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The effect of TRX, combined with vibration training, on BMI, the body fat percentage, myostatin and follistatin, the strength endurance and layup shot skills of female basketball players

Ahmed K. Hassan [a,b,*], Abdulmalek K. Bursais [a], Sobhi Noureldin Ata [a,d], Hossam S. Selim [a], Mohammed S. Alibrahim [a], Badry E. Hammad [c]

[a] Department of Physical Education, College of Education, King Faisal University, Al-Ahsa, 31982, Saudi Arabia
[b] Department of Team Sports and Racket Games, Faculty of Physical Education, Minia University, Minya, 61519, Egypt
[c] Department of Fights and Individual Sports, Faculty of Physical Education, Minia University, Minya, 61519, Egypt
[d] Department of Kinesiology, Faculty of Physical Education, Mansoura University, Egypt

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ABSTRACT

Introduction: Trx Vibration Training (TVT) focuses on using the entire body weight in combination with vibration. While research has separately examined TRX training and vibration training, there is limited literature on the combined effects of these two methods specifically for female individuals. Therefore, the objective of this study was to examine the impact of combining TRX and vibration training (TVT) on various factors including body mass index (BMI), body fat percentage (BFP), myostatin (MSTN), follistatin (FLST), endurance, and Lay up shooting skills of female basketball players. By addressing this research gap, we aim to shed light on the potential benefits of incorporating TRX and vibration exercises into the training regimen of female basketball players.

Method: The study sample comprised 24 female players who were divided into two groups of equal size, with each group consisting of 12 female players: the experimental group (n = 12, age = 19.17 ± 0.68 years, height = 168.33 ± 0.89 cm, weight = 67.00 ± 2.17 kg, training age = 4.54 ± 0.45 years) and the control group (n = 12, age = 19.33 ± 0.78 years, height = 168.08 ± 2.02 cm, weight = 67.33 ± 1.50 kg, training age = 4.58 ± 0.52 years). The experimental method was employed in the study. For eight weeks, the program was used (TVT), with the experimental group participants completing three training sessions each week. The TVT training lasted between 30 and 45 min, out of the overall training session time, which ranged from 90 to 120 min. The control group used a conventional program without Trx Vibration training. Study variables were evaluated before and after the intervention, and a two-way ANOVA was used for repeated measures.

Results: The results of the study showed the superiority of the experimental group over the control group in BMI (p = 0.037, [d] = 0.64), BFP (p = 0.001, [d] = 2.97), FLST levels (p = 0.029, [d] = 0.68), MSTN (p = 0.001, [d] = 2.04), endurance (CMS) (p = 0.001, [d] = 4.56), and Lay up skill Y (s) (p = 0.001, [d] = 4.27), Y (sc) (p = 0.012, [d] = 4.27).

Conclusion: The results showed that, when comparing the two groups, the TVT program significantly improved the study's variables. Basketball players' motor abilities and skill performance

* Corresponding author. Department of Physical Education, College of Education, King Faisal University, Al-Ahsa, 31982, Saudi Arabia.
E-mail address: amohhamed@kfu.edu.sa (A.K. Hassan).

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improved after eight weeks of training, and coaches are advised to take this into account when developing seasonal training plans.

1. Introduction

Basketball has long been recognized as a physically and skillfully demanding team sport [1]. It is widely played and enjoyed by participants and viewers in many nations around the world, attracting the attention of scholars [2–4]. In recent years, coaches have incorporated modern training resources and techniques to enhance players' performance. One such training method is the combination of TRX (Total Resistance Exercise) with vibration training (TVT), which provides an additional stimulus to control and rehabilitate damaged tendon muscle regions through oscillatory motion [5]. This approach considers factors such as amplitude, frequency, and volume to optimize the benefits. Total resistance training aims to improve balance, speed, force endurance, and power in the body [6]. The mechanical action of vibration training induces changes in the length of the muscular tendon complex, which are detected by sensory receptors. This, in turn, leads to alterations in muscle contraction through reflex muscle activity and the activation of muscle spindles [6]. Studies have shown that higher vibration frequencies (35–45 Hz) used in conjunction with attachment cords for static and dynamic exercises significantly increase muscle activation compared to lower frequencies (35 Hz) [7,8]. TVT is a sophisticated form of resistance training that does not rely on traditional weights. Instead, it utilizes vibrations to target and enhance all types of muscular strength. The intensity of the training can be adjusted by altering the body's position in relation to the vibration, making it suitable for both beginners and elite athletes.

TVT, is a training method that utilizes full body weight with vibration to enhance athletic performance and provide a competitive advantage. This form of training incorporates both single- and multi-exercise sets, utilizing gravity and body weight as resistance [9]. The use of vibrational stimuli during training has been shown to improve strength and athletic performance in athletes [10]. In the development of TVT, the TRX system and similar devices, created by Fitness Anywhere LLC in San Francisco, California, were taken into consideration. These devices are designed for resistance training in suspension or via traction, utilizing non-stretch belts that allow users to grip or connect themselves to one end while the other end remains attached to a fixed structure [11].

Trx vibration training (TVT) is effective in promoting dynamic muscle work and activating sensory muscle receptors, leading to increased muscular contraction force and tendon stabilization [12,13]. Additionally, TVT has been found to benefit lymphocytes and blood circulation, as it involves muscle fiber contraction and relaxation processes [14]. Several studies have demonstrated that TVT workouts contribute to functional improvements, particularly in the musculoskeletal systems of athletes participating in sports such as football, basketball, figure skating, and volleyball, resulting in enhanced motor skill transfer [13–15].The availability of a wide range of modern training methods and tools has significantly improved training processes [16,17], especially those that do not require expensive equipment. For example, a study showed that TRX exercise helped active women reduce their body fat percentage and improv e upper and lower body strength and endurance [18]. Another study involving postmenopausal women found that low, moderate, and high intensity TRX training significantly reduced hot flashes, improved mood, decreased body fat, and increased muscular endurance [19,20].

A recent study has found that individuals who engage in regular exercise have higher levels of myostatin in their serum, which has been associated with improved physical fitness [21]. Conversely, follistatin, also known as chemerin, is an adipocytokine that regulates adipocyte activity and glucose metabolism [22]. It has been shown that aerobic exercises can decrease chemerin levels [23]. Therefore, physical activity affects both myostatin and follistatin, with myostatin being linked to increased physical fitness and follistatin being reduced by aerobic workouts [24,25]. The purpose of this study was to examine the effects of combining vibration training and TRX on female basketball players' body mass index (BMI), body fat percentage, myostatin and follistatin levels, strength endurance, and layup shot proficiency. This research was crucial as female basketball players were found to have deficiencies in both physical strength and layup shot skills.

2. Materials and methods

2.1. Study participants

We used Steven K. Thompson's equation [26] to calculate the sample size. The study population consisted of 26 female basketball players (N = 26). The confidence level was set at 95 % (z = 1.96), the error proportion was 0.05 (d = 0.05), and the proportion was 0.5 (p = 0.5). Therefore, the initial sample size was determined to be 25 players (n = 25). However, one female player dropped out of the study and was excluded, resulting in a final sample size of 24 female basketball players. These participants were randomly assigned to two groups: the experimental group (n = 12) with an average age of 19.17 ± 0.68 years, height of 168.33 ± 0.89 cm, weight of 67.00 ± 2.17 kg, and training age of 4.54 ± 0.45 years; and the control group (n = 12) with an average age of 19.33 ± 0.78 years, height of 168.08 ± 2.02 cm, weight of 67.33 ± 1.50 kg, and training age of 4.58 ± 0.52 years. The research variables were used to assess the homogeneity of the study sample.

Steven K. Thompson's equation:

$$\mathrm{n} = \frac{N \times P(1-P)}{\left[\left[N-1 \times \left(d^2 \div z^2\right)\right] + P(1-P)\right]}$$

n: sample size; N: population size = 26; z: confidence level at 95 % (1.96); d: Error proportion (0.05); p: proportion (50 %)

2.2. Study design

During the intervention period, the female players received training at the YMCA Minya Club basketball court. Pre-measurements were conducted from October 11th to 12th, 2021, with the aim of applying uniform tests to all individuals. The experimental group underwent an eight-week training program using the TRX Pro3 Suspension Trainer (USA) and a Pro5 Power Plate (Power Plate® International Ltd., London, UK), as shown in Figs. 1 and 2. On the other hand, the control group followed a traditional program for eight weeks without incorporating TVT. The training sessions for both groups lasted between 90 and 120 min. The experimental group's main training session, lasting between 30 and 45 min, focused on TVT exercises. The program was implemented from October 16th to December 8th, 2021, with a total of 24 training sessions for the female players, conducted three times a week on Saturdays, Mondays, and Wednesdays. After completing the program, the dimensional measurements of both the experimental and control groups were conducted from December 11th to 12th, 2021, following the same procedures and conditions as the previous measurements.

2.3. Ethical considerations

Apermission form for the study was signed by participants after they had been advised of its dangers and the form had been authorized by the institution. The procedure was approved by the King Faisal University Ethics Committee (KFU-REC-2021-OCT-ETHICS620).

2.4. Instruments and procedures

Before collecting blood samples for testing follistatin and myostatin levels, the female players were instructed to fast for 12 h and refrain from physical activity. The blood samples were taken in the early morning after fasting overnight with at least 8 h of sleep. To prevent contamination, the area where the sample would be taken was disinfected using an antiseptic cleaner. A small needle was then used to draw a 5 ml blood sample from the cubital vein, which was placed in a tube containing an anticoagulant. The sample was kept at a low temperature in a refrigerator or freezer before being used for testing. A qualified medical professional conducted the laboratory-based biochemical analysis, and the results were delivered. The measurements were taken 48 h before the first training session and 48 h after the last training session. The serum concentrations of MSTN and FLST were measured using human MSTN and FLST ELISA kits (CKE11241 and CK-E10682) (human myostatin, Glory Science Co., Del Rio, TX, USA; human follistatin, Glory Science Co., DelRio, TX, USA). Their heights were determined using the Martin anthropometer, whose precision has already been shown [19]. The InBody 720 tool (InBody Co., Seoul, Republic of Korea) was used to calculate the body weight, BMI, and BFP; the validity of this instrument has been discussed previously [27,28]. Force endurance and layup shot skills were measured 24 h after the body composition measurements and the blood analyses.

2.4.1. Core Muscle Strength

Baseline muscle strength was assessed by having participants attempt to maintain a forearm plank for as long as possible. They were

Fig. 1. (Trx PRO3 suspension trainer system, USA) (Appendix A).

Fig. 2. a Pro5 power Plate (Appendix A) from power Plate International ltd. in London, UK.

instructed to position their elbows at a 90-degree angle and touch the floor just behind their shoulders. The head, shoulders, hips, knees, and ankles had to be aligned in a straight line. Prior to the test, participants were shown a visual representation of the correct posture and were instructed to maintain this position for as long as they could. Isometric plank fixation has been recognized as a valid and reliable method for evaluating fundamental muscle function [10,29].

2.4.2. Lay-up shooting test

Lay-up shooting was evaluated using the time taken from the starting line to the basket and reaching the starting point three times with a tan score calculated for each shot [See Fig. 3]. The players were asked to perform the test, where four cones were placed on one line, with the fourth funnel followed by the goal. A starting line is drawn 65 feet (19.5 m) from the target, the distance between the starting line and the second cone is 20 feet (6 m), and the distance between the rest of the cones is 15 feet (4.5 m), a stopwatch. The running tester starts by standing on a line the start with the ball, when hearing the start signal, the tester runs between the cones with the ball dribbling until he reaches the last funnel and aims at the basket, picks up the ball to return in the same manner with the dribble until he crosses the starting line. After carrying out the actions outlined in the performance standards, the tester's distance travelled from the time of the start signal until it passed the beginning line is determined [30].

2.5. TVT training procedures

The athletes were informed about the training regimens and exercise methods one week prior to the start of the treatment. Over a period of eight weeks, the training regimens were implemented three times per week. Each training session had a duration of 90–120 min. Specifically, the TVT training component took 30–45 min during each session (refer to Table 1 and Appendix C).

2.5.1. Data analysis

A two-way ANOVA for repeated measures was conducted to compare measurements and groups. If interactions were found, post hoc tests were performed using the Holm-Bonferroni correction to account for multiple comparisons. The results were presented in tables as mean and standard deviation. Effect sizes were calculated using the partial eta-square (ηp^2) technique, with Cohen (1988) [31] defining a modest influence as less than 0.01–0.06, a medium effect as between 0.06 and 0.14, and a large effect as greater than 0.14. The significance level was set at 0.05. The statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

3. Results

The results of the pre and post-measurements of the experimental and control groups for the research variables are displayed in Fig. 4. In favor of the post-measurement, we discovered a statistically significant difference between the repeated measures. There are statistically significant differences between the groups, favoring the experimental group.

Pre and post measurements of the experimental and control group in Fig. 4., BMI(Kg/m2) = Body mass index; BFP% = Body fat percentage; FLST(ng/ml) = Follistatin; MSTN(ng/ml) = Myostatin; CMS(s) = Core Muscle Strength; Y(s),(sc) = Lay up shooting test; s

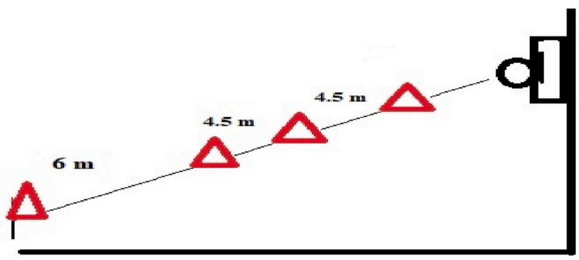

Fig. 3. Lay up Shooting test (Appendix B).

Table 1
TRX Vibrational Training Program.
T,(TRX); V, (Vibration); S,(Skill); TVT (TRX Vibrational Training).

Week	Training	(V)			(T)			(TVT)	
		Intensity	Sec× repeats	Rest	Intensity	Set× repeats	Rest	Intensity × Set × repeats	Rest
1	T&V	30 hz	45× 3	30 sec	60%	3× 15	35 sec		
2	V&T	35 hz	40× 2	30 sec	65%	3× 10	40 sec		
3	T&V	35 hz	40× 3	30 sec	70%	3× 10	40 sec		
4	V&T & S	40 hz	45×3	35 sec	75%	3× 10	40 sec		
5	TVT							35 hz×3×15	35 sec
6	TVT							40 hz×3×10	35 sec
7	TVT&S							45 hz×3×15	35 sec
8	TVT&S							45 hz×3×15	40 sec

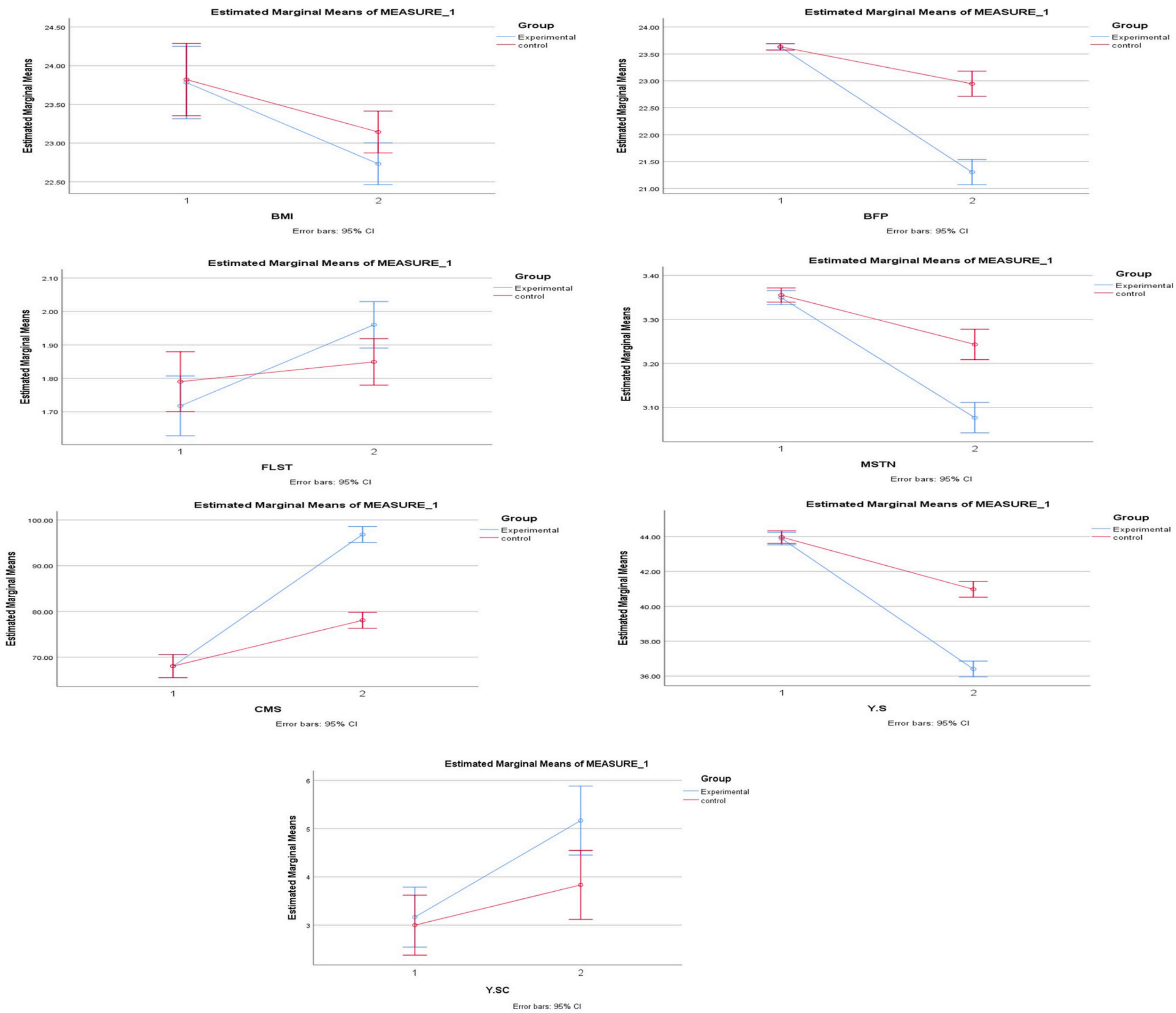

Fig. 4. Scree plot diagram showing mean and standard deviation of the experimental and control group, $p < 0.05$ compared to Pre.

= second; sc = score.

Bonferroni's post hoc analysis showed that the experimental group showed a greater increase in all variables compared to the control group. Table 2 presents ANOVA results. In short, significant effects ($p < 0.05$) were found with (measurement) for all study variables. Main effects of "group" were found in the BFP, MSTN, CMS, and Y (S) test. The "measure × group" interaction was small in BMI, medium in Y (SC), and large in BFP, FLST, MSTN, and Y (S).

Table 2 shows significant differences in measurements, (P = 0.00) for repeated measurements. The (ηp^2) effect coefficient ranged between (0.75 and 0.978). Despite the group It showed a small effect (0.006,0.39) but no FLST or BMI differences that were statistically significant ($P > 0.05$), and the rest of the variables showed significant (P = 0.00) where the (ηp^2) ranged between large effects (0.631–0.819). The results of the interaction also showed that there were non-significant differences in BMI (P = 0.90) and significant differences in the rest of the variables, and the (ηp^2)ranged between (0.647 and 0.911), with a large effect.

Figure (5) shows the results of the post-measurements of the experimental and control groups for the studied variables. We found that the result of the experimental group (BMI, BFP%) was (22.73 ± 0.30 kg/m^2;21.30 ± 0.49 %) and the control group was (23.14 ± 0.56 kg/m^2;22.95 ± 0.25 %). Whereas the FLST levels resulted in the experimental group of (1.96 ± 0.13 ng/ml) and control group of (1.85 ± 0.08 ng/ml).the MSTN Levels resulted in the experimental group of (3.08 ± 0.03 ng/ml) and control group of (3.24 ± 0.07 ng/ml)(P = 0.005). where we found that the result of CMS, the experimental group was (96.83 ± 1.19 s)and the control group was (78.07 ± 3.94 s),and found that the result of Y,the experimental group was(78.07 ± 3.94s),and found that the result of Y,the experimental group was (36.41 ± 0.89 s; 5.17 ± 1.03 sc)and the control group was (40.98 ± 0.60s; 3.8 ± 1.3 sc)($P < 0.05$)..

Pre- and post-measurement findings in the variables under study for the experimental and control groups in Fig. 5. BMI(Kg/m^2) = Body mass index; BFP% = Body fat percentage; FLST(ng/ml) = Follistatin; MSTN(ng/ml) = Myostatin; CMS(s) = Core Muscle Strength; Y(s),(sc) = Lay up shooting test; s = second; sc = score.

4. Discussion

We conducted a study to investigate the effects of combining TRX and Vibration Training on various physical parameters of female basketball players, including BMI, BFP, FSTN, MSTN, muscular capacity, strength endurance, and layup shot skills. The statistical analysis revealed significant decreases in BMI and BFP after the TVT training provided to the female basketball players in our study. The experimental group showed superior results compared to the control group in terms of BMI and BFP, which is consistent with previous research [9,28,32] indicating improved BMI and lower BFP. Several researchers [9,17,33] have agreed that standardized training programs incorporating TRX and Vibration Training, which involve a variety of physical exercises, can increase calorie consumption and fat metabolism, leading to improved fitness and increased fat burning. This is accompanied by an increase in muscle tissue, resulting in improvements in BMI and BFP. TVT can also reduce body fat by increasing daily energy expenditure, suppressing appetite, and promoting the release of growth hormones [34–36].

The experimental group showed a significant increase in FLST levels and a decrease in MSTN levels compared to the control group. This resulted in better performance by the experimental group. These findings are consistent with the results of other studies [37–39], including Bagheri et al. [34], which also found an increase in FLST levels and a decrease in MSTN levels after eight weeks of different procedures. Laurentino et al. [40] also reported a decrease in blood myostatin and an increase in serum follistatin after resistance training compared to the control group. Several other studies [41–44] have also reported similar results, with an increase in FLST and a decrease in MSTN after resistance training. Hittel et al. [45] found a decrease in MSTN following both resistance and endurance exercise.

In a controlled study, it was observed that physical activity had a significant impact on increasing circulating FSTL-1 levels in healthy participants [46]. Furthermore, resistance training has been proposed as a means to decrease serum myostatin and follistatin levels, potentially leading to a reduction in muscle atrophy and an increase in muscle growth [47]. The influence of physical activity on myostatin and follistatin levels can have implications for muscle metabolism and overall health [48].

Furthermore, the average results for the pre- and post-measurements of the experimental group indicate variations in endurance (CMS) among the female basketball players. The experimental group performed better than the control group in terms of CMS. The researchers attributed these improvements to the TVT course, as it had a positive impact on the physical abilities that were the focus of

Table 2
Analysis of variance with effect size (ηp^2) values for the main effects (measurement and group) and interaction (measurement group).

	Measurement			Group			Group × Time Interaction		
	F	P	ηp^2	F	P	ηp^2	F	P	ηp^2
BMI(Kg/m^2)	87.810	0.00	0.75	0.887	0.356	0.39	3.153	0.90	0.125
BFP%	338.159	0.00	0.939	99.416	0.00	0.819	99.868	0.00	0.819
FLST(ng/ml)	109.286	0.00	0.832	0.132	0.720	0.006	40.364	0.00	0.647
MSTN(ng/ml)	262.320	0.00	0.923	37.650	0.00	0.631	45.561	0.00	0.674
CMS(s)	964.574	0.00	0.978	48.885	0.00	0.690	225.969	0.00	0.911
Y(s)	550.769	0.00	0.962	195.631	0.00	0.899	101.001	0.00	0.821
Y(SC)	90.829	0.00	0.805	3.020	0.096	0.121	15.40	0.001	0.412

BMI= Body mass index; BFP=Body fat percentage; FLST= Follistatin; MSTN = Myostatin; CMS=Core Muscle Strength; Y= Lay up shooting test; s = second; sc = score.

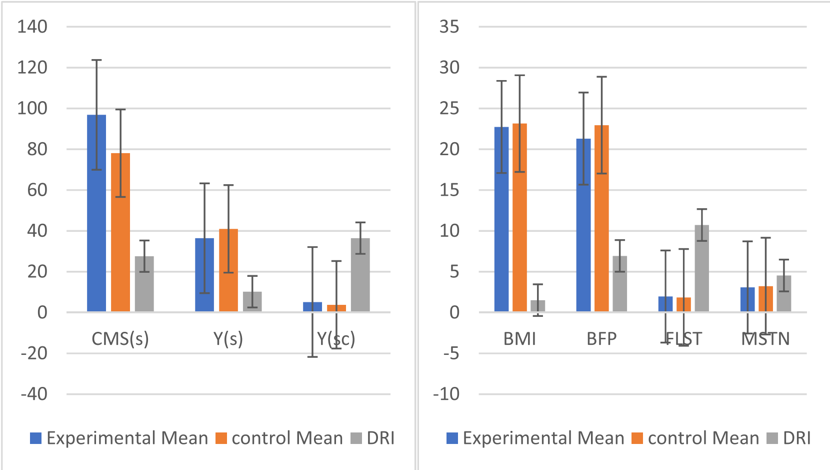

Fig. 5. Scree plot diagram showing mean and Differences improvement rates of the experimental and control group. Error bars: SD. $p < 0.05$.

Table 3
Descriptive statistics and post hoc differences between the experimental and control groups for the investigated variables.

Variables	Experimental		control		Cohen's d	DRI	P-value
	Pre - Test Mean ± SD	Post - Test Mean ± SD	Pre - Test Mean ± SD	Post - Test Mean ± SD			
BMI(Kg/m^2)	23.78 ± 0.78	22.73 ± 0.30	23.82 ± 0.78	23.14 ± 0.56	0.64	1.52 %	0.037
BFP%	23.63 ± 0.10	21.30 ± 0.49	23.63 ± 0.10	22.95 ± 0.25	2.97	6.94 %	0.000
FLST(ng/ml)	1.72 ± 0.18	1.96 ± 0.13	1.79 ± 0.11	1.85 ± 0.08	0.68	10.72 %	0.029
MSTN(ng/ml)	3.35 ± 0.02	3.08 ± 0.03	3.36 ± 0.03	3.24 ± 0.07	2.04	4.54 %	0.000
CMS(s)	68.03 ± 4.21	96.83 ± 1.19	68.06 ± 4.22	78.07 ± 3.94	4.56	27.62 %	0.000
Y(s)	43.88 ± 0.70	36.41 ± 0.89	43.97 ± 0.47	40.98 ± 0.60	4.27	10.23 %	0.000
Y(sc)	3.17 ± 1.03	5.17 ± 1.03	3.00 ± 1.04	3.8 ± 1.3	0.79	36.46 %	0.012

BMI= Body mass index; BFP=Body fat percentage; FLST= Follistatin; MSTN = Myostatin; CMS=Core Muscle Strength; Y= Lay up shooting test; s = second; sc = score; SD= Standard deviation; DRI = Differences improvement rates.
Table (3) shows the results of measurements for the experimental and control groups in the studied variables of basketball players, ($p < 0.037$) at the indicative level (0.05), where it was found that the value of " d" ranged between (0.64–4.56), and the differences in improvement rates ranged between (1.52 and 36.46 %).

the study. The course allowed for multiple repetitions of a performance with high efficiency. The inclusion of various workout types enabled consistent growth from week to week and increased the number of repetitions by extending the performance duration. This progress was logical and natural, resulting in improved physical abilities due to the external load imposed by TVT. These improvements had a direct impact on the participants' performance in the skills under investigation. TVT is also an effective training approach for enhancing and developing physical capabilities, including muscular ability and strength, while also providing enjoyment. The program includes numerous exercises designed to improve individual performance. These exercises are characterized by their diverse composition, intensity, and the participants' motivation to perform, all of which influenced their physical and motor skills. These findings support previous studies [9,12,13,45] that demonstrated the effectiveness of TVT in enhancing fitness, particularly in terms of ability and strength. These studies [14,49,50] showed that resistance training can improve physical fitness and athletic abilities in various sports such as tennis, swimming, football, basketball, wrestling, martial arts, gymnastics, and others.

Based on their research, Cardinale, M., & Bosco, C. [5], Tseng, S.-Y. [10], Lui, J. et al. [13], concluded that focusing on the development of muscular ability, agility, and strength endurance through TVT (Total Vibration Training) has a positive impact on achieving muscular balance. Additionally, this training method also enhances strength, balance, compatibility, and flexibility. Colson, Serge S. et al. [39] examined the benefits of a 4-week full-body vibration training program in conjunction with traditional training for basketball players. The study findings suggest that incorporating this training regimen during the preseason workouts can be an effective short-term stimulus to improve knee extensor strength and SJ (Squat Jump) performance, ultimately enhancing basketball players' overall performance levels.

The experimental group outperformed the control group in both Y (sec) and Y (sc), indicating that the experimental group showed improved lay-up shot skills (sec and score). This improvement was attributed to the use of TVT, which offered various workout types with different difficulty levels (introductory, intermediate, advanced, and composite). When designing and selecting exercises, it is important to include a range of actions such as different types of leaps, rotations, and fast rotations. Additionally, incorporating variations in arm movements at the start or break of movements can be beneficial. The enhanced physical capabilities of the players resulted in improved performance abilities, supporting the theory. The findings of a study by Hassan, A. et al. [14] revealed that resistance training not only strengthens the players' body components but also enhances their skilled performance within training facilities. Another study by Sanjaya M. et al. [30] examined the impact of rope skipping exercises on basketball players' lay-up shooting ability and found that both resistance training and rope skipping exercises improved lay-up shooting performance. Based on these findings, it can be concluded that the hypothesis predicting significant differences between pre- and post-measurements of female basketball players'BMI, BFP, MSTN, FSTN, strength endurance, and lay-up shot skills in favor of the post-measurement is supported.

4.1. Strengths and limitations

The study aimed to assess the impact of TVT training on basketball players' body mass index, body fat percentage, FLST, MSTN, and lay-up shooting performace. The findings of this study support the combination of vibration training with TRX exercises. However, it is important to acknowledge the limitations of this study. Firstly, the small sample size raises concerns about the generalizability of the results. Secondly, the study did not control for factors such as athletes' eating and sleeping patterns, technology usage, or other daily activities. Further research is needed to gain a more comprehensive understanding of these phenomena and to assist coaches and players in developing more effective training schedules. Additionally, future studies should include male players to examine any gender- or sport-specific differences.

5. Conclusions

The use of TRX vibratory training (TVT) for a duration of eight weeks resulted in significant improvements in the physical fitness of female basketball players, as indicated by a reduction in their BMI and BFP ($p = 0.001$). Additionally, the players exhibited higher FLST levels ($p = 0.001$), lower MSTN levels ($p = 0.001$), and improved force endurance ($p = 0.001$). These findings suggest that TVT can enhance the performance of female basketball players by increasing their physical fitness levels. Furthermore, the stability and agility of the players during skill competitions were positively influenced by TVT. In terms of specific variables, the experimental group outperformed the control group in terms of BMI ($p = 0.037$), BFP ($p = 0.001$), FLST levels ($p = 0.029$), MSTN ($p = 0.001$), strength endurance ($p = 0.001$), and lay up shooting ($p = 0.012$). This indicates that the TVT program had a favorable impact on the measured variables. Given the significance of these results for athletes, we recommend highlighting the use of TVT for basketball players and potentially extending this recommendation to other sports. Trainers should consider incorporating this type of training into seasonal training programs. Additionally, further research should be conducted to explore the benefits of TVT for improving both the physical and technical aspects of basketball, particularly at different age levels.

Ethical approval

The study was approved by the King Faisal University Ethics Committee (protocol code KFU-REC-2023-JAN ETHICS620, approved on 15/2/2023).

Informed consent statement

Consent was obtained from all study participants.

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Data availability statement

Data included in article/supp. material/referenced in article.

Additional information

No additional information is available for this paper.
The following is the Supplementary data to this article.

CRediT authorship contribution statement

Ahmed K. Hassan: Writing – original draft, Conceptualization. **Abdulmalek K. Bursais:** Methodology. **Sobhi Noureldin Ata:** Resources. **Hossam S. Selim:** Funding acquisition. **Mohammed S. Alibrahim:** Formal analysis. **Badry E. Hammad:** Writing – original draft, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix (A):1) The TRX Pro 3 System is the prime suspension trainer for full-body workouts [9]

2) The attachment includes information about the Power Plate Pro5 vibration trainer, such as its dimensions, maximum load, and power supply. The preset frequencies range from 25 to 50 Hz, with 1 Hz intervals. The vibration power output (amplitude) can be either low or high. The trainer utilizes Precision Wave TM-based technology, specifically the Twin Motor System with Dual Sync TM. This technology ensures precise balance at every frequency and amplitude level, resulting in exceptional performance and outcomes.

Appendix (B): Tests

This section contains the tests used in the study (Core Muscle Strength- Lay up Shooting.

Appendix (C): Program

This appendix contains TVT program days, weeks and months of training program, each training has intensity, volume, frequency and combinations for female basketball players.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20844.

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