The effects of Whole Body Vibration training on Vertical Jump height in Dancers: a systematic review with meta-analysis

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KEY-WORDS: Dancing; Athletic Performance; Ballet.

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ABSTRACT: Dancers must be strong and flexible for a balanced body and great performances. However, dance training and fitness methods are quite divergent between dance styles, dance coaches and teachers. It was verified in the scientific literature that whole-body vibration (WBV) training can improve the vertical jump height (VJH) for dancers from different styles when compared to other interventions or no intervention. The purpose of this study was to verify the effects of WBV training on VJH in dancers, compared to other interventions or no intervention, in randomized controlled trials (RCTs), through a systematic review with meta-analysis. The search used the databases MEDLINE, LILACS, Cochrane, PEDro, Psycinfo and Google Scholar (Between 1985-Septemper 2019). RCTs that analyzed the effects of WBV training on vertical jump height in dancers, compared to other models of training or no intervention, were included. Four studies met the eligibility criteria; fifty-six were excluded. The data from the selected studies were extracted by two independent and blinded reviewers. Four RCTs that assessed 84 participants in total, were included. WBV training promoted significant improvements in VJH, compared to other interventions such as intense stretching, or extra dance classes. WBV training proved to be beneficial even with a short time intervention.

KEY-WORDS: Dancing; WBV; Athletic Performance; Ballet.

Introduction

Dancers need muscular strength and flexibility to perform (Koutedakis et al., 2007; Twitchett et al., 2011; Angioi et al., 2012), and need to combine their technical expertise with an excellent physical condition (Koutedakis & Sharp, 2004). However, many dancers consider themselves as artists, not athletes, prioritizing artistic perfection to physical training (Koutedakis & Sharp, 2004; Wyon, Smith & Koutedakis, 2013). Although dance requires extensive physical effort, dance classes do not always provide sufficient training stimulus to prepare dancers for the physical demands of performance (Roussel et al., 2014; Wyon, et al. 2004), as the main focus is on technique.

Poor aerobic capacity, lower muscular strength and altered motor control are factors considered as contributors to musculoskeletal injuries in dancers (Riding McCabe et al., 2014; Twitchett et al., 2011; Angioi et al., 2012). However, recently, physical training has gained importance because it helps prevent musculoskeletal injuries and improves technique for dance professionals (Guidetti et al., 2008).

Traditionally, dancers perceive that dance class provides enough stimulus to physically prepare them to perform (Roussel et al., 2014; Wyon, et al. 2004). Although, as the physical demands of dance increase, and as dancers are asked to perform movements with more power, bigger ranges of motion and faster speed, they cannot rely on technique classes alone. Adequate supplementary training programs improve dancers' fitness elements of body composition, cardiorespiratory efficiency, and muscular strength (Koutedakis et al., 2007; Koutedakis & Sharp, 2004). On this way, supplementary training programs are becoming more and more necessary to improve dancers' physical capacities, in both small and large companies, as they are challenged to keep up with the technical demands of artistic directors and choreographers alike.

Jumping is an integral aspect of dance performance (Koutedakis & Sharp, 2004). A number of studies have shown that different interventions have beneficial effects on vertical jump height (VJH) in dancers. Annino et al. (2007) used an eight-week whole body vibration (WBV) training intervention resulting in significant increases in VJH for the experimental group. Lorrenzzetti & Morales (2014) used a plyometric training intervention that significantly improved jump height.

WBV has been described to produce gravitational acceleration changes similar to those of power and strength training, reported to improve muscular power of upper and lower musculature (Cardinale & Bosco, 2003). The major documented benefit of this kind of training is explosive strength performance, usually considered as VJH (Bosco et al., 1998). Additionally, WBV training protocols require only a limited amount of time and very limited specific skills to be performed (Cardinale & Bosco, 2003).

The use of WBV has become increasingly common as a training method for enhancing dancer's VJH (Anino et al., 2007; Wyon, Guinan & Hawkey, 2010; Marshall & Wyon, 2012; Angioi et al., 2012). Even so, most of the studies are about the effects of WBV training on the VJH in ballet and modern dance, and there is a lack of research, including clinical trials, in the last 8 years.

Thus, the present systematic review aims to verify the effects of WBV training on the VJH in dancers, compared to other interventions or no intervention, in randomized controlled trials (RCTs), through a systematic review with meta-analysis. This systematic review with meta-analysis is intended to help dancers, choreographers and dance teachers understand more about the benefits of WBV for dancers and how it can be integrated into dance training routines.

Methods

This study is a systematic review with meta-analysis design to investigate the effects of WBV training interventions on the VJH in dancers.

Eligibility Criteria

RCT's included in this systematic review were those that compared WBV training intervention, for at least three weeks, with either another group exposed to another exercise protocol or a control group in dancers of any dance style, gender or age that analyzed VJH.

Study Search and Selection Strategy

The studies were identified from the databases MEDLINE, LILACS, Cochrane, PEDro, Psycinfo and Google Scholar. Search for articles was conducted in September 2019. The search did not restrict languages or periods. The MeSH terms "Dancing", "WBV" and "Jump" were used in the study search.

The selection of the studies was done in two phases, by two independent and blinded reviewers. Firstly, with the reading of the titles and abstracts, the studies that did not present dancers as population, WBV as intervention and were not RCTs were excluded. In the second phase the reviewers, still blinded and independent, read the full texts of the studies included in the first phase and evaluated whether they presented the eligibility criteria for the review through a table with 5 items produced by Cochrane, and filled independently by the two reviewers (Higgins & Green, 2008). In the last phase of the selection, each time there was disagreement between the two reviewers, the evaluation was made by a third reviewer.

Data Extraction and Risk of Bias

The data extraction was also conducted by two independent and blind reviewers, that verified the methodological characteristics of the studies included, such as: title, authors and date, objectives, design, type of intervention, frequency and duration of classes, sample number, gender, age, follow-up, comparators between groups and the evaluated outcome (VJH - Just Jump Test).

All included studies were assessed for risk of bias by two reviewers, independently and blindly, in a table proposed by Cochrane (Higgins & Green, 2008) with title, authors and date, randomization, random sequence generation, secrecy of allocation, blinding of patients and therapist, blinding of outcome assessors, description of losses and exclusions (with flowchart), intent to treat. Each study could score a maximum of five criteria. They were defined as high risk of bias: less than 3 points; low risk of bias: more than 4 points; or risk of bias not clear: more than 3 indefinite points (Higgins & Green, 2008).

Data Synthesis and Data Analysis

We conducted a meta-analysis for the continuous outcome VJH in RCTs that compared WBV training with another exercise intervention. Estimates were computed from the changes in the scales between the beginning and end of the intervention, their standard deviations (SDs) and the sampled "n". Authors of the clinical trials were contacted via e-mail and undeclared data was provided, if available. If SD values were not available or not provided in the e-mails, the numbers pre- and post-intervention of the studies were allocated, due to the similarity between the pre-intervention groups and baseline values. The results are presented as SDs and calculations were performed using continuous effects models, since the heterogeneity was 0%. The statistical heterogeneity of treatment effects between studies was assessed by the Q test and p inconsistency of Cochrane; Forest Plots were generated to show the com-

bined effect and mean difference (MD), calculated with a 95% confidence interval. All analyses were performed using Review Manager version 5.3 (Cochrane Collaboration).

Results

From the 144 articles identified in MEDLINE, LILACS, Cochrane, PEDro, Psycinfo and Google Scholar databases, after removal of duplicates, 90 studies remained. Of these, after the reading of titles and abstracts, 48 articles were excluded for not having dancers as participants or because they were not RCTs. The 12 studies selected on phase 1 were fully read, and then, 8 were excluded for not meeting the eligibility criteria. Four RCTs were included, which were in accordance to the eligibility criteria of this research.

Figure 1 shows the flowchart of the studies included in this review.

(INSERT FIGURE 1 HERE)

Characteristics and Description of Included Studies

The four studies included in the review compared a WBV training intervention group with a group that performed another type of exercise or with a group not exposed to any intervention other than regular dance classes. A total of 84 dancers participated in the studies, 42 in the intervention groups and 42 in the comparator groups.

Table 1 summarizes the characteristics of the 4 RCTs included in this review, presenting: characteristics of the trainings and participants, interventions versus comparators, and analyzed outcomes.

(INSERT TABLE 1 HERE)

Angioi et al. (2012) included WBV and resistance training in their study. The training consisted of a one-hour-long circuit, twice a week, for six weeks. The intervention group (IG) was compared to a control group (CG) with the same sample number of dancers who practiced one more hour per week of contemporary dance during the same period. The training circuit focused on local muscle endurance and aerobic conditioning, and the WBV protocol, on muscle power. As a result, there were significant increases in the intervention group of lower limb muscle power, upper limb muscle endurance and aerobic fitness, among others.

Annino et al. (2007) analyzed the effect of eight weeks of WBV training on VJH in elite adolescent dancers. The intervention consisted of WBV training three times a week, always done before ballet practice. During the training period, the IG and CG undertook the same amount of ballet practice. After the intervention period, the 11 participants in the IG significantly increased their VJH and power ($p < 0.001$).

Marshall and Wyon (2012) studied the effects of four weeks of WBV training were investigated on 17 pre-professional female dance students. They assessed jump height, active ROM and legs anthropometry. The training consisted of 30 seconds per position at a frequency of 35 Hz, displacement of 8 mm in the first two weeks and 40 seconds at 40 Hz in the last two weeks. Nine positions were used on the platform: a narrow and wide semi squat (first and second position, in plié, respectively), high toe rise, pelvic bridge, pelvic bridge with the back on the floor and feet on the platform, right leg leading lunge, a bent-over hamstring hold with a 90º angle between the torso and the legs, and a active hip flexor exercise (*développés)* on each leg. The control group performed the same exercises, but without vibration. The IG showed improvement in the VJH ($p < 0.01$) and active ROM, but no significant difference was reported for anthropometric data (leg girth measurements).

Finally, a study performed a six-week intervention, with 18 university dancers, dividing them into control and intervention group (Wyon, Guinan & Hawkey, 2010). The IG carried out 2 sessions a week for 6 weeks of static-position WBV training with 2 rest days between the sessions. They held each position twice for 30 seconds at a frequency of 35Hz and amplitude of 4mm. The positions were: demi-plié in first position, right leg leading lunge (with just the foot on the platform), left leg leading lounge, high toe raise (maximal plantar flexion) and bent over hamstring hold (legs remained straight and the torso bent over from the waist more than 90º). The CG was exposed to a similar isometric contraction stress. The results showed a significant improvement in VJH ($p < 0.05$) in the IG. The power of lower limbs was assessed by a vertical jump, in which the participants, bare feet, started it off standing in ballet first position on a digital vertical jump meter (Takei Yashiroda, Japan). Afterwards, they performed a demi-plié and immediately jumped as high as possible, keeping heels together, externally rotated hips and pointed feet. The IG showed a significant improvement in VJH ($p < 0.001$).

Risk of Bias and Methodological Quality

Three studies were defined as high risk of bias (less than 3 points): Annino et al. (2007); Marshal & Wyon (2012); and Wyon, Guinan & Hawkey (2010). One study presented an unclear risk of bias (between 3 and 4 points): Angioi et al. (2012). The four RCTs found to be eligible, all were randomized, but only two presented adequate randomization sequence generation and reported allocation concealment: Angioi et al. (2012), and Wyon, Smith & Koutedakis (2013). Two described their losses and exclusions: Angioi et al. (2012), and Wyon, Smith & Koutedakis (2013). None of the studies blinded patients and therapists, because in studies with practical interventions, such as those looking at dance technique classes, this blinding is not feasible.

The methodological quality and risk of bias of the included studies are presented in Table 2.

(INSERT TABLE 2 HERE)

Analyzed outcome for WBV: VJH

Meta-analysis was performed only for the VJH outcome, with the only two studies that presented a similar methodology. The graph of the meta-analysis can be seen in Figure 2.

(INSERT FIGURE 2 HERE)

The Figure 2 presents the VJH measures in the two RCTs (Marshall & Wyon, 2012; Wyon, Guinan & Hawkey, 2010) that used the Vertical Jump Mat test, applying it to a total of 38 participants. The results showed significant improvements in favor of the IG, exposed to WBV training, that presented a better result in the test (6.52 cm, CI = 3.31 to 9.73 cm, p = 0.00001). The results showed, with 0% heterogeneity (p = 0.88), significant improvements in favor of the intervention with WBV training, which was conducted concomitantly with the regular dance practices of the sample, demonstrating the effectiveness of this type of training to improve the VJH in dancers, with a difference of -1.15 confidence interval between -2.03 and 0.27 and a statistically significant value p <0.0001.

Discussion

223 The aim of this systematic review was to verify the effects of WBV training on the
224 VJH in dancers, compared to other interventions or no intervention. The findings of the stud-
225 ies included in this review showed that WBV training presented better responses in dancers'
226 VJH than other types of training interventions, such as: stretching exercises, other styles of
227 dance classes or increased hours of regular dance classes.
228 It was detected, after 8 weeks of WBV training, performed three times a week before
229 the ballet practice, a significant increase in VJH in the IG (Annino et al., 2007). WBV training
230 is effective in increasing VJH even with very low volume and intervention time (e.g.: only ten
231 minutes per week for six weeks) (Wyon, Guinan & Hawkey, 2010). WBV intervention was
232 beneficial in shorter intervention periods (4 weeks) and in better-conditioned dancers, which
233 makes this type of training very effective for this population (Marshall & Wyon, 2012). These
234 findings are of great relevance, since improved vertical jumping helps dancers develop their
235 technical skills, facilitates a wider variety of movements and contributes towards a longer ca-
236 reer, due to the lower risk of injuries.
237 Twitchett et al. (2011) suggests that larger samples would provide better analysis of
238 the effects of WBV training in dancers. Other authors also suggest that a six-week follow-up
239 already showed effective results for this population (Wyon, Guinan & Hawkey, 2010; Angioi
240 et al., 2012). Studies suggest supplemental training should be of short duration and adapted to
241 the high-volume schedules of dancers, as otherwise there is a potential risk of overtraining
242 (Koutedakis, 2000; Wyon, 2010). Nevertheless, with a few hours of training per week, a very
243 positive result was observed in the VJH, which presented significant increases in all studies
244 included on this review.
245 In order to improve dance technique, on a daily basis, dancers often perform exercises
246 that may become harmful if over-repeated. If prescribed correctly, WBV training is capable to
247 improve VJH (Koutedakis et al., 2007; Wyon, 2010; Angioi et al., 2012; Marshall & Wyon,

2012). However, physical supplemental training is only beneficial when practiced on a regular basis. Therefore, dance companies, choreographers, dancers and related professionals should look at how physical supplemental training can be integrated into their present schedules, as they have proven to be essential in promoting benefits for this population. Hence, in order to be able to exercise and continue to improve their aesthetics and performance, dancers can use WBV, and not only artistic or technical training (Marshall & Wyon, 2012).

Furthermore, to play an effective role in helping dancers, a supplementary training program should include specific activities to support their training technique. Such a program could focus on prime and synergist muscles, with the aim of balancing antagonistic pairs and developing the posterior muscle chain.

Study limitations

Although this systematic review with meta-analysis was performed with the maximum methodological rigor possible, some limitations should be highlighted. The main difficulties for the eligibility of the studies were: lack of randomization; very different evaluative instruments and, in some studies, instruments created specifically for that research; lack of clear methodology; and lack of specificity about details of clinical trials, even when further explanations were received via email.

In relation to the studies included in this systematic review, we found the majority of the intervention protocols did not provide sufficient details to be replicated. Moreover, the included studies used a wide variety of measuring instruments and methods. This situation makes it difficult to evaluate methodological quality and study bias risks. Regarding interven-

tion intensity, which is a key parameter, we found it was sometimes omitted or presented in a non-standard form, in either relative or absolute terms.

Conclusion

The results of the present study showed that WBV training is an effective short-term methodology to induce improvements in dancers VJH when comparing with other types of training interventions. According to the data presented in this study, it is important to include a specific supplementary training program in the dancers' routine to improve their physical capacities and to prevent injuries, enhancing their technical skills, facilitating a wider variety of movements and contributing towards a longer career. Another important finding from the study is that a few hours of WBV training per week provided a very positive result in the VJH.

Nevertheless, we would like to highlight that there is a scarcity of conclusive evidence due to the lack of research in this area. The lack of methodological detail in the selected studies, the diversity of intervention types and assessment methods undermine the analysis in this systematic review.

Therefore, there is a need to conduct more research and establish some methodological guidelines for future RCTs. It is suggested that more RCTs need to be conducted to investigate the effects of WBV training on VJH, studying other dance genres (not only ballet or modern dance) with more scientific rigor.

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371 **Table 1 - Summary of study characteristics**

STUDY	CHARACTERISTICS	PARTICIPANTS	INTERVENTION	OUTCOMES
Angioi et al., 2012	Period: 6 weeks IG: 2x week: 1h of training exercises CG: 2x week: 1h more of contemporary dance	24 contemporary dancers Gender: F Age: 27 ± 5.9 IG: n=12 CG: n=12	Strength Training and WBV in circuit versus Contemporary Dance	Anthropometry, Body Composition, Muscle Power, Upper musculature Resistive Strength, Aerobic conditioning (Tests + Choreographic Sequence)
Annino et al., 2007	Period: 8 weeks IG: 3x week - WBV training CG: 5x week - 1.30hofclassical ballet	22 elite classical dancers Gender: F and M Age: 21.25 ± 1.5 IG: n=11 CG: n=11	WBV vs. Classical Ballet Training	VJC; Knee extensor performance in selected external loads (50, 70 and 100 kg)
Marshal & Wyon, 2012	Period: 4 weeks IG: 2x week - 30s per position in freqs. 35Hz (4 sessions) and 40s per position at 40Hz (4 sessions). CG: 25h of classes + rehearsals per week	20 dance conservatory pupils Gender: F Age: IG (22 ± 1.17); CG (25 ± 5.92) IG: n = 10 CG: n = 10	WBV vs. Modern Dance Training	Jump height; Active range of motion of the hip *(développé* height); Anthropometric variables of the legs
Wyon, Guinan & Hawkey, 2010	Period: 6 weeks IG: 2x WBV at 35 Hz for 5 minutes CG: Similar isometric contraction stress, but without vibration	18 dance graduate students Gender: F Age: IG (19 ± 0.78); CG (21.1 ± 0.67) IG: n=9 CG: n=9	WBV Training versus Strength Training	VJC

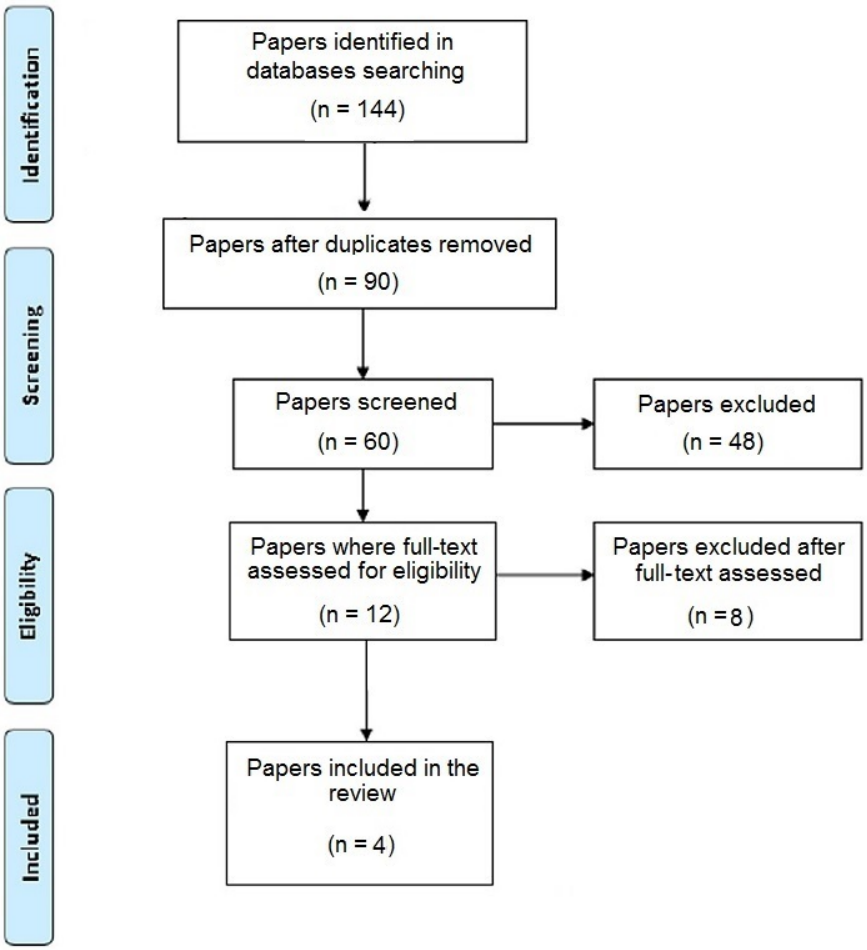
372 *** Legend:** CG = Control Group; IG = Intervention Group.

373 **Table 2 - Methodological Quality Assessment**

Author/ Year	Generation of random sequence	Concealment of Allocation	Blinding of Patients and Therapists	Blinding of Evaluators	Description of Losses and Exclusions	Intent to Treat	TOTAL
Angioi et al., 2012	Y	Y	N[1]	NI	Y	NI	**3**
Annino et al., 2007	NI	NC	N[1]	NI	N	NI	**0**
Marshal and Wyon, 2012	NI	NC	N[1]	NI	N	NI	**0**
Wyon, Guinan and Hawkey, 2010	NI	NC	N[1]	NI	N	NI	**0**

374 ***Legend:** Y = Yes; N = No; NC = Not clear; NI = Not informed; N[1] = This parameter will not be taken into account.

Figure 1 - Flowchart diagram of articles selection process



388 **Figure 2 - VJH Meta-analysis**

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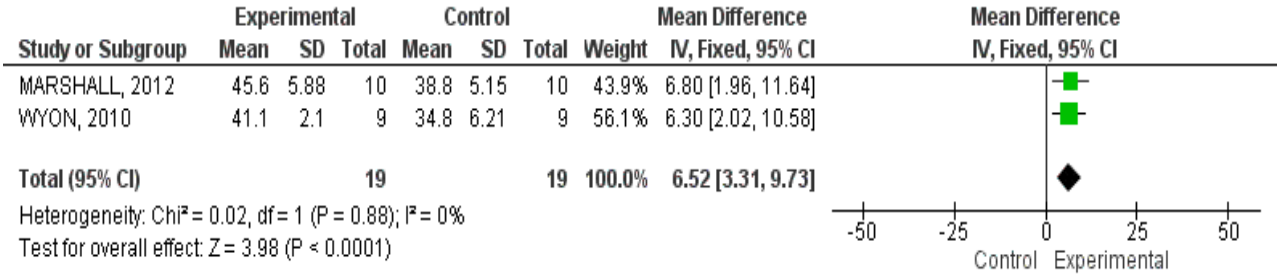

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