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The Effect of 8 Weeks Vibration Training on Special Strength and Balance of Lower Limbs in Long Jump Athletes

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Abstract

The purpose of this research is to explore the effects of 8-week vibration training courses (of different frequencies, i.e., 30 Hz and 50 Hz) on long jump athletes' lower limb special strength, special physical fitness indicators, and balance and how these effects differ according to the vibration frequency. This study will help introduce this new training method into long jump training regimens. Overall, this effort will add diversity and innovation to current practices, improving both the training and teaching in long jump.

Keywords: vibration training, long jump, special strength, balance, frequency

Introduction

Long jump is an exercise that requires both speed and strength. Specialized long jump training places extreme importance on developing athletes' fast takeoff ability and good balance. This is both the focus and the most difficult part of long jump training because it determines the speed and effectiveness of the specialized movements as well as the final event score (Wang, 1987).

Vibration training is through a place on the ground of the vibration of vibration table, make its produce impact vibration stimulation through body passed on to the muscles, and improve the active degree of muscle activation and increase the activity of the high threshold motion unit and cause the motor unit with high frequency discharge, and neuromuscular excitability improve training effect.

Vibration training not only increases maximum strength, but also strengthens joint stability (Berschin & Sommer, 2004). A single vibration training has a function of muscle strength and body balance, which improves the balance of the body and the ability to jump (van der Meer, Zeinstra, Temperlaars, & Hopson, 2007). Vibration training and the resulting reflexive muscle contractions can increase the muscle strength of the quadriceps, and this growth is not due to psychological effects (Delecluse, Roelants, & Verschueren, 2003).

In light of the facts mentioned above, this research explores the effects of 8-week vibration training courses (of different frequencies, i.e., 30 Hz and 50 Hz) on long jump athletes' lower limb strength (Ren, Yan, & Liu, 2008), special physical fitness indicators, and balance and how these effects differ according to the vibration frequency used. This study will help introduce this new training method into long jump athletes' training regimens. Overall, this effort will add diversity and innovation to current practices (Hou, 2009), improving both the training and the teaching of long jumpers.

Methods

Participants

Fourteen long jump athletes of second level from Class 2011 and 2012 in Beijing Sport University took part in this study. Subjects were divided into high (50 Hz) and low (30 Hz) frequency groups based on their scores in specific fitness tests. All subjects were informed of the process of the experiment and the possible risks involved in the experiment and volunteered to participate in the experiment. Subjects' basic information has been displayed in Table 1.

Vibration Training Plan

The training program (Tables 2 & 3) was

Table 1
Subjects' Basic Information

Group	Sample size	Age (years)	Height (cm)	Weight (kg)	Years trained
30 Hz	7	21.14 ± 0.90	181.50 ± 5.73	68.51 ± 6.45	6.14 ± 1.21
50 Hz	7	20.57 ± 0.98	181.44 ± 6.49	66.11 ± 5.17	6.43 ± 1.13
Total	14	20.86 ± 0.95	181.50 ± 5.73	67.31 ± 5.69	6.29 ± 1.14

Table 2
Training Plan of the First 4 Weeks

Training content	Movements	Practice time (s)	Amplitude (mm)	Rest interval (s)	Practice group
Lower limb strength	• Single knee raise balance • Single leg reverse lunge • Double leg half squat • Single leg quiet squat • Single leg lunge squat • Switch leg lunge squat	30–60	2	90–180	2–3
Core strength	• Prone balance • Rear axle support • Dynamic rear axle support • Single leg rear axle support • Double elbow recline	30–60	4	60–120	2–3

Table 3
Training Plan of the Second 4 Weeks

Training content	Movements	Practice time (s)	Amplitude (mm)	Rest interval (s)	Practice group
Lower limb strength	• One leg in front, one leg lunging behind • Alternating single, leg squat and stand • Single leg balance • lumbar pressure • Single leg half squat and stand • Single leg lunge squat and stand • Alternating leg jump on vibrating platform	30–60	2	90–180	2–3
Core strength	• Push up • Single leg push up • Single arm balance push up • Single leg side plank bilateral prone push up	30–60	4	60–120	2–3

formulated according to the relevant literature (Adams et al., 2010; Cardinale & Lim, 2003a, 2003b; Deleelusec et al., 2003; Sun, 2011) and based on the types of strength required and muscle groups involved in the long jump. The training is divided into the basic training period of the first 4 weeks and the improvement of the second 4 weeks.

Procedure

Each participant took tests of three types, including lower limb muscle strength, specific fitness, and balance, before and after training intervention with 48 hours rest interval between each category. All tests included in three types are listed in Table 4.

Equipment

Power Plate Pro 5 AIRdaptive™ Vibration Trainer (Frequency: 25–50 Hz, Amplitude: 2–4 mm) (Performance Health Systems, LLC, Northbrook, IL), KISTLER 3D Force Measuring Platform (Kistler Group, Winterthur, Switzerland), Good Balance Static Balance Tester (Metiuer Company, Finland), sit-and-reach tester, steel ruler, iron shovel, stopwatch, etc.

Expert Interview Method

While developing our training program and selecting our test indicators and testing methods, we consulted separately eight experts from Tianjin University of Sport, Beijing Sport University Track and Field Department and other organizations that study vibration training.

Statistical Analyses

SPSS 16.0 was used to compare all test indicators, including intra- and inter-group between the 30 Hz and 50 Hz groups ($\alpha = .05$).

Results

Effects of 8-Week Training Courses (at Different Frequencies) on Athletes' Lower Limb Strength

According to Table 5 and Table 6, it is easy to find out that the 30 Hz and 50 Hz groups enjoyed a marked increase in their lower limb max strength after the 8-week vibration training. In terms of counter movement jump (CMJ), drop jump (DJ), and takeoff leg run-up and jump (ZT) max strength, the 30 Hz and 50 Hz groups obtained the following results respectively: 1,968.18 N (7.91%), 4,261.57 N (23.97%), 2,825.01 N (22.38%) and 1,796.59 N (11.17%), 4,682.75 N (28.93%), 3,001.70 N (27.00%). Intra-group comparisons with pre-test groups showed a significant increase ($p < .01$). There was no significant difference in results between the 30 Hz and 50 Hz groups ($p > .05$).

Fast strength indicator. After 8-week vibration training, both the 30 Hz and the 50 Hz groups showed significant increases. In terms of CMJ, DJ, and ZT fast strength, the 30 Hz and 50 Hz groups obtained the following results respectively: 2.92 m/s (5.12%), 2.00

Table 4
Test Indicator List

Type	Test indicators
Lower limb strength	Counter movement jump, deep jump, takeoff leg run-up and jump
Special fitness	Standing 100-m dash, 8-step run-up long jump, 4-step run-up level 5 single foot long jump, 4-step run-up level 5 step jump
Balance	Normal standing when eyes opened (NSEO), normal standing with eyes closed (NSEC), one leg right standing when eyes open (OLRSEO), one leg left standing when eyes open (OLLSEO)

Table 5
Effects of 30 Hz Vibration Training on Test Subjects' Lower Limb Strength

Change	Participants	Test	Average (*SD*)	Increase (%)
CMJ				
Max strength	7	Pre-test	1,823.87 ± 235.45	7.91%
	7	Post-test	1,968.18 ± 333.44**	
Fast strength	7	Pre-test	2.77 ± 0.24	5.12%
	7	Post-test	2.92 ± 0.32**	
DJ				
Max strength	7	Pre-test	3,437.61 ± 736.01	23.97%
	7	Post-test	4,261.57 ± 937.75**	
Fast strength	7	Pre-test	2.81 ± 0.30	6.75%
	7	Post-test	3.00 ± 0.27**	
Reflex strength	7	Pre-test	8,483.94 ± 2,143.92	13.91%
	7	Post-test	9,664.08 ± 1,992.92**	
ZT				
Max strength	7	Pre-test	2,308.47 ± 442.88	22.38%
	7	Post-test	2,825.01 ± 1,044.22**	
Fast strength	7	Pre-test	2.59 ± 0.24	8.05%
	7	Post-test	2.80 ± 0.20**	
Reflex strength	7	Pre-test	9,051.44 ± 3,213.23	11.56%
	7	Post-test	10,097.56 ± 3,555.19**	

Note. CMJ = counter movement jump; DJ = deep jump; ZT = takeoff leg run-up and jump.
**means that compared with the pre-test results, $p < .01$.

m/s (6.75%), 2.80 m/s (8.05%) and 2.89 m/s (12.39%), 2.84 m/s (8.74%), 2.63 m/s (9.01%). Furthermore, an intra-group comparison between the 30 Hz and the 50 Hz groups determined that although all indicators showed significant increases ($p < .01$), the differences between the two groups were not significant ($p > .05$).

Reflex strength indicator. After 8-week vibration training, the 30 Hz and the 50 Hz groups had significant increases in reflex strength. In terms of DJ and ZT lower limb reflex strength, the 30 Hz and the 50 Hz groups obtained increases of 9,664.08 N/S (13.91%) and 12,956.43 N/S (12.04%), respectively. Moreover, a comparison between the groups determined that the increases were extremely significant ($p < .01$). At the same time, as shown in Table 7, there was a significant difference in the results obtained in the 30 Hz and the 50 Hz groups ($p < .05$). This means that the 50 Hz group had more significant effect than the 30 Hz group.

In summary, in terms of the three types of lower limb strength, CMJ, DJ, and ZT, athletes' (from both the 30 Hz and the 50 Hz groups) max strength, fast strength, and reflex strength showed significant increases. In addition, the 50 Hz group had the most significant increases in reflex strength.

Table 6

Before and After Effects of 50 Hz Vibration Training on Test Subjects' Lower Limb Strength

Change	Participants	Test	Average (*SD*)	Increase (%)
CMJ				
Max strength	7	Pre-test	1,616.02 ± 109.41	11.17
	7	Post-test	1,796.59 ± 172.33**	
Fast strength	7	Pre-test	2.66 ± 0.22	8.74
	7	Post-test	2.89 ± 0.19**	
DJ				
Max strength	7	Pre-test	3,632.01 ± 814.09	28.93
	7	Post-test	4,682.75 ± 1,032.05**	
Fast strength	7	Pre-test	2.53 ± 0.15	12.39
	7	Post-test	2.84 ± 0.06**	
Reflex strength	7	Pre-test	11,263.64 ± 3,567.32	15.03
	7	Post-test	12,956.43 ± 3,156.90**	
ZT				
Max strength	7	Pre-test	2,363.59 ± 900.79	27.00
	7	Post-test	3,001.70 ± 1,031.80**	
Fast strength	7	Pre-test	2.41 ± 0.23	9.01
	7	Post-test	2.63 ± 0.23**	
Reflex strength	7	Pre-test	8,936.66 ± 3,815.14	19.79
	7	Post-test	10,704.80 ± 4,524.10**	

Note. CMJ = counter movement jump; DJ = deep jump; ZT = takeoff leg run-up and jump.

**means that compared with the pre-test results, $p < .01$.

Table 7

Comparative Effects of 30 Hz and 50 Hz Vibration Training on Test Subjects' Lower Limb Reflex Strength

Change	Test	Average (*SD*)		*p*
		30 Hz group	50 Hz group	
DJ:	Pre-test	8,483.94 ± 2,143.92	11,563.64 ± 3,567.32	0.044
Reflex strength	Post-test	9,664.08 ± 1,992.92*	12,956.43 ± 3,156.90*	

Note. DJ = deep jump.

*indicates the comparison of different frequencies, $p < .05$.

Effects of 8-Week Vibration Training on Athletes' Specialized Physical Fitness Indicators

According to Tables 8–10, we can see that after 8-week vibration training (at different frequencies), 100-m dash results significantly increased, with the 30 Hz and the 50 Hz groups showing increases of 11.31 s and 11.18 s (0.93% and 1.97%, respectively). This increase was

Table 8

Before and After Effects of 30 Hz Vibration Training on Specialized Fitness Indicators

Change	Participants	Test	Average (*SD*)	Increase (%)
100-m dash	7	Pre-test	11.41 ± 0.05	0.93
	7	Post-test	11.31 ± 0.04**	
8-step run-up long jump	7	Pre-test	6.08 ± 0.06	3.17
	7	Post-test	6.28 ± 0.03**	
4-step run-up and 5-step hop	7	Pre-test	19.93 ± 0.29	1.32
	7	Post-test	20.19 ± 0.26**	
4-step run-up and 5-step jump	7	Pre-test	20.17 ± 0.24	1.26
	7	Post-test	20.43 ± 0.21**	
Sit and reach	7	Pre-test	18.83 ± 1.78	35.28
	7	Post-test	25.47 ± 2.00**	

**means that compared with the pre-test results, $p < .01$.

Table 9

Before and After Effects of 50 Hz Vibration Training on Specialized Fitness Indicators

Change	Participants	Test	Average (*SD*)	Increase (%)
100-m dash	7	Pre-test	11.41 ± 0.07	1.97
	7	Post-test	11.18 ± 0.06**	
8-step run-up long jump	7	Pre-test	6.08 ± 0.06	6.21
	7	Post-test	6.45 ± 0.06**	
4-step run-up and 5-step hop	7	Pre-test	19.93 ± 0.23	4.24
	7	Post-test	20.78 ± 0.21**	
4-step run-up and 5-step jump	7	Pre-test	19.99 ± 0.15	5.14
	7	Post-test	21.02 ± 0.06**	

**means that compared with the pre-test results, $p < .01$.

significant when compared with the intra-group pre-test results ($p < .01$). There was a significant difference in the results of the 30 Hz and the 50 Hz groups (Table 10).

There was a significant increase in the 8-step run-up long jump results as well. The 30 Hz and the 50 Hz groups obtained increases of 6.28 m and 6.45 m, respectively. The differences among participants in the respective groups were extremely significant ($p < .01$). The differences between the two groups were also significant ($p < .05$, see Table 10).

There was also a significant increase in the 4-step run-up and 5-step hop results. The 30 Hz and the 50 Hz groups showed increases of 20.19 m and 20.78 m (3.17% and 6.21%, respectively). The differences among participants within respective groups were extremely significant ($p < .01$). The differences between the two groups were also significant ($p < .05$, see Table 10).

In addition, there was a significant increase in the 4-step run-up and 5-step jump results.

Table 10

Comparative Effects of 30 Hz and 50 Hz Vibration Training on Specialized Fitness Indicators

Change	Test	Average (*SD*) 30 Hz group	Average (*SD*) 50 Hz group	*p*
100-m dash	Pre-test	11.41 ± 0.05	11.41 ± 0.07	0.016
	Post-test	11.31 ± 0.04	11.18 ± 0.06*	
8-step run-up long jump	Pre-test	6.08 ± 0.06	6.08 ± 0.06	0.012
	Post-test	6.28 ± 0.03	6.45 ± 0.06*	
4-step run-up and 5-step hop	Pre-test	19.93 ± 0.29	19.93 ± 0.23	0.044
	Post-test	20.19 ± 0.26	20.78 ± 0.21*	
4-step run-up and 5-step jump	Pre-test	20.17 ± 0.24	19.99 ± 0.15	0.042
	Post-test	20.43 ± 0.21	21.02 ± 0.06*	

* indicates the comparison of different frequencies, $p < .05$.

The 30 Hz and the 50 Hz groups obtained increases of 20.43 m and 21.02 m (3.17% and 6.21%, respectively). The differences among participants within respective groups were extremely significant ($p < .01$). The differences between the two groups were also significant ($p = .042$, see Table 10).

In summary, after 8-week vibration training, the 30 Hz and the 50 Hz groups showed significant increases in their specialized indicators (100-m dash, 8-step run-up long jump, 4-step run-up and 5-step hop, and 4-step run-up and 5-step jump). Besides, the 50 Hz group seemed to gain more benefits from the training than the 30 Hz group.

The Effects of 8-Week Training Courses (of Different Frequencies) on Long Jump Athletes' Balance

This study selected the following indicators to reflect the test subjects' balance: normal standing with eyes open (NSEO), normal standing with eyes closed (NSEC), one leg right standing with eyes open (OLRSEO), and one leg left standing with eyes open (OLLSEO) (Li & Zhang, 2005; Peng & Wei, 2003). The results are displayed in Table 11 and Table 12.

Speed index of center of gravity on x axis. The 30 Hz and 50 Hz groups both experienced decreases in the speed at which their center of gravity moved on the x axis in all four balance exercises (31.13%, 18.47%, 12.51%, and 10.01%, and 40.86%, 14.66%, 25.84%, and 24.64%, respectively). The groups experienced significant changes in the NSEO exercise ($p < .05$) (30 Hz group showed a decrease of 1.24 mm/s and 50 Hz group of 0.87 mm/s). The 30 Hz and 50 Hz groups experienced extremely significant changes in the NSEC, OLRSEO, and OLLSEO exercises ($p < .01$) (30 Hz showed a decrease of 2.76, 3.49, and 3.31 mm/s, respectively, and 50 Hz group of 3.80, 11.33, and 8.94 mm/s, respectively). A comparison between the groups showed that the groups differed significantly only in the OLRSEO and OLLSEO exercises ($p < .05$ and $p < .01$, respectively), but no significant differences between the two groups in the NSEO and NSEC exercises were observed. Therefore, different vibration frequencies can effectively decrease athletes' center of gravity movement speed on

Table 11

Before and After Effects of 30 Hz and 50 Hz Vibration Training on Ability to Balance on Both Feet

		NSEC		NSEO	
Change	Time	30 Hz group	50 Hz group	30 Hz group	50 Hz group
Vx	Pre-test	8.86 ± 4.07	5.50 ± 1.23	6.93 ± 2.88	5.94 ± 1.41
	Post-test	6.10 ± 2.26**	9.30 ± 4.14**	5.49 ± 2.56*	5.07 ± 1.25*
Vy	Pre-test	9.34 ± 2.61	9.07 ± 2.76	6.64 ± 1.96	5.80 ± 0.80
	Post-test	7.76 ± 1.15	2.76 ± 1.15	6.17 ± 1.05	5.53 ± 0.76
v.s	Pre-test	39.44 ± 21.84	40.93 ± 28.58	24.46 ± 10.70	34.14 ± 37.80
	Post-test	21.03 ± 9.13**	21.97 ± 14.85**	20.44 ± 11.00	17.63 ± 10.52
Lx	Pre-test	530.76 ± 244.41	557.66 ± 248.59	404.17 ± 173.18	356.89 ± 85.00
	Post-test	366.21 ± 136.61**	329.08 ± 67.87**	329.13 ± 152.68*	303.80 ± 76.08*
Ly	Pre-test	560.04 ± 103.33	486.37 ± 251.64	398.44 ± 116.26	347.67 ± 46.78
	Post-test	501.13 ± 103.33	466.33 ± 67.77	370.69 ± 63.54	329.76 ± 45.47
Dx	Pre-test	16.01 ± 6.75	16.01 ± 6.75	13.81 ± 5.99	10.86 ± 3.15
	Post-test	11.17 ± 4.27**	9.03 ± 3.36**	9.76 ± 2.43*	9.54 ± 3.02*
Dy	Pre-test	21.07 ± 11.13	21.07 ± 11.14	21.06 ± 7.16	18.90 ± 11.18
	Post-test	18.71 ± 4.08	19.44 ± 8.90	19.19 ± 6.79	18.69 ± 5.98

Note. NSEC = normal standing with eyes closed; NSEO = normal standing with eyes open; Vx, Vy = average speed of center of gravity on x and y axes, respectively; v.s = area by which center of gravity moves in two-dimensional plane during the duration; Lx, Ly = total distance that the center of gravity moves on x and y axes, respectively; Dx, Dy = max distance that center of gravity rocks on x and y axes, respectively.

*indicates that compared with the pre-test results, $p < .05$; ** means that compared with the pre-test results, $p < .01$.

the x axis during single foot balance exercises, with the 50 Hz group showing the most significant effects.

Center of gravity speed on the y axis. The pre-test/post-test differences among the 30 Hz and 50 Hz groups were only extremely significant ($p < .01$) in the OLRSEO and OLLSEO exercises. The 30 Hz group experienced decreases of 3.57 mm/s (16.90%) and 2.77 mm/s (19.35%), respectively. The 50 Hz group experienced decreases of 4.20 mm/s (13.86%) and 4.01 mm/s (19.26%), respectively. However, neither group saw significant differences in the NSEO or NSEC exercises. Therefore, different vibration frequencies can effectively decrease athletes' center of gravity movement speed on the y axis during single foot balance exercises, with the 30 Hz and 50 Hz groups experiencing similar changes.

Area that center of gravity moved in a 2D plane. The 30 Hz group and 50 Hz groups both experienced decreases in the speed at which their center of gravity moved on the x axis in all four balance exercises (30 Hz group: 18.41, 4.01, 24.93, and 23.47 mm^2/s; 50 Hz group: 18.96, 16.51, 30.99, and 24.36 mm^2/s). However, the groups only experienced significant differences in the NSEC and OLRSEO exercises ($p < .01$). Therefore, different vibration frequencies can effectively

Table 12

Before and After Effects of 30 Hz and 50 Hz Vibration Training on Ability to Balance on One Foot

		OLRSEO		OLLSEO	
Change	Time	30 Hz group	50 Hz group	30 Hz group	50 Hz group
Vx	Pre-test	24.44 ± 0.83	25.16 ± 0.81	24.54 ± 0.85	25.04 ± 1.10
	Post-test	21.39 ± 0.87**	18.66 ± 1.21**	22.09 ± 1.10**	18.87 ± 1.49**
Vy	Pre-test	21.13 ± 5.18	21.70 ± 5.29	20.00 ± 5.37	20.84 ± 4.44
	Post-test	17.56 ± 6.33**	17.50 ± 3.25**	17.23 ± 4.38**	16.83 ± 1.97**
v.s	Pre-test	102.81 ± 44.92	117.00 ± 29.50	101.49 ± 35.66	105.00 ± 21.82
	Post-test	77.89 ± 36.17**	86.01 ± 12.64**	78.01 ± 22.51*	80.64 ± 23.58*
Lx	Pre-test	664.24 ± 87.57	759.90 ± 157.22	705.99 ± 101.96	682.04 ± 118.81
	Post-test	546.36 ± 125.07**	522.63 ± 114.32**	621.19 ± 40.47**	543.20 ± 112.96**
Ly	Pre-test	652.20 ± 181.14	631.53 ± 127.99	600.27 ± 161.41	625.11 ± 132.94
	Post-test	540.49 ± 167.00**	511.36 ± 128.60**	516.63 ± 130.92**	504.54 ± 58.62**
Dx	Pre-test	18.27 ± 4.66	18.00 ± 3.54	19.80 ± 4.91	18.36 ± 1.74
	Post-test	15.97 ± 3.29**	15.19 ± 2.29**	14.79 ± 2.66	15.31 ± 1.93
Dy	Pre-test	26.20 ± 6.67	27.41 ± 3.36	29.11 ± 7.52	31.79 ± 6.64
	Post-test	26.16 ± 8.10	30.24 ± 6.33	23.59 ± 4.73	25.13 ± 4.82

Note. OLRSEO = one leg right standing with eyes open; OLLSEO = one leg left standing with eyes open; Vx, Vy = average speed of center of gravity on x and y axes, respectively; v.s = area by which center of gravity moves in two-dimensional plane during the duration; Lx, Ly = total distance that the center of gravity moves on x and y axes, respectively; Dx, Dy = max distance that center of gravity rocks on x and y axes, respectively. *indicates that compared with the pre-test results, $p < .05$; ** means that compared with the pre-test results, $p < .01$.

decrease the amount by which athletes' center of gravity moves in a 2D plane during two balance exercises: standing on both feet with eyes closed and standing on right foot with eyes open, with the 30 Hz and 50 Hz groups experiencing similar changes.

Total distance the center of gravity moved on the x axis. In all four exercises, the 30 Hz group experienced decreases of 164.54 mm, 70.04 mm, 117.89 mm, and 84.80 mm, and the 50 Hz group experienced decreases of 228.57 mm, 53.03 mm, 237.27 mm, and 138.84 mm. Furthermore, the participants within the groups experienced varying degrees of decreases in all four exercises. The differences experienced in the NSEO exercise were significant ($p < .05$). The differences experienced in the NSEC, OLRSEO, and OLLSEO exercises were extremely significant ($p < .05$). Therefore, different vibration frequencies can effectively decrease the total distance that athletes' center of gravity moves on the x axis during single foot and double feet balance exercises, with the 50 Hz groups experiencing more significant changes.

Total distance the center of gravity moved on the y axis. In the NSEO and NSEO exercises, the 30 Hz and 50 Hz group experienced decreases, but the changes within the groups were not significant ($p > .05$). In the OLRSEO and OLLSEO exercises, the groups experienced decreases of 111.71 mm (17.13%) and 80.64 mm (13.93%) and 120.17 mm (19.03%) and 120.57 mm (19.29%), respectively. The differences within and between both groups were extremely significant ($p < .01$). Therefore, vibration training can significantly change the amount by which the center of gravity moves on the y axis while standing on one foot. It can effectively reduce the total distance by which athletes' center of gravity moves on the y axis. Moreover, 50 Hz training is more effective.

Maximum displacement of center of gravity as it rocks on x axis. The maximum displacement of the center of gravity as it rocked on the x axis decreased in all four exercises. In terms of the NSEO exercise, the differences between and within groups were significant ($p < .05$) (30 Hz group showed a decrease of 29.37% and 50 Hz of 12.10%). In terms of the NSEC and OLRSEO exercises, the differences between groups and within groups were extremely significant ($p < .01$) (the 30 Hz group showed a decrease of 38.08% and 125.32% and the 50 Hz of 43.62% and 16.58%, respectively). Therefore, vibration training can cause significant changes in the total distance that the center of gravity moves as it rocks on the x axis during single and double leg balance exercises, that is, it can effectively decrease the maximum distance the center of gravity moves as it rocks on the x axis and that the 30 Hz group showed the most significant changes based on the said training.

The maximum displacement of the center of gravity as it rocks on the y axis. The maximum displacement of the center of gravity as it rocks on the y axis decreased in all four exercises, but the decrease was fairly small. There was no significant difference both within and between the 30 Hz and 50 Hz groups ($p > .05$). Therefore, vibration training (at different frequencies) does not have a significant influence on the maximum displacement of athletes' center of gravity as it rocks on the y axis during single and double leg standing exercises.

Conclusions

1. Vibration training (at different frequencies) can increase athletes' lower limb strength. Eight-week vibration training courses can significantly increase long jump athletes' lower limb max strength, fast strength, and reflex strength. The 50 Hz group received more benefits from said training in terms of reflex strength than the 30 Hz group.
2. Vibration training (at different frequencies) can increase athletes' specialized fitness indicators. Eight-week vibration training courses can significantly increase long jump athletes' 100-m 8-step run-up long jump, 4-step run-up level 5 single foot jump, 4-step run-up level 5 jump, etc. In addition, 50 Hz training yields better effects than 30 Hz training.
3. Vibration training (at different frequencies) actively affects long jump athletes' balance. After an 8-week course of training, we gave the athletes single foot and double foot standing tests and discovered that with the exception of the maximum displacement of the center of gravity as it rocks on the y axis, the other indicators showed significant changes. These include the center of gravity speed on the x and y axes, displacement of the center of gravity in a 2D plane, movement of the center of gravity on the x and y axes, and maximum displacement of the center of gravity on the x axis. The 30 Hz group gained more benefits in terms of the center of gravity speed on the y axis and maximum

displacement of the center of gravity as it rocks on the x axis in all four exercises. The 50 Hz group gained more benefits in terms of the center of gravity speed on the x axis and maximum displacement of the center of gravity on the y axis in all four exercises.

4. The 30 Hz and the 50 Hz vibration training can be widely used as effective training methods for long jumpers to develop special lower limb strength and balance ability.

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