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Title: The effect of Whole Body Vibration on jump height and active range of movement in female dancers

Short Title: WBV, VJ and AROM in female dancers

Article Type: Original Investigation

Keywords: Vertical jump; dance; active flexibility; whole body vibration

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Abstract: Whole-body vibration (WBV) has been shown to have beneficial effects on strength and power indices in sedentary and moderately trained individuals. The aim of the present study was to investigate the effect of 4 weeks WBV on jump height, active range of motion and leg anthropometry in conservatoire dance students. 17 female dancers were randomly assigned to a control or intervention group. The intervention group trained for 30 seconds per position at 35Hz frequency, 8mm displacement in the first 2 weeks, and 40 seconds at 40Hz for the final two weeks whilst the control group carried out the same exercises but without vibration stimulation. A significant ($p < 0.01$) difference in the intervention group was noted over time for vertical jump and active ROM. No significant changes over time were noted for the anthropometric data. In conclusion WBV can be used as a beneficial supplemental training intervention to increase jump and active flexibility in highly trained dancers without corresponding increases in relative anthropometric data.

Response to Reviewers: JSCR-08-1377, entitled "The effect of Whole Body Vibration on jump height and active range of movement in female dancers"

Reviewer #1:

Interesting paper. Some brief questions for consideration.

How did you determine time (sec) at each position on the platform? Was this based on previous literature?

Au: yes this was based on previous literature and the references have now been provided.

Also how did you determine what frequency (Hz) to set the platform at? Again, was this a collaborative decision or based on previous literature?

Au: yes this was based on previous literature and the references have now been provided.

Pictures of the positions (the ones performed on the platform) would be helpful and add conceptualization to the article.

Also, the exercises used (positions) on the platform seem understandably chosen, but adding why you choose those specific positions would be relevant.

Au: this detail has now been added.

Reviewer 2

The introduction while interesting should be clear and concise and be hypothesis driven to allow the reader to see the basis of your hypothesis. I do not get the time frame for adaptation is this all neural and warm up?

Au: the introduction has been re-written to be more clear and concise. The reason for the time frame is that shorter intervention periods are rarely looked at especially in trained individuals and we have seen significant improvements from WBV using 4 week interventions on FAI subjects in previously published research. The concept of neural adaptation is only applicable to untrained subjects for initial adaptations to "strength" training.

Why is this study important to the literature and what was the major question that led to the study and how would it impact practice if published.

Au: a lot of previous studies have assumed that all interventions should be 6 weeks and 3 x a week without challenging this concept - hence our use of 4 weeks at 2 x a week. Also a lot of previous research has used sedentary or untrained subjects and the noted adaptations can't truly be applied to trained subjects - this study has looked to see if the adaptations we see in untrained subjects are also seen within trained subjects.

The methods need to be pristine so that the study can be replicated as to each independent and dependent variable.

Au: this has been reviewed and improved.

You need to check formatting guidelines and Instructions to Authors very carefully.

Au: this has been reviewed

What about controls for such things as time of day, hydration status, nutritional intakes, activity profiles etc.

Au: subjects were in the same year and completed the same training. All testing was standardised for time of day and activity exposure (as mentioned in text).

The approach to the problem is so important as to the rationales for the study and its dependent and independent variables. Expand

Au: this section has been improved

What was the test retest reliability e.g., ICCRs SEM and confidence intervals, not sure the statistical section is very informative and you need some work here with your statistical consultant. Usually $P < 0.05$ is significant.

Au: we have added ICCRs and added figures to illustrate the statistics. Significance, as stated at $p < 0.05$ but when meets $p < 0.01$ critical this is reported. The authors are not sure what the reviewer means by our statistics not being informative as they clearly state where significant changes exist.

Subject informed consent has very specific wording per author guidelines and this needs to be double checked.

Au: the article has reported that the study underwent ethical clearance and all subjects completed informed consent and a pre-test medical questionnaire

You really need to look at the writing tips for the JSCR and make sure every section of the paper contains needed information etc.

Au: this has been completed

What is the training background coming into the study and what time of year etc were they tested.

Au: more information has been provided on this

The clarity of the paper needs to be improved a bit through out the whole paper.

Au: hopefully this has been achieved now

The discussion needs to better reflect the introduction and show the answers to the questions raised and allow the reader to see what it means in context to the literature and as well physiologically or mechanically. i work with dancers and you want me to use WBV,, what about weight training and conditioning we use and what else do you do as this is not a primary modality and this is the message I am worried about you sending as I work with top dancers at an American Theater company... So you have a responsibility to put this into context and properly portray it... not sure you have at this point.

Au: A member of the team have worked with elite dancers for the last 20 years as strength and conditioning trainers and there is very little published evidence for the majority of interventions strategies used on dancers, especially Pilates for instance. We use vibration training with 3 international touring ballet companies as we can get the visible improvements in dance performance with minimal intervention time using WBV (and circuits). We have found WBV to produce quality sessions without a time issue. Again previous research has often been too traditional in its approach (3x wk training sessions) which is impossible to implement within a professional dance company setting - hence the present study has shown significant improvements can be achieved with minimal intervention as this also allows for the training the dancers are already exposing their bodies to through more traditional sessions of dance class and rehearsal. See Twitchett E, Angioi M, Koutedakis Y, and Wyon M. Do increases in selected fitness parameters affect the aesthetic aspects of classical ballet performance. *Med Probl Perform Artists* 26: 14-17, 2011.

The practical applications are for the coach or end user and needs to be clearer. After reading this study I will change my practice how? Based on what, how does your study enhance this for the reader? This is the whole purpose of this section. Again per above comments and see work in the JSCR on this topic.....

Au: this has been significantly updated and now provides the required information

The effect of Whole Body Vibration on jump height and active range of movement in female dancers

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The effect of Whole Body Vibration on jump height and active range of movement in female dancers

ABSTRACT

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4 Whole-body vibration (WBV) has been shown to have beneficial effects on strength and
5 power indices in sedentary and moderately trained individuals. The aim of the present study
6 was to investigate the effect of 4 weeks WBV on jump height, active range of motion and leg
7 anthropometry in conservatoire dance students. 17 female dancers were randomly assigned to
8 a control or intervention group. The intervention group trained for 30 seconds per position at
9 35Hz frequency, 8mm displacement in the first 2 weeks, and 40 seconds at 40Hz for the final
10 two weeks whilst the control group carried out the same exercises but without vibration
11 stimulation. A significant ($p<0.01$) difference in the intervention group was noted over time
12 for vertical jump and active ROM. No significant changes over time were noted for the
13 anthropometric data. In conclusion WBV can be used as a beneficial supplemental training
14 intervention to increase jump and active flexibility in highly trained dancers without
15 corresponding increases in relative anthropometric data.
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28 **KEY WORDS:** Vertical jump, dance, flexibility, whole body vibration
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2 INTRODUCTION
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4 Dance is possibly the most physical art form and its participants require high levels of skills
5 underpinned by physical fitness levels similar to moderately trained individuals (1, 9, 21).
6 Recent studies have shown a link between certain physical fitness attributes and the artistic
7 aspects of classical ballet and contemporary dance performance (2, 29). These are active
8 range of movement in the lower limbs (développé height), vertical jump height and upper
9 body muscular endurance, though the authors point out that the optimum physical fitness
10 attributes will vary according to the choreography. The training and performance schedules
11 of professional dancers (30-38 hours a week) often allows little time for supplemental training
12 (1) and increased hours could potentially lead to overtraining (20, 22, 31).
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21 The use of Whole Body Vibration (WBV) as a training modality has received much attention
22 in exercise science (25). Overall it appears the literature demonstrates a positive effect of
23 WBV on jumping performance with several short term cumulative effect studies (10 days-8
24 weeks) have noted improvements in jump height (4, 6, 7, 13, 15, 26, 33) whilst a few have
25 noted no improvements (11, 12, 23). In relation to dance training the studies by Wyon and
26 colleagues (33) and Aninno and colleagues (4) both noted increases in jump height as well as
27 no significant changes in leg anthropometry and significant increases in knee extensor
28 strength respectively. The lack of anthropometric change is very important within dance as
29 muscle bulk, especially within females, is undesirable aesthetically. There are no published
30 studies that have measured the effect of WBV on active flexibility. The psoas has been noted
31 to play a major role in a développé à la seconde (16, 17, 27) and Gilsanz and colleagues (14)
32 suggest that WBV is effective in developing hip musculature, including the psoas.
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44 The purpose of this investigation was to measure the effects of 4 weeks WBV on jump
45 performance, active range of movement around the hip and leg anthropometry in a female
46 dance population.
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51 METHODS
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53 Experimental approach to problem
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56 This study was a randomized, controlled experimental design. The study was designed to
57 replicate a realistic supplementary training program for dancers with heavy schedules and
58 therefore involved only 2 intervention sessions per week. Jump height, active range of
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1 motion of the hip (développé height) and anthropometric variables were tested pre and post a
2 4 week intervention period.
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6 Subjects

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9 20 subjects were recruited for the study, all subjects were given a verbal and written
10 explanation of the training and testing procedures as well as possible risks or discomfort
11 associated with training and testing. Subjects were excluded if they had a soft or bone injury
12 within the past 2 months that compromised their dance activity. All gave written consent and
13 completed a medical Par-Q before beginning the study. The study gained ethical approval by
14 the institution's ethics committee. Summarised subject data is displayed in table 1.
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21 ***** Table 1 approximately here *****
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24 Subjects were final year full time students on an undergraduate or one-year program at a
25 conservatoire modern dance school completing approximately 25 hours dance technique and
26 rehearsal a week in the second term. Both intervention and control groups continued with
27 their regular scheduled dance classes and rehearsals throughout the study and were asked to
28 complete no additional resistance, strength or power training over the 4 week testing period.
29 Intervention and control groups both completed the same amount of training.
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36 Procedures

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39 Subjects underwent a familiarisation period before tests were conducted. Subjects completed
40 a uniformed warm up before testing and training consisting of 5 minutes of aerobic
41 choreographed activities maintaining their heart rate intensity between 120 and 160 b.min⁻¹, 2
42 minutes of dynamic stretching of the quadriceps, hamstrings and calf muscles followed by a 2
43 minute rest prior to testing. Post intervention testing was carried out 2 days after the
44 intervention period to avoid any interference of acute training effects. All tests were carried
45 out mid-morning after the first dance class of the day.
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54 Countermovement jump height was measured in a parallel position using the Just jump mat
55 (Probiotics inc, Hunstville, AL). Subjects completed 3 vertical jumps with a 20 second rest in
56 between attempts and the highest score was recorded. Active range of movement (développé
57 en second, Figure 1) was recorded using a digital video camera and was analysed using two
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1 dimensional movement analysis software (Dartfish version 5.5). The left and right anterior
2 superior iliac spine (ASIS) and medial malleoli were marked using medical white tape.
3 Subjects completed 3 développés on the right and left leg to their maximum height and the
4 greatest score recorded.
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8 *** Figure 1 approximately here ***
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11 Thigh circumference was measured at the midpoint between the fold of the hip crease and top
12 of the patella. Calf circumference was taken at the point at which the calf had the largest
13 circumference.
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16 17 18 Vibration training procedure 19

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21 The intervention group completed 8 sessions in total training twice a week for four weeks
22 with at least two days in between sessions to allow recovery time. The intervention group
23 trained for 30 seconds per position at 35Hz frequency, in the first 2 weeks, and 40 seconds per
24 position at 40Hz for the final two weeks (19, 24, 33). Platform peak to peak displacement was
25 8mm throughout. Each exercise was completed once statically and once dynamically. The
26 nine positions used on the platform were a narrow and wide semi squat (first and second
27 position plié, respectively), high toe raise, pelvic bridge with the back on the floor and feet on
28 the platform, right leg leading lunge (with just the front foot on the platform), left leg leading
29 lunge, a bent over hamstring hold with a 90 degree angle between the torso and legs and an
30 active hip flexor exercise (développés) on each leg (fig 1). The extension phase of the later
31 exercise was held for 2 seconds, with an increase of external hip rotation on count 2. These
32 positions were chosen as they targeted the prime muscles used during jumping and
33 développés (AROM for the hips), with a “turned out” foot position to replicate the external
34 leg rotation required in dance. The control subjects completed the same exercises as
35 intervention subjects but on the floor without vibration.
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49 50 Statistical analyses 51

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53 Data were compared pre and post intervention using a RM-ANOVA with post hoc difference
54 contrasts. Mauchy’s test of sphericity was used as a measure of homogeneity between
55 groups. Significance was set at an alpha level of 95% ($p < 0.05$).
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59 60 RESULTS 61 62 63 64 65

1 Jump height data noted a significant improvement in the intervention group over time
2 compared to the control group ($F_{1,15} = 6.239$, $p < 0.05$; ICCR 0.888); no significant changes
3 were noted in the control group (Table 2, Fig 2).
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6 ****Figure 2 and 3 approximately here****
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9 AROM saw a significant improvement in the intervention group (I) for both legs compared to
10 the controls (right leg: $F_{1,15} = 11.165$; $p < 0.01$; ICCR 0.814; left leg: $F_{1,15} = 15.218$; $p < 0.01$;
11 ICCR 0.834) (Table 2, Fig 3). No significant changes were noted for the control group.
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13 Neither group reported any significant changes in thigh and calf circumferences.
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17 *** Table 2 approximately here ****
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19 20 DISCUSSION

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23 The reported data shows that WBV training has the potential to increase jump height and
24 AROM in young trained dancers without increasing thigh and calf circumferences. Previous
25 research (4, 6, 7, 13, 15, 26, 28, 33) often used sedentary subjects where it is to be expected
26 that performance adaptations occur without circumferential changes in muscles due to the
27 primarily muscular adaptation to overload being neuromuscular. The present study using
28 trained subjects still noted an improvement in jump performance without hypertrophical
29 development suggesting the WBV can still cause neuromuscular adaptations, as suggested by
30 Bosco et al (7, 8). This is extremely beneficial in activities where the aesthetic look of limbs
31 is important, as in dance and gymnastics, or where body weight is an issue e.g. distance
32 running, rock climbing, judo.
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43 It is suggested that increased motor unit recruitment as a result of TVR stimulates a greater
44 training effect by allowing the participant to train with higher loads (18) and by stimulating
45 increased motor unit fatigue (26). The substantial sensory stimulation and subsequent
46 reflexive contraction responses of WBV are thought to result in an overall increased
47 efficiency of the afferent pathways and sensitization of the muscle spindles (13). The
48 similarity between the sensory stimulation and subsequent reflexive response seen in both
49 WBV and in the eccentric phase of jumping, is suggested to be one of the reasons for the
50 improvements in jump performance seen in this study and commonly in other studies.
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59 The 5.7% increase in jump height in dancers after 4 weeks in this study is comparable to the
60 5.9% increase found in dancers by Wyon and colleagues (33) in 6 weeks using a very similar
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1 protocol. It is suggested the incorporation of a progressive training protocol, the 5Hz increase
2 in frequency and 10 additional seconds in each position, in the present study allowed for jump
3 height improvements to be achieved in a shorter time due to an increased overload effect.
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6 While the study by Aninno and colleagues (4) saw a greater increase in performance (6.3%),
7 the feasibility of dancers in full time training completing 3 WBV sessions per week for 8
8 weeks may be questionable due to their heavy and increasingly demanding timetables (5, 22,
9 31). Considering the limited time a dancer may be able to dedicate to supplementary training,
10 the design structure used in this study is noted to be more realistic than those using 3 or more
11 sessions per week.
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18 Active range of movement, especially around the hips, is a vital component of most dance
19 forms (2, 29). A number of studies have reported different methods of improving hip AROM
20 using stretching (32) and strengthening (16). The present study was the first study to
21 demonstrate the benefit of short exposure to WBV has on AROM, though Gilsanz and
22 colleagues (14) reported a WBV effect in the some of the muscles used in active hip
23 flexibility (psoas, hip flexors). Subjects in the present study improved their mean AROM by
24 15% and 17% (right and left leg) compared with the 11% mean improvement recorded by a
25 strengthening intervention (16).
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34 The use of external load and individualized vibration frequencies and the subsequent effects
35 on muscular hypertrophy warrant further research as well as further measurements of the
36 EMG and power ratio after WBV training. Although invasive research methodology is
37 generally avoided, methods such as MRI or muscle biopsy may allow a much deeper
38 understanding of the muscle fibres targeted and the modifications taking place.
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45 CONCLUSION

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47 In conclusion, this study provides evidence toward to the suitability of WBV training to
48 dancers to provide rapid performance gains in jump height and active range of movement
49 (développé) without significantly altering leg muscle size. The study also demonstrates that
50 significant improvements can be achieved in relatively shorter periods of time (4 weeks) with
51 less exposure to WBV than reported in earlier studies (4, 6, 7, 13, 15, 26, 28, 33). The
52 mechanisms responsible for physiological adaptation are much debated; however the present
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1 study appears to favour neurological adaptation as the dominant mechanism even in trained
2 subjects.

3 4 PRACTICAL APPLICATIONS 5

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7 Dancers are often contracted to work 36-40 hour weeks with the majority of time spent in
8 dance class rehearsal or performing. This equates to 6-8 hours dancing a day and often over
9 215 dance performances a year which often leads to dancers being prone to overtraining. The
10 need for supplemental training has been well-documented with evidence showing how their
11 training (class and rehearsal) is mismatched with their performance demands, though there is
12 often little time between performance periods to implement traditional interventions. These
13 interventions, especially weight training, are often perceived by dancers to be detrimental to
14 their aesthetic lines. WBV has been shown to be a time-efficient method of improving
15 flexibility, balance, strength and power indices, which are all vital physical fitness
16 components that support dance performance. The fact that research has shown WBV
17 adaptation is mainly neuromuscular allays dancers' fears of bulky muscles and decreased
18 flexibility. The study has shown that minimal intervention time (two ten-minute progressive
19 overload sessions over a four week period) can achieve improved vertical jump and développé
20 height.
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18 Table1. Subject data

21 Table 2. Mean jump height, AROM and anthropometric data

24 Figure 1: Active range of movement: développé en seconde.

27 Figure 2: Group changes in vertical jump height over time

30 Figure 3: Group changes in AROM over time

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Table1. Subject data

Group	Age (yrs)	Height (cm)	Weight (kg)	BMI	Total yrs dancing
Intervention	22 ± 1.17	168.3 ± 6.99	57.8 ± 10.09	20.3 ± 2.44	16 ± 5.71
Control	25 ± 5.92	169.0 ± 4.93	59.5 ± 6.96	20.7 ± 2.78	13 ± 6.37

Table 2: Jump height, AROM and anthropometric data (Mean \pm SEM)

Test	Group	Pre-intervention	Post-intervention
Jump Height (cm)	Intervention	43.2 \pm 1.09	45.6 \pm 1.86*
	Control	39.4 \pm 1.51	38.8 \pm 1.63
Right AROM ($^{\circ}$)	Intervention	99.9 \pm 6.56	117.5 \pm 7.92*
	Control	105.3 \pm 3.78	107.1 \pm 3.57
Left AROM ($^{\circ}$)	Intervention	101.4 \pm 7.63	116.9 \pm 10.08*
	Control	105.9 \pm 3.66	107.9 \pm 4.01
Thigh girth (cm)	Intervention	49.5 \pm 2.11	48.9 \pm 2.24
	Control	49.5 \pm 1.21	49.5 \pm 1.23
Calf girth (cm)	Intervention	37.1 \pm 0.677	36.9 \pm 0.75
	Control	36.9 \pm 1.04	37.6 \pm 1.01

*Denotes significance at $p < 0.05$

Figure 1
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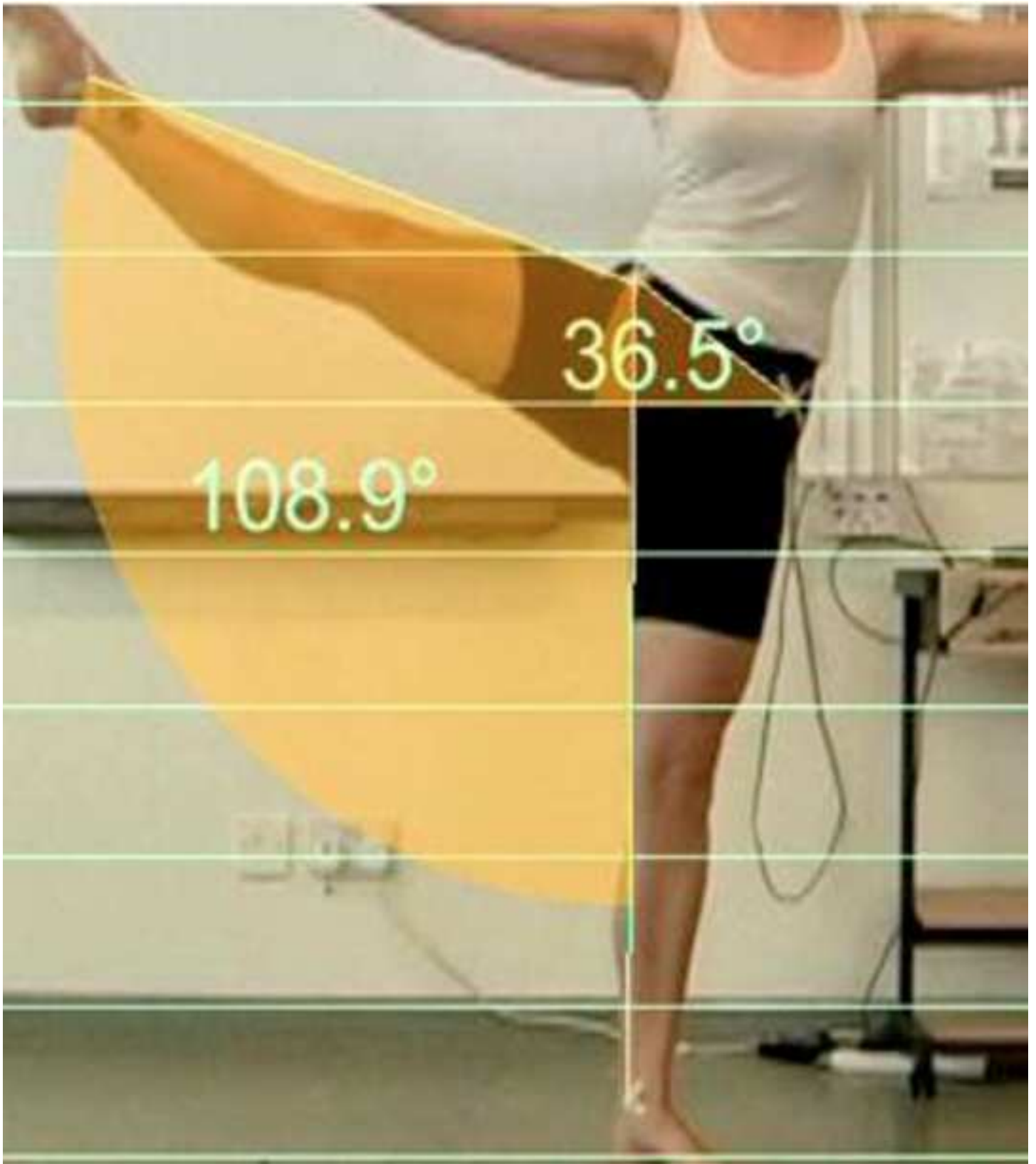


Figure 2
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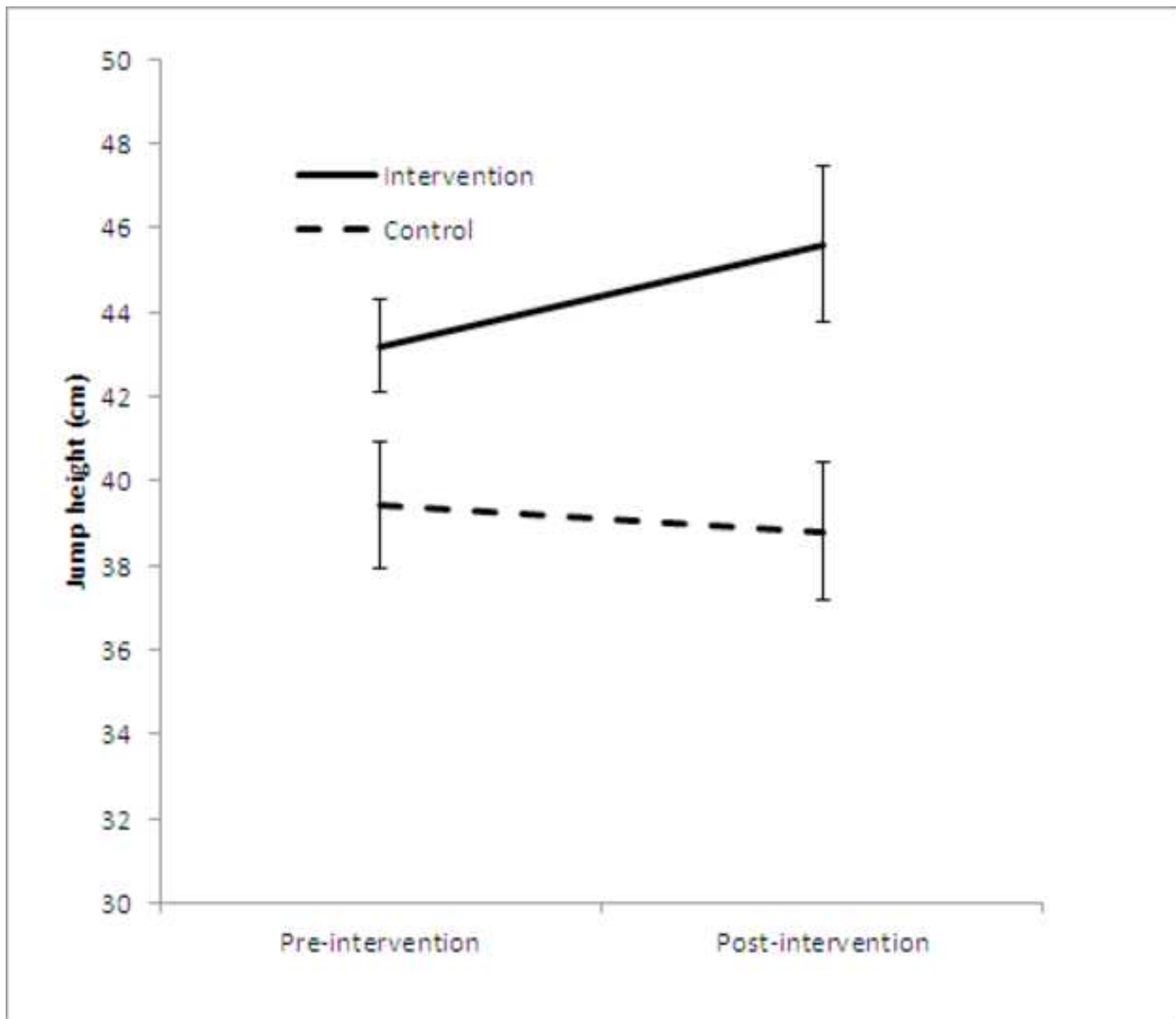


Figure 3
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