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Change in certain physical fitness factors after the whole-body vibration and strength training

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ABSTRACT

The purpose of the present research was a comparative study of the effect of whole-body vibration and strength training on dynamic balance in students. From the male students of IAU, Abhar Branch, 90 students voluntarily participated in the research. The participants were divided into three groups of 30 subjects– vibration training, strength training, and control. Star Excursion Balance Test was used to estimate the dynamic balance of the subjects in the pretest and posttest. Accordingly, the reach distance of the subjects in the eight directions of SEBT was measured in cm, divided by leg length and multiplied by 100, yielding subjects' reach distance as an ability to maintain balance. Muscle endurance was estimated by sit-ups, agility by36-meter run, and speed by 60-meter run. After obtaining the pretest data, the vibration training group undertook WBV exercises for six weeks and the strength training group performed strength exercises in a similar period. During this period the subjects in the control group continued their normal daily activities. Descriptive statistics, one-way analysis of variance, and Tukey's post hoc test were applied for data analysis at the 0.05 significance level. The results of one-way ANOVA showed that in the pretest there was no significant difference between the subjects of the three groups in dynamic balance ($P > 0.05$), yet this difference was significant in the posttest ($P = 0.001$). Given the findings of the research, it can be recommended to physical fitness trainers and sport planners to make use of strength and vibration training for improving dynamic balance at different stages of general preparation, especially WBV training due to having greater effectiveness and reducing the risks of injury.

Keywords: Vibration training, Strength training, Dynamic balance, SEBT.

INTRODUCTION

Training is defined as any organized and systematic exercise that is meant to improve the performance of athletes [1], and it is divided into different types with respect to the specific functional needs of athletes. One of the types of training used by athletes for improving various functions are strength and plyometric training, the latter being a special type of strength training for converting strength into power. Using strength training has a millennial history, but during the past 20 years and with the strife of some strength athletes it has turned into a major part of the training program of most athletes. Historically, strength training was performed to increase strength and muscle size. Recently, however, it has been also used for increasing power, increasing muscle stiffness and tonicity, helping with rehabilitation, preventing injures, and helping to maintain muscle function in the decliningyears [2]. Also over the last decade vibration training has received special attention. Whole-body vibration (WBV) is a training method in which people stand on a vibration platform that vibrates, creating vertical displacement, and the generated waves are transmitted to the body from the point where the body meets the platform [3].Research has shown that WBV may be another training method for those who are less willing to participate in sport classes and/or have problem with traditional training methods due to injury or reduced ROM in certain body joints [4]. Since WBV exercises are done while the individual is standing on the vibration platform, there is less possibility of the occurrence or development of exercise-induced injuries such as falls or stress fracturesand WBV can be introduced as an effective training method. The studies carried out on vibration training have reported post-exercise improvement in the neuromuscular system [5].

Balance is one of the essential elements of almost all daily and personal activities and a determinant in examining the functional ability of athletes [6]. Gambetta and Gray (2001) consider balance as the most important ability involved in different types of activity of the athlete [7]. Balance is divided into static, semi-dynamic, and dynamic [7] and all the three forms, in particular dynamic balance, are needed in sports. Dynamic balance is the ability of the individual to maintain balance from the dynamic to static state [7]. Dynamic balance provides an innate protection against injury in such sports as volleyball, basketball, or skiing that require quick reactions [8]. Assuming and maintaining balance in the static state or during exercise requires enough power generated by muscles and exertion of the power on the bones. This entails a complex interaction between musculoskeletal and nervous systems. The neural components needed for maintaining balance in the static state consist of motor processes (neuromuscular synergies), sensory processes (the visual, vestibular, and sensorimotor systems), and higher neural processes [9], while mainly somatosensory processes are needed for maintaining dynamic balance [9].

Given the prevalence of ankle and knee injuries due to jumping and cutting movements in sports like volleyball, basketball, and skiing [10], and the role of lower extremity muscles in putting the body in a balanced condition, many training programshave been studied by researchers [10]. Further, due to the need ofathletes for greater improvement in some physical fitness factors in sports where they are more applicable, and the ineffectiveness of some training methods under certain conditions – e.g. injury or overweight – identification of the effects of different training methods on physical fitness factors that are effective for preventing sport injuries is one of the prerequisites of designing training programs.

A review of the literature reveals that there are contradictory results regarding the effect of various training programs on balance. For instance, Torvinen et al. (2002) studied the effect of four-month WBV training on performance and balance and came to the conclusion that there is no significant difference between the control and experimental group in static and dynamic balance after 4 months of vibration training [11]. In contrast, Ivanet al. (2005) studied the effect of a 6-week vibration training period on muscular function, balance, and mobility in elderly nursesand showed that the performance of the experimental group in the balance test was significantly better than the control group [12]. In another research, Mattacola et al. (1997) studied the effect of a six-week strength and proprioception training program on dynamic balance in three subjects with lateral ankle sprains and reported that the interventions did not bring about any obvious improvement in the balance of the subjects [13].However, Kollmitzeret al. (2000) studied the effect of back extensor strength trainingversus balance training on postural control in 26 young, healthy subjects and showed that both strength and balance training improve balance in the subjects [14].Nonetheless, no research was found to have studied the effect of strength and vibration training on static and dynamic balance. Thus, the present research carries out a comparative study of the effect of whole-body vibration and strength training on dynamic balance in university students.

MATERIALS AND METHODS

The researchers sought to study and compare the effect of whole-body vibration and strength training on dynamic balance in university students. Thus, the present research is quasi-experimental with a pretest-posttest design with two training intervention groups and a control group. The male students of IAU, Abhar Branch, who had enrolled in the first semester of the Physical Education program in the period 2010-2011 formed the population of the research of whom 90 students with no record of injury in lower extremities and CNSover the last year and with no regular exercise during the research period voluntarily participated in the research. The subjects were divided into three groups of 30– (1) vibration training, (2) strength training, and (3) control.

Star Excursion Balance Test (SEBT) was used for estimating the dynamic balance of the subjects in the pretest ad the posttest. Considering the standard protocol of this test, 8 directions, spaced by 45°, are drawn on the ground in the shape of a star and the subject has to reach in each of these directions. For normalizing the data, the reaching distance in each direction is measured, divided by the leg length – i.e. the distance between anterior superior iliac spine and interior ankle in centimeters – and multiplied by 100 to yield the normalized reaching distance of the subject in each direction [15]. After providing the necessary explanations regarding the procedures of the test, each subject practiced the test six times. In addition, before beginning the test the preferred leg of the subjects was determined so that if the preferred leg is the right leg, the test would be performed counterclockwise and if the left leg is the preferred one, the test would be performed clockwise. The mean reaching distance in all the directions of the test (in cm) was taken as the ability of the subject to maintain balance [15].

Muscle endurance was estimated by sit-ups test, agility by 36-meter run, and speed by 60-meter run. After collecting the pretest data, the subjects in the experimental groupperformed the following exercises for 6 weeks:
Vibration training

The subjects in the vibration training group performed whole-body vibration training for six weeks, four sessions per week, and 40 minutes per session. This involved standing for 90 s on the device with a frequency of 30 Hz and amplitude of 10 mm in three position: (1) single-leg squat on the preferred leg, (2) single-leg squat on the non-preferred leg, and (3) double-leg squat with 45° trunk flexion. After a 90-second rest, the next stage would start [16].
Strength training

The strength training program was also conducted for six weeks, four sessions per week, and 40 minutes per session. The program involved: (1) squats, (2)split squats, (3) leg press, (4) Hug move (a move for reinforcement of quadriceps and gluteus muscles), and (5) splits with dumbbells.For all the exercises, the training started with eight repetitions and 60% VO_2 max and then the subjects performed 3 sequences of the moves with 6 repetitions and 80% VO_2 max.The training program of both the vibration and strength training groups started with5 minutes of warming up and ended with 5 minutes of cooling down [17].

Descriptive statistics were used for describing the personal characteristics of the subjects and F-test and Tukey's post hoc test were applied at the 0.05 significance level for determining the significance of the data related to SEBT and single-leg standing between the three groups.

RESULTS

Table 1 present the personal characteristics of the subjects of the research by groups. The results of F-test showed that there is no significant difference between the three groups in the factors that affect the balance ($P > 0.05$; table 1).

Table 1: Personal characteristics of the subjects

Variable	Group	Mean (SD)	F	P
Age (Years)	Vibration	24.07 (1.14)	0.87	0.67
	Strength	22.80 (2.32)		
	Control	23.87 (3.17)		
Height (cm)	Vibration	174.2 (1.57)	0.44	1.07
	Strength	171.53 (4.91)		
	Control	176.73 (2.43)		
Weight (kg)	Vibration	70.37 (4.31)	0.59	0.47
	Strength	71.93 (2.31)		
	Control	69.60 (1.13)		

Moreover, no significant difference was observed between the pretest and posttest data of the groups in endurance of abdominal muscles, agility, and speed ($P > 0.05$; table 2).

Table 2: Certain physical fitness factors of 3 groups in pre and post test

Index		Vibration Training	Strength Training	Control	F	P
Pretest	Muscle Endurance (Rep)	64.21±5.27	70.21±4.36	68.21±5.84	0.201	3.56
	Agility (s)	9.41±0.9	9.09±0.8	8.21±0.6		
	Time of 60-Meter Run (s)	7.46±0.3	7.53±0.4	7.54±0.2		
Posttest	Muscle Endurance (Rep)	69.21±6.23	71.21±4.72	69.21±5.86	0.329	4.45
	Agility (s)	9.32±1.4	9.21±0.4	9.51±0.3		
	Time of 60-Meter Run (s)	7.49±0.2	7.73±0.5	8.01±1.01		

The results of F-test revealed that in the pretest there is no significant difference between the three groups in mean balance score ($P > 0.05$). But, after the training intervention for the experimental groups, analysis of variance revealed a significant difference between the data of the groups. The data are presented in table 3.

Table 3: Dynamic balance of subjects

Time	Index Group	Dynamic Balance (Reaching Distance in cm)	F	P
Pre test	Vibration Training	72.21±5.4	2.09	0.652
	Strength Training	76.34±6.2		
	Control	70.9±3.3		
Post test	Vibration Training	90.2±3.7	23.9	0.000
	Strength Training	85.8±2.9		
	Control	71.14±5.2		

The results of Tukey's post hoc test revealed that the difference between the control and vibration training groups ($F = 4.287, P = 0.018$) and between the control and strength training groups($F = 6.021, P = 0.038$) was significant, but no significant difference was observed between the data of the vibration and strength training groups ($P > 0.05$).Comparing the percentage of increase in the data of the vibration and strength training groupwhich is a more precise index of the exercise-induced changes revealed that the subjects in the vibration training group experienced greater increase in dynamic balance than the subjects in the strength training group (17% vs. 11%).

DISCUSSION

The purpose of the present research was to study and compare the effect of whole-body vibration training and strength training on static and dynamic balance of students. The results indicated increased ability of the subjects to maintain static and dynamic balance after the mentioned interventions. No significant difference was observed between the effects of the two training programs. However, Comparing the percentage of increase in the data of the vibration and strength training group as a more precise index of the exercise-induced changes revealed that the subjects in the vibration training group experienced greater increase in dynamic balance than the subjects in the strength training group.

The results of the present research are consistent with previous findings that reported an improvement in static and dynamic balance after a period of strength training (e.g. Kollmitzer et al. [14]) and vibration training (e.g. Ivanet al.[12]). However, the results were inconsistent with the research of Mattacola et al. [13] and Torvinen et al. [11].In addition, the results of the present research showed that whole-body vibration training has a greater effect on the ability to maintain balance than strength training and this was not examined in previous research. Thus, what follows is a discussion regarding the possible reasons for the different effect of these two types of training on balance and the possible mechanisms for such effects.

The effect of whole-body vibration training on balance

One of the most important systems involved in adaptationto vibration training is the neuromuscular system and the coordination between the activity of motor units involved in movement and muscle spindles and Golgi tendon organs. Due to its nature, vibration training will mostly lead to the activation of muscle spindles. However, neuromuscular response to vibration involves activation of the muscle spindles, mediation of the neural signals by Ia afferents, and finally, activation of muscle fibers via large α-motoneurons [11].But theoretically the concept of WBV is based on activation of muscle spindles. Muscle spindlesprovide feedback of the position and extension of muscles to gammamotoneurons. In γ-motoneurons, this response leads to stimulation and increased firing rate of the Ia fibers through the gamma loop, and this is known as alpha-gamma coactivation [12]. Vibration appliedto the tendons and muscles results in intense stimulation and activation of muscle spindles. Activation of muscle spindles leads to tonic vibrationreflex (tonic contraction) in the stretch reflex arcand this has been observed during the application of vibration to muscles [4].The result of activation of muscle spindles is stimulation and preparation of muscles for contraction and increased sensitivityof muscle spindles,and the latter can improve neuromuscular responses [4].

Force generation is a function of various factors such as muscle size, the number of activated motor units, and joint angle [5].Since the initial exercise-induced strength gain is mainly neural and it can increase without a structural change in the size and volume of the muscle [12],these neural adaptations mainly suggest more recruitment of motor units; the more motor units are recruited, the more will increase the power [4]. Another factor in force generation is the level of actin-myosin cross-bridges interaction and it can be asserted that more interactionsbetween cross-bridges will lead to increase in strength. Increased interaction between actin and myosin cross-bridges and recruitment and activation of more motoneurons as a result of vibration training has been observed in various research studies and can be another reason for improvement in performance [16].

Considering the activation of sensory receptors through vibration, it is clear that the vibration applied to various body parts can directly affect the brain [12]. This theory indicates that mobilization of motoneurons in a functional group of muscles and joints for performing a movement and adapting it with the environment and increase coordination and integration of motor units, coactivation ofagonist muscles, and increased inhibition of antagonist muscles [12] which will finally lead to neuromuscular responses through which it can improve athletic performance.
SEBT requires neuromuscular control for the appropriate position of joints and strength of the musculature around that joint during the test [15]. Olmsted et al. (2003) found that during the test the stance leg requires ankle dorsiflexion, knee flexion, and hip flexion. Thus, the lower extremities require proper range of motion, strength, activity of proprioceptors, and neuromuscular control [18]. Hamstring-quadriceps co-contraction occurs while reaching in all the direction of SEBT [15].The quadriceps has the greatest activity in anterior, anterolateral, and posteromedial directions. Since in these anterior directions the person has to lean backwards and keep the trunk in extension so as tomaintain their balance, the gravitational force acting on the upper trunk lead to high knee flexion torque that must be controlled by the extension torque (eccentric contraction) generated by the quadriceps. The activity of vastus lateralis muscle is greatest in the medial and posteromedial directions. This is perhaps due to muscle stability against the muscle forces that are active in reaching for these directions. According to the findings, it can be concluded that increased strength and eccentric control of the quadriceps can improve balance control in these directions and show improvement of injury at different stages [15].

Given the above issues, it is clear that strength of the muscles surrounding and acting on the joint and their co-contraction is of foremost importance in stabilizing lower extremity joints, proper range of motion, and neuromuscular control for maintaining balance while reaching and achieving the greatest distance.

Vibration increases the stimulation threshold of Golgi tendon receptors and they will transmit fewer inhibitory impulses to the CNS and as a result autogenic inhibition decreases [18]. Also vibration leads to the binding of myosin and actin cross-bridges and recruitment of more motor units in a certain activity [3]. All these effects lead to increased strength and as a result the supporting lower extremity muscles can better stabilize the muscles; moreover, increased muscle strength can counteract the torques generated while reaching and the subject can reach farther without making an error. For instance, increased strength of the hamstrings after vibration training can more effectively control the torque generated due to trunk flexion that occurs while reaching in posterior directions, leading to greater reaching distance. Similarly, increased strength in all lower extremity muscles can probably control the torques generated during each of the excursions of SEBT and thus balance improves after vibration training [15].

The effect of strength training on balance
As mentioned before, SEBT requires neuromuscular control for proper position of the joint and strength of the musculature around that joint during the test [15]. The strength of the muscles surrounding and acting on the joint and their co-contraction is of foremost importance in stabilizing lower extremity joints, proper range of motion, and neuromuscular control for maintaining balance while reaching and achieving the greatest distance. Thus, one of the possible reasons for improved of balance as a result of strength training can be associated with increased strength of the lower extremity muscles of the subjects after participating in the strength training protocol. The main reason for strength gain in the first few weeks of strength training is adaptation in the nervous system. It is assumed that changes observed in first 6-8 weeks is due to neural adaptation, but there is no general consensus in this regard [2].
Adaptation in the nervous system leads to increased strength in the following ways:

1. Large, fast-twitch motor units are activated only when large forces are required. It has been suggested that during maximum voluntary contractions, some of these units are not at all activated in untrained individuals. Thus, training can be considered as a way for facilitating the activation of these large, fast-twitch motor units.
2. Changes may occur in the electrical stimulation pattern of motor units, or in the frequency of stimulation, and/or in the synchronous activation of motor units, thus leading to increased strength.
3. The process of removing autogenic inhibition: naturally, internal feedback mechanisms (e.g. Golgi tendon organs) inhibit the body in generating large tensions. But when the body is exposed to high degrees of tension through strength training, sensitivity of these organs may decrease via the process of removal of autogenic inhibition, allowing the individual to approach the capacity of generating absolute maximum force.
4. With the mastering of the nervous system through repetition, muscle coordination increases and this facilitates performance. Meanwhile, the strength training in the present research may have increased balance though applying stress on the neuromuscular systems [14 &17].

Considering the findings of the present research, it can be recommended to physical fitness trainers and sport programmers to make use of strength and vibration training for improving dynamic balance at the general preparation levels, especially whole-body vibration training due to having greater effectiveness and reducing the possibility of injuries.

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