Effects of Plyometric and Whole-body Vibration on Physical Performance in Collegiate Basketball Players: A Crossover Randomized Trial

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Abstract

Background

While many studies suggested the effects of plyometric and whole-body vibration exercises on post-activation potentiation, few studies have compared the acute effects of plyometric and whole-body vibration on the occurrence of post-activation potentiation. Therefore, this study aimed to compare the acute effects of plyometric and whole-body vibration exercises on postactivation potentiation in collegiate basketball players.

Methods

Twenty-four collegiate basketball players (Age 20.8 ± 2.02 Y, height 1.79 ± 0.7 m, weight 71.2 ± 7.6 kg, and body mass index 22.00 ± 1.49 kg/m^2) participated in this randomized crossover study. Subjects were received both plyometric and whole-body vibration exercises after 48-hour washed-out period. Countermovement Jump height, sprint, and agility time were measured at baseline, 4- and 12-minute post-plyometric and whole-body vibration exercises.

Results

The result suggests a positive effect of both the plyometric and whole-body vibration exercises on countermovement jump and agility time ($p = 0.001$). While the countermovement jump height and agility were higher in the plyometric group (mean difference 1.60 cm and 0.16 sec, respectively), the sprint performance was higher in the whole-body vibration group (mean difference 0.28 sec). However, these differences were statistically nonsignificant between the two groups ($p > 0.05$).

Conclusions

This study suggests that both plyometric and whole-body vibration exercises may improve postactivation potentiation, which leads to a better physical performance.

Trial registration

CTRI/2019/05/019059. Registered with the Clinical trials registry, India on 10th May, 2019. http://ctri.nic.in/Clinicaltrials/advsearch.php

Background

Warm-up helps improve the optimum force, maximum peak acceleration, and rate of force development by increasing the recruitment of motor units, firing the muscle spindles, and increasing synergistic musculature. Additionally, it also aids in reducing the inhibition of the Golgi apparatus and psychological effects; all of which together directly or indirectly influence postactivation potentiation.[1] Therefore, warm-ups eliciting postactivation potentiation may be the key to improved power performance.

Postactivation potentiation is the process in which muscle performances are acutely enhanced due to their contractile property.[2,3] There is considerable literature in favour of using conditioning activity (performance of maximum or near maximum muscle contraction) to stimulate enhancement in subsequent upper body ballistic performance, jumping, sprinting, and throwing.[2,4] Two main mechanisms have been suggested to be responsible for postactivation potentiation. One is the phosphorylation of light chains regulating myosin, which make the protein filaments actin and myosin are sensitive to the release of calcium (Ca2+)[2,5,6] and the other is an increase in the recruitment of higher-order motor units.[2,7,8] There is evidence which suggests that the changes in the angle of pennation may contribute to postactivation potentiation.[4,9,10] Previous studies demonstrated that subject features such as training condition (strength levels) and type of fibre distribution may determine the ability to display postactivation potentiation.[5,8,11] Last few decades, researchers tried to examine the effects of postactivation potentiation on athletic performance using dynamic movements such as plyometrics, back squats, resistance training,[12] whole-body vibration (WBV),[13–16] and isometric maximum voluntary contractions.[17,18] The eccentric activity followed by fast concentric contraction of the involved muscles is commonly used by athletes to increase jump performance and improve muscular activation patterns.[19,20] A previous study suggested that an increase in countermovement jump (CMJ) height and maximum force is due to induced PAP after 1–5 minutes of plyometric exercises.[21] Another study reported an increased CMJ power by about two percent after completion of five modified drop jumps at one minute of rest-interval.[1]

WBV is an alternative exercise method used to improve muscle power,[13,22,23] strength,[24–26] and flexibility.[24] WBV is implemented on a platform that typically vibrates between 30-50Hz by standing, squatting, or performing dynamic movements. Physiologically, WBV is proposed to activate α-motor neurons to improve muscle performance by increasing muscle activation, stretch reflex potentiation, antagonistic muscle inhibition, and synchronization of the motor unit.[27]

Cochrane et al.,[15] investigated the effect of WBV (36 HZ) and five minutes of static body weight squat on postactivation potentiation, muscle twitch, and patellar reflex properties among 12 national level athletes. They found an increased muscle peak force of about 12% and a force production rate of about 11% following a WBV exercise. Likewise, Ronnestad et al.[28] and Padulo et al.[29] used WBV exercises to improve 40 m sprint and repeated sprint performance in soccer players. Additionally, Haris et al.,[30] and Pojskic et al.,[31] reported that WBV with the addition of 30% of body weight may increase CMJ height, and decreased sprit and agility time.

While many studies suggested the effects of plyometric and WBV on postactivation potentiation, few studies have compared the acute effects of plyometric and WBV on the occurrence of postactivation potentiation. Chen et al.,[32] found that resistance and plyometric exercise, WBV, and a complex training of vibration induce similar benefits of postactivation potentiation. To the best of our knowledge, no study compared the acute effects of plyometrics and WBV on CMJ height, sprint, and agility. Therefore, this study aims to compare the acute effects of plyometrics and WBV on postactivation potentiation in collegiate basketball players by measuring physical performance.

Methods

Participants

Twenty-four university basketball players participated in this randomized crossover study. All the participants signed an informed consent form approved by the institutional ethical committee, Jamia Millia Islamia, New Delhi (**No. 31/10/188/JMI/IE/2018)**. The sample size was determined using software G*Power Version 3.1.9.2 using the data of a previous study done by Dallas et al.,[33] in which change in CMJ performance was analysed and 24 subjects (considering 12% dropout) with an effect size of 0.34, alpha level of 0.05 and power (1- beta) of 0.80 was calculated. Participants were included if they are a member of a collegiate male basketball team, continuously playing for more than 2 years at the university level, involved in sport-specific training for at least 2 days per week, and playing competitive sports once a week. Participants were excluded if they had a history of any surgery of the lower extremities in the past one year or musculoskeletal disorders that would prohibit the subject to participate in sports and who were taking performance-enhancing supplements. All testing and training was performed at the sports ground, Jamia Millia Islamia, New Delhi.

Randomization and crossover

The participants were randomly assigned to WBV or Plyometric train. Blank folders were numbered from 1 to 24, given concealed codes for group assignment by an independent assessor, and kept in a safe locker. Once a participant fulfilled the eligibility criteria and agreed to participate, an independent assessor drew the next folder of the file to assign the group. Participants were randomized to first receive either WBV or plyometric training and after 48 hours of the washed-out period they were crossed over to receive the opposite intervention. Participants in group one (n = 12) first did WBV followed by plyometric training, while the other group (n = 12) first did plyometric training followed by WBV.

Testing

Participants were screened to rule out any disease with the help of a medical screening questionnaire and they were given one day rest from the game before the training and testing to avoid the training effects. Participants were instructed not to perform any form of exercise and not to consume alcohol or coffee 24 hours prior to each session,[34] as it may affect the training and testing.[35] On day first, participants were familiarized with the testing procedure.

Before the training, general warm-up exercises comprised of five minutes jogging and stretching of the major muscles of the lower limb were given. After one-minute rest, the baseline measurements of CMJ, sprint, and agility performance were obtained. After 5 minutes, they were asked to receive either the plyometric training or WBV as per group allocation. The posttest measurements of CMJ, height, sprint time, and agility were taken at 4- and 12-minute after training. Participants were asked to take a 48 h rest to minimize the fatigue effects on test performance.

Training

Plyometric training protocol[36] included double legged vertical and broad jumps, single and double legged bounding and depth jumps, and tuck jumps, all were completed from a height of 40 cm. Participants were asked to minimize ground contact during bounding depth jump exercises and asked to achieve a maximal height during the exercises. A 15–30 s of recovery time between repetition and set was given.

In WBV training, participants were asked to stand on a WBV platform in which they were exposed to a vertical sinusoidal mechanical WBV.[33] A 30 Hz vibration frequency and 5 mm amplitude of WBV dose was given for 2 min. Participants were given a single bout of WBV training during a two 30- second squatting exercise sets and two 30-second single-leg squatting exercise sets with 30- second rest intervals.

Outcomes

CMJ height

The CMJ test was used to find the strength of the lower limbs.[37] Participants applied ink at the end of their fingertips using a stamp pad. The participants were instructed to stand aside 15 cm from the marking board, keeping both feet remaining on the ground. They asked to reach up as high as possible with one hand and marked onto the marking board with the fingertip. This is the standing reach height. The participants were then instructed to jump vertically (90-degree knee bend) as maximum as can while actively swinging the arms and marking on the board. The height of the jump was determined using a measuring tape attached to a graph paper that marked the initial and final jump ink prints of each participant.

20-m single sprint

20-m sprint was used to assess the speed performance.[38] Two cones were placed 20 m apart. Participants ran on a call of ready-get set-go and was asked to complete the 20 m sprint as quickly as possible. The timing was recorded with the stopwatch in seconds.

Agility T-test

Four cones were placed at a distance of 4.57 m and 9.14 m in a T shape. The participants were asked to start at cone A. On the command of ready-get-set-go, to run touched cone B and shuffled sideways to the left and touched cone C. Then shuffled sideways to the right and touched cone D. Finally, they shuffled back to the left and touched cone B, and return to cone A. Once they crossed the cone A, the stopwatch was stopped.[30]

Statistical analysis

Statistical analysis was done using SPSS software 21.0. The descriptive data are presented as mean ± standard deviation. Shapiro- Wilk test was used to confirm the normality of the distribution scores. A 2 × 3 repeated measures analysis of variance (ANOVA) with time (at baseline, 4 min, 12 min of posttest), protocol (plyometric training and WBV), and the interaction effect (time × protocol) was used. If the main effect of the protocol was not significant, post hoc analysis was not employed. Whereas, if the main effect of time was significant, a post hoc analysis using Bonferroni correction was applied on time. The significance level was set at $p < 0.05$.

Results

All 24 participants (age 20.8 ± 2.02 Y, height 1.79 ± 0.7 m, weight 71.2 ± 7.6 kg, and body mass index 22.00 ± 1.49 kg/m^2) completed study procedure. Descriptive statistics of dependent variables are presented in Table 1. CMJ height had a significant effect with respect to time ($p = 0.001$), the effect of the protocol was nonsignificant ($p = 0.807$), and the time × protocol interaction effect was also significant ($p = 0.001$), indicating that CMJ improved following both protocols and there was an insignificant difference between the plyometric and WBV exercises (Table 2). A post hoc pairwise comparison with respect to time showed a significant increase in height from baseline to the 4th minute ($p = 0.001$) and from baseline to the 12th minute ($p = 0.001$) (Table 3, Fig. 1 (a)).

Table 1
Descriptive statistics of dependent variables

Dependent Variable	Time (min)	Plyometric exercise	WBV Exercises
CMJ, cm	Baseline	45.18 ± 3.06	44.53 ± 2.99
	Post 4 min.	48.80 ± 2.70	46.55 ± 3.00
	Post 12 min.	47.05 ± 2.91	45.38 ± 3.07
Sprint, sec	Baseline	3.44 ± 0.21	3.80 ± 1.64
	Post 4 min.	3.31 ± 0.19	3.39 ± 0.21
	Post 12 min.	3.38 ± 0.20	3.41 ± 0.21
Agility, sec	Baseline	11.51 ± 0.51	11.51 ± 0.50
	Post 4 min.	11.24 ± 0.51	11.37 ± 0.50
	Post 12 min.	11.35 ± 0.53	11.44 ± 0.50

CMJ: Countermovement Jump, min: Minute, SD: Standard Deviation

Table 2
Two-way (2 × 3) repeated measures analysis of variance

Variable	Source	Df	Partial η^2	F-value	p-value
CMJ	Time	1.469	0.530	24.829	0.001*
	Protocol	1	0.003	0.061	0.807
	Time x protocol	1.357	0.874	152.281	0.001*
Sprint	Time	1.010	0.058	1.359	0.267
	Protocol	1.000	0.042	0.964	0.337
	Time x protocol	1.004	0.089	2.154	0.156
Agility	Time	1.866	0.580	30.413	0.001*
	Protocol	1.000	0.099	2.405	0.135
	Time x protocol	1.162	0.819	99.681	0.001*

CMJ: Countermovement Jump, *Significant differences at $p < 0.01$

Table 3
Post hoc pairwise comparison with time

Variables	T_1 vs T_2	T_2 vs T_3	T_1 vs T_3
CMJ	0.001*	0.673	0.001*
Sprint	0.646	0.958	0.015*
Agility	0.001*	0.002*	0.001*

CMJ: Countermovement Jump, T_1: at baseline, T_2: at 4-min, T_3: at 12-min; *Significant difference at $p < 0.01$.

20 m Sprint had a nonsignificant effect with respect to time ($p = 0.267$), protocol ($p = 0.337$), and the time × protocol interaction was also nonsignificant ($p = 0.156$) (Table 2, Fig. 1 (b)).

Agility time had a significant effect with respect to time ($p = 0.001$) and the time × protocol interaction effect ($p = 0.001$), however, the protocol was nonsignificant ($p = 0.135$), indicating that agility was improved following both protocols and there was a statistically insignificant difference between the plyometric and WBV exercises (Table 2). Post hoc pairwise comparison with respect to time showed a significant decrease in agility time from baseline to the 4th minute ($p = 0.001$), from the 4th minute to the 12th minute ($p = 0.002$) and from baseline to the 12th minute ($p = 0.001$) (Table 3 Fig. 1(c)).

Discussion

The result of this study shows an acute positive impact of both plyometric and WBV exercises on CMJ and agility. While the CMJ height and agility were improved more with plyometric exercise and sprint performance improved more with WBV exercise, there was a statistically insignificant difference between the two protocols. As compared to the baseline, CMJ height increased by 8.01% and 4.53% after 4 min of plyometric exercise and WBV, respectively. However, after 12 min of plyometric and WBV exercises, the CMJ height increased by 4.13% and 1.90%, respectively. The enhancement in the protocols can be speculated by an increase in the neuromuscular responses. In a previous study, Tobin et al.,[39] reported increased CMJ heights by 4.8%, 3.9%, and 3.5% after 1, 3, and 5 min of plyometric exercise, respectively. Similarly, Requena et al.,[40] reported an increase in CMJ height of 3.08 cm at a 5-minute rest interval after 25 plyometric repetitions. Additionally, Sharma et al.,[41] reported decreased CMJ height by 4.8% immediately after plyometric exercise, however, after 10 min of recovery the CMJ height was increased by 13%. The contrary, Esformes et al.,[42] reported no additional benefit of plyometric exercise in increasing the performance of CMJ height. However, the protocol they used was a single 70-second plyometric exercise effort. The long duration of the effort must have led to an increased level of metabolic fatigue that interfered with the response to potentiation. Similarly, Till et al.,[43] observed no additional benefits of plyometric exercise on CMJ's performance.

In line with the current results, Dallas et al.,[33] showed an increase in CMJ performance of 6.51% and 4.57% at one minute and 15 minutes after WBV exercise. The protocol used in this study was similar to our study. Similarly, Naclerio et al.,[44] observed an enhanced CMJ performance after 4-minute post-WBV exercise. Additionally, Cormie et al.,[45] reported an increased CMJ performance after 5- and 10-minute post-WBV exercise. In contrast, while Rittweger et al.,[46] found a reduced CMJ performance by 9.1% after WBV exercise, other studies reported no changes in CMJ performance after WBV exercise.[47,48]

With both protocols, this study showed no significant improvement in the 20 m sprint. However, the average sprint time was reduced by 3.77% and 10.78% in 4-min post-plyometric and WBV exercises, respectively. Similarly, the average sprint time was reduced by 1.74% and 10.26% in 12-min post-plyometric and WBV exercises. These results indicate that the sprint time was reduced more after WBV than that of plyometric exercise. Many past studies have shown the interactions between post-activation potentiation and sprint performance. For example, Turner et al.[49] found improved sprint performance by 1.9% in 4-min and 2.3% in 8-min post-plyometric exercises. The speculated mechanism for this potentiation was enhanced activation of the musculature and an increased recruitment of type 2 motor units.[49] Sharma et al.,[41] reported increased sprint time by 2.4% immediately after plyometrics, however, the sprint time was reduced by 8.9% after 10-min of recovery. This improvement in sprint performance could be because of optimal motor neuron excitability and recruitment of fast twitch fibres.[50] Pojskic et al.,[31] observed an improvement in sprint performance after 2-min of recovery following WBV exercise. In contrast, Bullock et al.[47] and Kavanaugh et al.,[51] reported no benefit of using WBV exercises to elicit potentiation in sprint performance. The reason for this could be that the intensity of the exercise used was not enough to produce any enhancement or potentiation.

Our study showed that compared to baseline, the agility time was reduced by 2.34% and 1.21% in 4-min post-plyometric and WBV exercises, respectively. However, the agility time was reduced by 1.39% and 0.60% after 12-min post-plyometric and WBV exercises. Agility performance was improved in both protocols, however, it was more enhanced with the plyometric protocol. Only a few studies have shown the interactions between postactivation potentiation and agility performance. Consistent with the current results, previous studies have shown that sufficient recovery time is required to reduce fatigue and carry out postactivation potentiation.[8,52] Agility time in our study showed an improvement which supports the finding of Young et al.,[52] and other researchers,[7,53] as they also documented the relationship between agility and postactivation potentiation phenomenon and explained the neural activation of the phenomenon. There are limited studies that investigated the effect of WBV exercise on the performance of agility. For example, Pojskic et al.,[31] observed an enhanced improvement in agility performance after WBV exercise. Similarly, Pienaar et al.,[54] reported an improvement in agility time after WBV exercise. In contrast, Cochrane et al.,[16] and Torvinen et al.[55] observed no significant enhancement in agility after WBV exercise. It can be speculated that the volume of the stimulus was not enough to enhance the acute performance.

This study acknowledged some potential limitations. First, a stopwatch was used to measure the timing of agility and sprint, however, it is not considered a reliable and accurate method. Therefore, an advanced method such as timing gates may be used to measure more accurate values in future studies. Second, postactivation potentiation was not recorded with the help of electromyography. Therefore, future studies can be performed to measure and compare the muscular activity and potentiation by using electromyography after plyometric and WBV exercises. Third, this study is limited to collegiate male basketball players and therefore, the results cannot be generalized to the whole population.

Conclusion

This study suggests that both plyometric and WBV exercises are able to enhance the performance of countermovement jump and agility as well as induce postactivation potentiation. Therefore, athletes may use both of these exercises as both are equally efficient and effective to enhance their performance. Both plyometric exercises and whole-body vibration exercises may be included as warmup protocols during an on-field and off-field training programs.

Abbreviations

WBV: Whole-body vibration

CMJ: Countermovement jump

Declarations

Ethics approval and consent to participate

All participants signed an informed consent form approved by the institutional ethical committee, Jamia Millia Islamia, New Delhi (No. 31/10/188/JMI/IE/2018).

Consent to publish

Not applicable.

Availability of data and materials

The datasets during and/or analyzed during the current study are available from the first author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization: PM, MHK, SH, SA, HL and AHA; Data curation: PM, MHK and SN; Formal analysis: PM, MHK and SN; Funding acquisition, AHA; Methodology, PM, MHK and SN; Supervision, HL; Validation, SA; Visualization, SA; Writing – original draft, PM, MHK and SN; Writing – review & editing, SA, HL and AHA. All authors have approved the final version of the manuscript.

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Figures

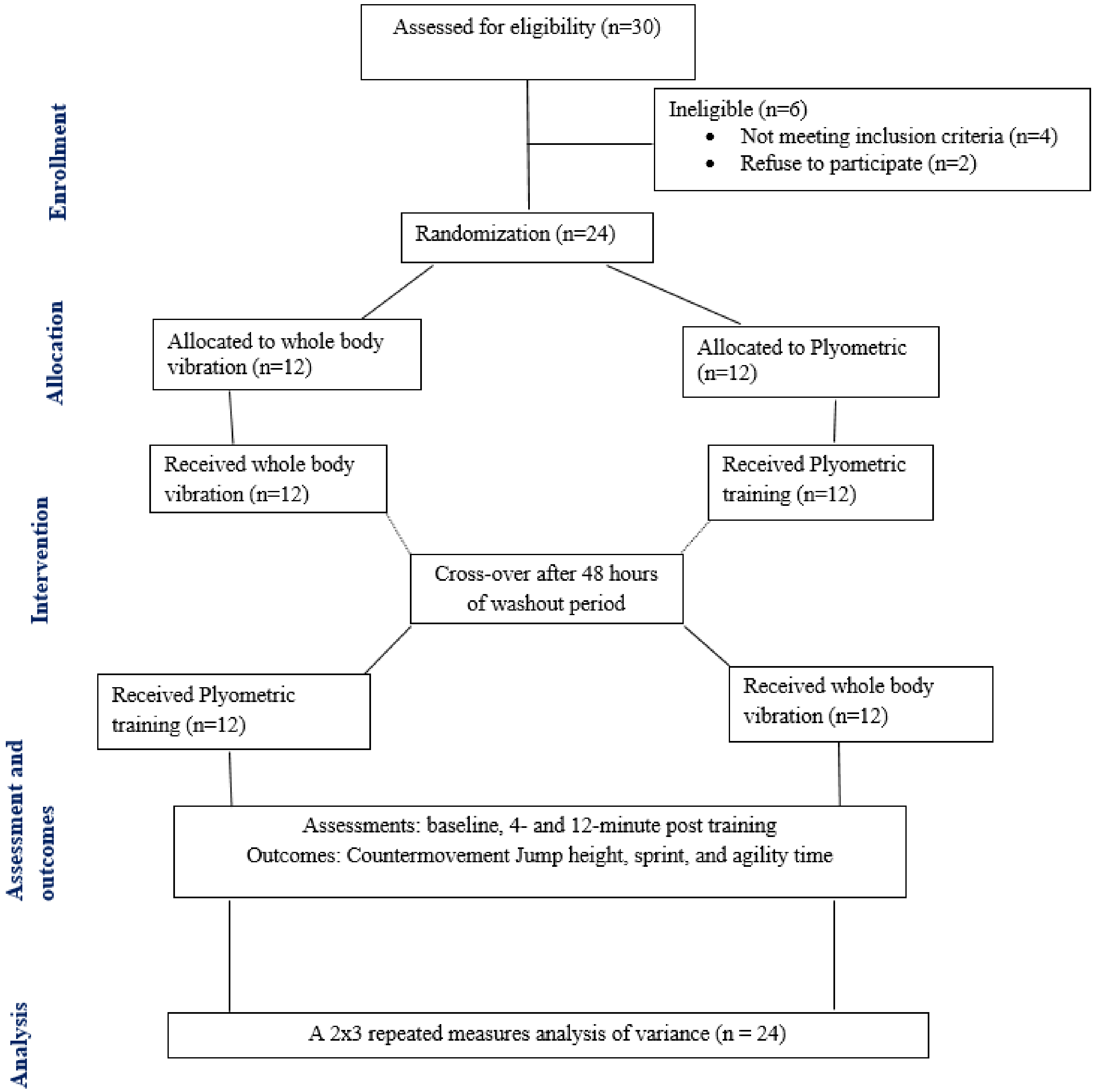

Figure 1

Flow of participants through each stage of the randomized trial

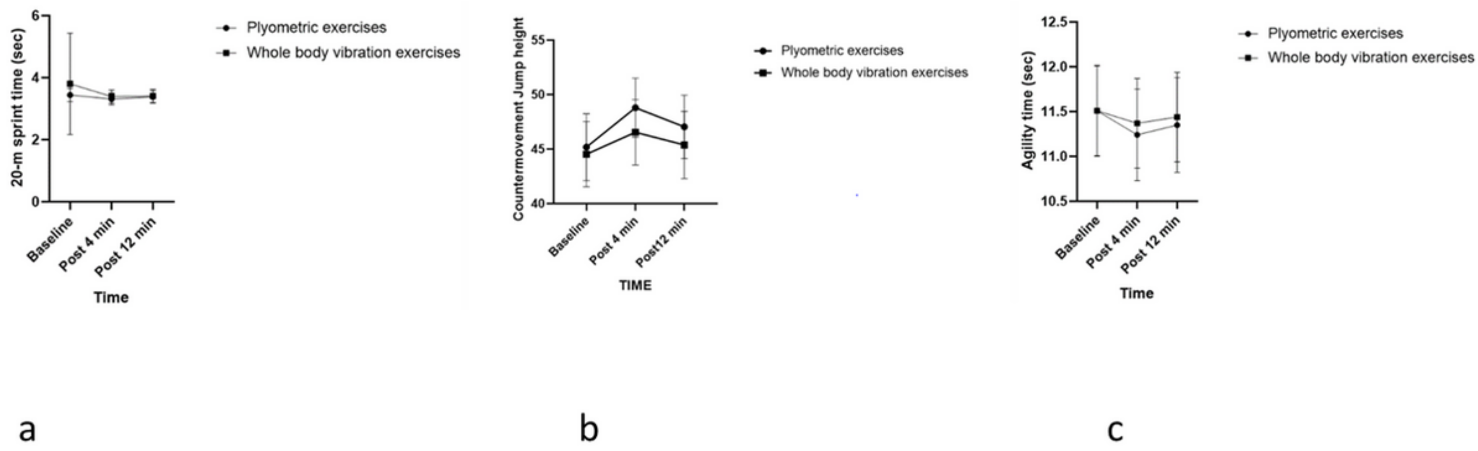

Figure 2

(a) Maximal height in the Counter movement Jump performance for plyometrics and whole-body vibration group at specified intervals; (b) Maximal 20-m sprint time for the plyometric and whole-body vibration group at specified time intervals; (c) Maximal agility time for the plyometric and whole-body vibration group at specified time intervals

Supplementary Files

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