudes of change, within and between group comparisons, were calculated using Cohen's effect size (ES) [28]. The criterion for interpreting these magnitudes was <0.2 = trivial, 0.2 - 0.6 = small, 0.6 - 1.2 = moderate, 1.2 – 2 = large and >2.0 = very large [28]. Within-session reliability for the pre-test session for CMJ, SJ and *sauté* was assessed using the intraclass correlation coefficient (ICC) and the coefficient of variation (CV), with the corresponding 95% confidence interval (CI). Acceptable reliability was determined as a CV < 10% and ICC > 0.70 [29].

The associations between the magnitude of improvement in CMJ (Δ%-CMJ) and SJ (Δ%-SJ) height with the magnitude of improvement in *sauté* height (Δ%- *Sauté*) were analyzed using a Pearson correlation (r) and the coefficient of determination (R^2), the level of significance was set at $p \leq 0.05$. The chosen criteria to interpret the magnitude of r were: ≤ 0.1 = trivial, > 0.1 – 0.3 = small, > 0.3– 0.5 = moderate,> 0.5 – 0.7 = large,> 0.7– 0.9 = very large, > 0.9 – 1.0 = almost perfect [28]. The magnitudes of improvement for the variables previously mentioned were calculated using the formula:

$$\left(\left(\frac{\text{Post} - \text{Test Value}}{\text{Pre} - \text{Test Value}}\right) - 1\right) * 100.$$

RESULTS

Acceptable reliability between the 3 trials for each jump [29] was observed in the pre-test. CMJ height (Female Pre-ICC=0.95, CV=7.4%, C.I.=30.7-31.4 cm; Male Pre-ICC=0.92, CV=5.3%, C.I.=49.6-51.7 cm), SJ height (Female Pre-ICC=0.91, CV=9%, C.I.=26.5-29 cm; Male Pre-ICC=0.91, CV=6.7%, C.I.= 47.2-47.9 cm) and *sauté* height (Female Pre-ICC=0.92, CV=9.1%, C.I.= 29.1-30.5 cm; Male Pre-ICC=0.94, CV=6.9%, C.I.= 48.8-49.5 cm). The data for the CMJ, SJ and *sauté* performance in the pre and post comparisons after 9 weeks of intervention for female and male dancers are provided in Table 2.

Table 2 here

The two-way ANOVA (3group x 2time) for the pre-test, reported no significant differences between groups, for CMJ (Female F=0.08, p=0.92 and Male F=0.38, p=0.69), SJ (Female F=1.09, p=0.35 and Male F=1.22, p=0.31) and *sauté* (Female F=0.47, p=0.63 and Male F=0.01, p=0.99) height in female and male dancers. The post-test analysis showed significant differences for CMJ (Female F=18.4, p≤0.001, Male F=11.2, p≤0.01), SJ (Female F=34.2, p≤0.001, Male F=3.54, p=0.04) and *sauté* (Female F=14.9, p≤0.001, Male F=5.16, p=0.01) in both experimental groups (PT and CTr) against the CG for female and male participants, as the post-hoc revealed.

Associations between the magnitude of improvement in CMJ height (Δ-CMJ) and SJ (Δ%-SJ) height compared with the magnitude of improvement in *sauté* height (Δ%-*Sauté*) for each group can be observed in figure 1 and table 3.

Figure 1 here

Table 3 here

DISCUSSION

The aim of this study was (i) to compare the effects of two common methods of supplementary training (PT, CTr) on CMJ, SJ and *sauté* height; and (ii) to observe whether changes in CMJ and SJ were associated with changes on *sauté* after 9 weeks of physical supplementary training in female and male dancers. Both methods significantly improved CMJ, SJ and *sauté* in male and female dancers. In addition to this, our results suggest that the improvement in CMJ and SJ has a positive transference to specific dance skills based on jumping ability as measured during a *sauté*.

To our knowledge, this is the first study to observe the effect of supplementary training to improve vertical jumping ability (CMJ and SJ), and its effect on a specific dance skill such as *sauté*. Our findings suggest that irrespective of the sex of ballet dancers, PT and CTr supplementary training are beneficial ways to improve jumping ability [2,13]. These results align with those of Brown and colleagues for female dancers [2]. However, their findings reported better results for CMJ using PT in comparison to traditional weight training, while in our study the CTr showed a higher ES than PT. The reason for this may be the different strength training programs that were applied in each study. The exercises included by Brown and colleagues in their strength training group did not include loaded jumps. This exercise has reported large improvements in vertical jump, besides being a relevant training stimulus for the optimization of the stretch-shorten cycle [30]. Therefore, the loaded CMJ and SJ (with one or both limbs) included in our study, based on a percentage of the participants' BM, may have caused a specific adaptation in jump height performance.

Our results show that male dancers jump higher than females (~20cm either in CMJ, SJ and *sauté*), as has been previously suggested in other studies [31]. The CMJ showed the highest value for jump height, followed by *sauté*, as previous investigators have reported [22,23]. The lack of involvement of the stretch-shortening cycle during the SJ provides an explanation for the lower values for this type of jump [32]. Interestingly, the CG for female dancers shows a significant decrease of ~1.3cm in CMJ (E.S.=0.52 Small) and ~1.2cm in SJ (E.S.=0.46 Small). Similar results can be seen in the dance science literature [13,14,16], and may be related to the insufficient number of supplementary training sessions provided for dancers [2,6–9], especially female participants [31]. Similarly, an analysis of the force-velocity profile during jumping, conducted by Escobar and colleagues, found that female dancers have a force deficit. This analysis of the mechanical variables during jumping suggests that dance training develops an insufficient amount of force to reach the optimal performance in CMJ [17]. On the other hand, our results also support the findings reported by Brown and colleagues, reporting plyometric training as an effective methodology to improve vertical jump height in female collegiate dancers [2]. The involvement of the lower limbs in quick eccentric and concentric actions enhance the capacity to use the stored energy in the muscle tendons [33]. All the above supports the suggestion that professional ballet dancers must implement supplementary training programs to develop force capabilities and improve vertical jump ability [2,6–9,17]. In contrast with the female dancers, the CG for male participants does not show a significant decrease in CMJ, SJ and *sauté*. This may be explained by the different choreographic demands and training programs for female and male dancers, as has been previously reported by some authors [7].

One of the novel aspects of this investigation was observing the effect of improving CMJ and SJ height on *sauté*. The significant change found in *sauté* height in male and female participants in both experimental groups (see table 2), suggests that supplementary training has a positive transference to this specific dance skill. Moreover, the improvements in CMJ and SJ are strongly associated with improvements in *sauté* jump height. Table 3 shows a very large association between the improvement in CMJ and SJ and improvement in *sauté*. Interestingly, the r values for CMJ compared with the *sauté* are higher than those for SJ for each group regardless of the participants' sex, especially for the CTr group. This may be related to the adaptions caused by heavy strength training. The findings of Cormie and colleagues suggest that maximal strength plays an important role in the production of maximal power and the enhancement of athletic performance (i.e., jumping) [30]. Therefore, the combination of exercises with loads using 80% of 1RM, as well as loaded jumps using a percentage of the participants' BM, may have caused more optimal adaptations in both specific and non-specific dance jumps (*sauté* and CMJ, respectively).

Despite the kinetic and kinematic differences between CMJ, SJ and *sauté* [22], our study supports the use of supplementary training based on plyometrics and strength training to improve *sauté* performance. In our study, the CTr group for male and female dancers showed a higher ES than the PT group in the pre- vs post-test comparison. Although the turnout position is not the conventional resistance training technique, used for exercises with loads such as back squats or loaded jumps, this study confirms the positive effect of lifting weights in a standard position on *sauté*. Moreover, our findings suggest that non-ballet specific testing (CMJ and SJ height) are appropriate for ballet dancers if only jump height is of interest.

One strength of our study lies in including professional ballet dancers. This is especially relevant regarding the male dancers, due to the limited number of studies observing this population [19]. Also, this study suggests that as little as two sessions (1 hour each) of supplementary training such as PT or CTr provides a significant improvement on *sauté*. However, our investigation also has limitations that must be considered. The transference of improved CMJ and SJ to a specific jump action such as *sauté* was observed from the perspective of performance. However, it may be interesting to observe the impact of this improvement on subjective or qualitative dance performance [1,2,13,34]. Although the validity and reliability of the contact mat used in our study have been reported [27], the use of a force platform would be more optimal, due to being considered the gold standard to measure jump height. In addition to the above, it is important to point out that progressive overload in volume or intensity was not applied to the experimental groups, even so, large changes were observed in the height of the CMJ. The prescription of exercises based on 1RM were not adjusted within the 9 weeks of intervention, and the groups were self-selected instead of randomized.

PRACTICAL APPLICATIONS

The findings of this investigation may be relevant for classical dancers and S&C coaches, due to the large number of vertical jumps that are part of ballet choreographies [5,34]. This study supports the use of combined and plyometrics training programs as effective methods for improving specific (*sauté*) and non-specific dance jumps (CMJ and SJ).

Conclusion

Plyometric and combined training programs are effective ways to improve jumping ability in female and male ballet dancers. The improvement in CMJ and SJ has a positive transference to an essential dance skill such as *sauté*.

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PT	1st Session (Tuesdays)		2nd Session (Fridays)	
	Exercises	**Sets/repetitions**	**Exercises**	**Sets/repetitions**
	Horizontal SJ	3x10	Single leg SJ	3x10 each leg
	Single leg CMJ	3x10 each leg	Sidestep up + Drop SJ	3x10 each leg (F40-M50cm)
	Box SJ	3x10 (F40-M50cm)	Box CMJ	3x10 (F40-M50cm)
	Step up + Drop CMJ	3x10 each leg (F40-M50cm)	Drop CMJ	3x10 (F40-M50cm)
CTr	**1st Session (Mondays)**		**2nd Session (Thursdays)**	
	Exercises	**Sets/repetitions/Training load**	**Exercises**	**Sets/repetitions/Training load**
	Leg press	3x8 (80%1RM)	Back-Squat	3x8 (80%1RM)
	Deadlift	3x8 (80%1RM)	CMJ	3x8 (80% BM)
	Leg Curl	3x8 (80%1RM)	Leg extension	3x8 (80%1RM)
	SJ	3x6 (80%BM)	Single leg CMJ	3x6 (10% BM)

Table 1: Training programs followed by both intervention groups; Plyometric training (PT) and Combined training (CTr). Box height in females set at 40cm (F-40) and 50cm in males (M50).

	Variables	Pre	Post	P	95%C.I.	E.S.
CG♀	**CMJ (cm)**	30.9±2.6	29.6±2.3	***0.04****	-1.28±0.22	0.52 (S)
	S.J. (cm)	27.2±2.7	26±2.5	***0.05****	-1.21±0.28	0.46 (S)
	***Sauté* (cm)**	29.5±2.6	28 ±2.4	0.1	-1.35±0.15	--
PT ♀	**CMJ (cm)**	31.2±2	33.4±2.5	***0.03****	0.21±1.72	0.97 (M)
	S.J. (cm)	28±2.3	30.3±2.6	***0.03****	0.16±1.67	0.91 (M)
	***Sauté* (cm)**	30.1±2.9	31.6±2.3	***0.03****	0.12±1.34	0.61 (M)
CTr ♀	**CMJ (cm)**	31±2.3	34.7±2.9	***0.01****	0.52±2.3	1.41 (L)
	S.J. (cm)	28.1±2.4	31.2±2.6	***0.01****	0.36±2.11	1.23 (L)
	***Sauté* (cm)**	29.8±2.7	31.9±2.5	***0.02****	0.02±1.63	0.80 (M)
CG♂	**CMJ (cm)**	50.2±3.1	49.9±3.6	0.7	-0.90±0.71	--
	S.J. (cm)	47.4±3.4	47.3±3.5	0.8	-0.80±0.77	--
	***Sauté* (cm)**	49.1±3.3	48.4±3.6	0.5	-1±0.60	--
PT ♂	**CMJ (cm)**	51±2.7	53.6±3.4	***0.03****	0.02±1.70	0.84 (M)
	S.J. (cm)	47.7±3.3	50.1±3.5	***0.04****	0.15±1.56	0.70 (M)
	***Sauté* (cm)**	49±3.7	52.1±3.4	***0.02****	0.00±1.74	0.87 (M)
CTr ♂	**CMJ (cm)**	50.8±2.2	54.3±3.1	***0.01****	0.56±2.04	1.30 (L)
	S.J. (cm)	47.6±3	50.9±3.4	***0.02****	0.31±1.74	1.02 (M)
	***Sauté* (cm)**	49.3±3.3	52.3±3.2	***0.02****	0.21±1.63	0.92 (M)

Table 2: Mean ± S.D., p-values ($p \leq 0.05$), 95% confidence intervals (95% C.I.) and effect size (Small-S, Medium-M, Large-L and very large-VL) for jumping performance in female (♀) and male (♂) dancers in control group (C.G.), plyometric group (PT) and combined training group (CTr). The presented variables are defined as countermovement jump (CMJ), squat jump (S.J.) and *sauté* in first position (*sauté*). Statistically significant differences are denoted in bold an *.

Group		Δ- *Sauté*	R^2
PT♀	**Δ-CMJ**	0.82 (VL)*	0.67*
	Δ-SJ	0.79 (VL)*	0.62*
CTr ♀	**Δ-CMJ**	0.88 (VL) *	0.78*
	Δ-SJ	0.78 (VL) *	0.61*
PT♂	**Δ-CMJ**	0.85 (VL) *	0.72*
	Δ-SJ	0.77 (VL) *	0.59*
CTr ♂	**Δ-CMJ**	0.88 (VL) *	0.78*
	Δ-SJ	0.83 (VL) *	0.68*

Table 3: Pearson's correlation ($r \leq 0.1$ = trivial, > 0.1 – 0.3 = small, > 0.3– 0.5 = moderate,> 0.5 – 0.7 = large,> 0.7– 0.9 = very large, > 0.9 – 1.0 = almost perfect) and coefficient of determination (R^2), between the magnitude of improvement for CMJ height (Δ%-CMJ) and SJ (Δ%-SJ) height with the magnitude of improvement for *sauté* (Δ%- *Sauté*) in female (♀) and male (♂) dancers for the plyometric training group (PT) and combined training group (CTr). Associations statistically significant ($p \leq 0.05$) denoted in bold an *.

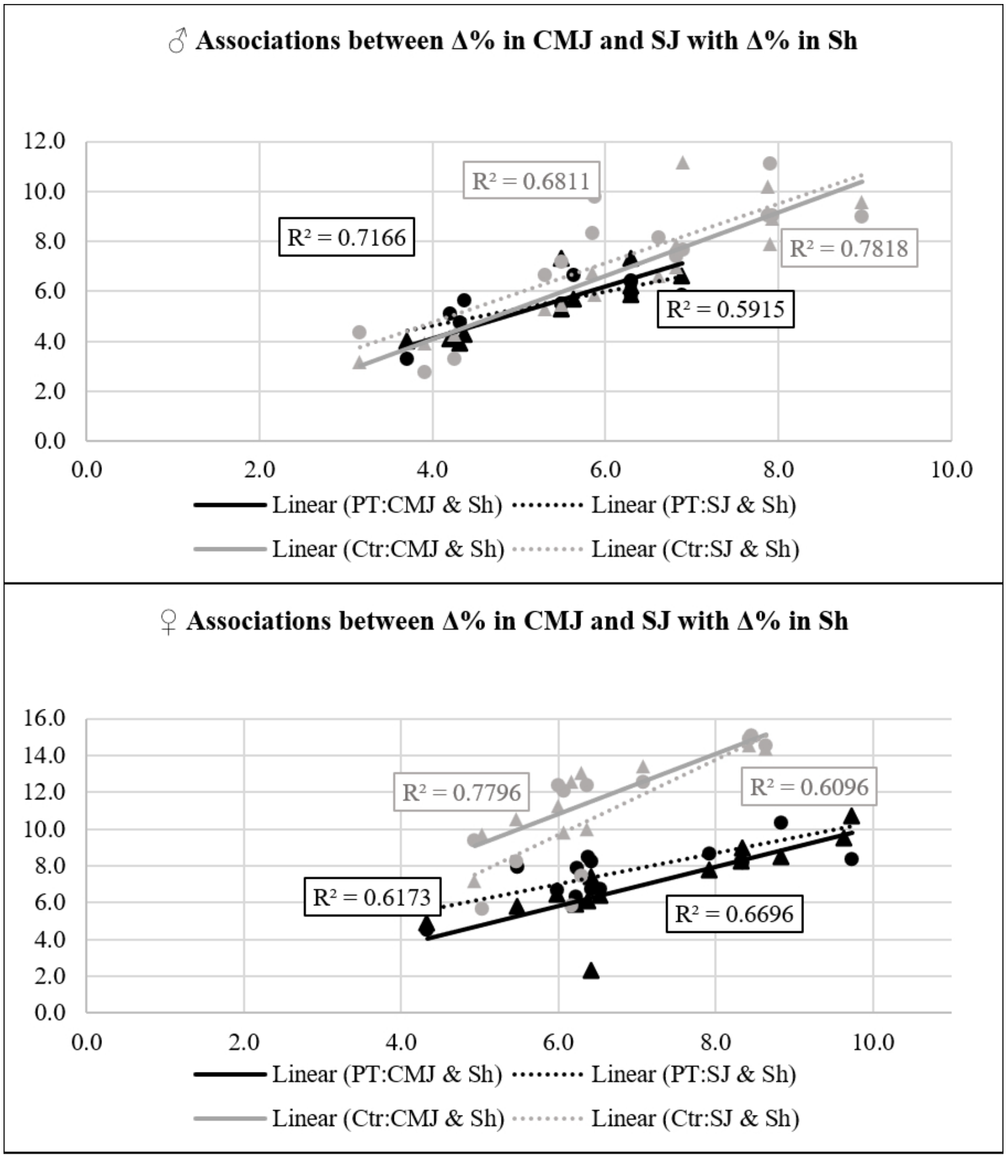

Figure 1: Coefficient of determination between the magnitude of improvement for CMJ height (Δ%-CMJ) and SJ (Δ%-SJ) height with the magnitude of improvement for sauté (Δ%- Sauté) in female (♀) and male (♂) dancers for the plyometric training group (PT) and combined training group (CTr).

605x697mm (38 x 38 DPI)