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Annals of Biological Research, 2011, 2 (6):489-495
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Changes in balance and neuromuscular performance following Whole body vibration and aquatic balance training in elderly subjects

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ABSTRACT

The aim of this study was to determine changes in balance and neuromuscular performance following Whole body vibration training (WBVT) and aquatic balance training (ABT) in elderly subjects. Forty five adult male subjects voluntarily participated in study and assigned in to WBVT, ABT and control group (CG) (n = 15 per groups). Timed Up & Go and 5-Chair stand tests were taken as pre-test and post-test and also after four, six, and eight weeks of detraining. Neuromuscular performance and walking ability improved significantly for two trained groups. Significant differences observed between post-test and six and eight week detraining period in WBVT group, while no significant differences seen in these parameters in ABT group. Due to results, ABT are more persistent than WBVT and reduce the risk for falling in male able-bodied elderly individuals. However, WBVT can be recommended as an additional exercise besides ABT.

Key words: Elderly, Whole body vibration training, Aquatic balance training, Balance, Neuromuscular performance.

INTRODUCTION

Falling is among the most common and serious problems whose potential of occurrence increased with ageing. It usually has physical (pelvic fracture, disability, loss of physical ability and death), psychological (loss of confidence and self esteem and life expectancy reduction), and financial consequences [1, 2]. Just from financial aspects, in the United States, $10 billion are annually imposed on families and society for the treatment of hip fractures among elder persons who fall [3]. It has been documented that the causes of falling among elderly subjects could be attributed to internal factors (including lower limb muscle weakness, loss of balance, reduced mental ability, loss of sensory information and slow motor responses) and external factors (factors that are induced by environmental conditions, including psychotropic drugs, environmental conditions such as dim light in passageways, uneven surfaces, moving the base of support and gliding, cumbersome furniture in passageways).

It has been also documented that balance deficit is one of the main risk factors that affect falling among adults [3-5]; therefore, its aspects including rehabilitation of balance is the main concern the researchers and physiotherapist attend to. Balance is a component of basic needs for daily activities and it plays an important role in static and dynamic activities. Postural control or balance system is a complicated mechanism that coordination in three balance systems include visual, vestibular and proprioceptive systems have the basic role in it [6]. It is well proven that the conventional training programs, which had been used to improve balance, significantly affected balance, gait, strength and aerobic endurance; while in some occasion, they led to reduce incidence of falling among adults [7-10]. Though the conventional exercises perform on the ground have benefits for many adults, however, there are certain medical conditions among adult subjects (i.e. osteoporosis, arthritis, stroke and obesity) which, because of pain and/or decrease in joint mobility, decrease their ability to participate or prevent them from doing training programs [11].

Recent findings emphasize that WBVT may provide another way of training for those who are less willing to participate in exercise classes in gyms, or the ones who have difficulty in walking. Since the WBVT done while standing on the Vibration platform, it reduces the probability of risk for injuries such as falling and stress fracture associated with other exercises; it is also possible to introduce WBVT as a suitable method for adults. Studies on vibration have reported improvement in neuromuscular system too [12-14]. A Study conducted by Van Nes & colleagues (2004) supports the idea that WBVT has the potential to be used as a therapeutic tool for reducing the risk for falling and improving postural control in elderly [15] . The probable hypothesis is if WBVT is able to stimulate the muscles effectively, it must have the ability to improve neuromuscular performance, balance and walking ability in adult subjects.

The water environment, due to its unique nature, such as buoyancy, viscosity and hydrostatic pressure, also makes it unique to develop confidence and reduces the effect of weight bearing from the Earth's gravity, and allows adults to be interested in doing exercise and physical activity without Pain [1, 11]. Recent studies have reported multiple gains from exercise in water for the adults, which they include postural oscillations reduction [16], blood lipids diminish, increased maximal oxygen uptake, strength, muscular endurance and flexibility enhancement, increase in the reaching distance [17], as well as greater independence in daily tasks [18]. However, few studies have investigated the effects of aquatic exercise on balance and mobility in the elderly while their results are somewhat ambiguous [1, 17, 19, 20].

Reviewing the literature did not show any studies that compare the effect of WBVT and ABT in the elder group. Also no study was available to consider the effect of detraining (a period after the exercise intervention that subjects do not do any exercise) after ABT, while there are just a few studies which have examined the effects of detraining after WBVT. The purpose of this study was to examine and compare changes in balance and neuromuscular performance following WBVT and ABT in elderly subjects.

MATERIALS AND METHODS

Study Participants

Current study was a Quasi-experimental one with pretest - posttest design on two experimental groups and one control group. Forty five healthy male adults (age: 70 ± 9.6 years, height: 168 ± 6.9 cm, mass: 70 ± 10.5 kg) voluntarily participated in this study; they were randomly assigned in to three groups of WBVT, ABT and CG (15 subjects per group. All participants signed an informed consent document approved by the Institution human subjects review board.

Participants were asked to fully explain the history of possible dislocation of joints and falling. Participants who had a history of falling or suffered from any kind of displacement or dislocation of joint in the past 12 months, or had chronic arthritis or dizziness were excluded.

Study Protocol and Intervention

This study was approved by the university institutional review board. Initially, subjects performed 5-Chair Stand (5CS) and Timed Get Up & Go (TUG) tests which are criteria for neuromuscular performance and walking ability in adults [15, 21-23]. WBVT group performed exercises for eight weeks, three sessions per week and each session about 30 minutes using Whole Body Vibration Plate system, The Nemes-LB Bosco System (Table 1).

Table 1: Whole body vibration training program intervention

Training weeks	1	2	3	4	5	6	7	8	12	14	16
WBVT sets 1 min exercise 1 min rest	5×15 Hz	2×15 Hz 3×20 Hz	5×20 Hz	2×20 Hz 3×25 Hz	5×25 Hz	2×25 Hz 3×30 Hz	5×30 Hz	2×30 Hz 3×35 Hz	First detraining test	Second detraining test	Third detraining test

The ABT group performed exercises in water with the aim of increasing the neuromuscular performance and walking ability for eight weeks and three 60-minute sessions per week in accordance with previous studies done in this regard [1, 17, 19, 24]. All exercises were conducted in water with subjects' chest high depth. Each exercise session in water was divided into three stages: adaptation with water environment, stretching exercises, and static and dynamic ones for balance. ABT was designed to improve the control of center of gravity and ability to combine sensory information, compensatory postural control, and walking. All eight-week activities were progressively consolidated due to manipulated and switching hands position (i.e. cross arms to be placed on the breasts) or an increase in the difficulty of performed activities (i.e. to move with closed eyes, walking in different directions or use the insoles). Duration of each exercise session was approximately 60 minutes, each session were started with a 10-minute warm-up including walking in water, aerobic activity in water, resistance training and flexibility activities; the exercise were ended with 10-minute cool-down one, including static flexibility. The remaining time of each session (about 40 minutes) was allocated to balance and walking exercises in water. Post-tests were performed on three groups after training. After the post-test, to assess and compare persistence of exercises in groups, tests were taken after four, six and eight weeks on all three groups.

Statistical Analysis

Subjects' distribution in groups was normal according to Kolmogorov-Smirnov test. Descriptive statistics, repeated measure ANOVA, and one-way ANOVA were applied to examine and compare changes in balance and neuromuscular performance following WBVT and ABT in elderly subjects. To examine the performance changes in TUG and 5CS tests, a repeated-measure ANOVA with a within-subjects factor (time, including pre-test, post-test, persistence test after four, six, and eight weeks) and a between-subjects factor (three groups) were used. One-way ANOVA with Bonferroni test as Post Hoc was used on each varying levels of within-subjects factor; for further analysis repeated-measure ANOVA was used to examine changes in each group over the five tests (within group) at the significant level of $P \leq 0.05$.

RESULTS

Descriptive data of subjects including age, height and mass is given in Table 2.

Table 2: descriptive characteristics of participants

Group*	Age (yr)	Height (cm)	Mass (kg)
ABT	71 ± (7.4)	168 ± (6.5)	69 ± (11.5)
WBVT	70 ± (8.2)	170 ± (4.9)	71 ± (9.8)
CG	70 ± (8.8)	167 ± (7.9)	70 ± (10.3)

**subjects' distribution in groups are normal*

Repeated-measure ANOVA results on 5CS test showed significant interaction between time (five tests) and groups (3 experimental groups) ($F_{8, 168}$ = 95.33, P = 0.000). Furthermore, the main effect of time ($F_{4, 168}$ = 294.69, P = 0.000) and experimental intervention ($F_{2, 42}$ = 3.01, P = 0.04) were significant. The results of repeated-measure ANOVA (within groups) separately for each groups in 5CS test showed that the effect of time in the ABT group ($F_{4, 56}$ = 307.25, P = 0.000), WBVT group ($F_{4, 56}$ = 155.73, P = 0.05) was significant, but this effect in the CG was not significant ($F_{4, 56}$ = 1.61, P = 0.18).

The result of one-way ANOVA (between groups) for this test showed that the three groups did not have any significant difference in the pre-test ($F_{2, 44}$ = 0.65, P = 0.52), but the performance during the post-test ($F_{2, 44}$ = 7.26, P = 0.002), after four weeks of detraining ($F_{2, 44}$ = 6.12, P = 0.05), six weeks of detraining ($F_{2, 44}$ = 4.55, P = 0.016) and eight weeks of detraining ($F_{2, 44}$ = 3.80, P = 0.03) had significant differences in three groups. Mean and standard deviation in each group during pre-test, post-test, and detraining periods as well as the Post Hoc test results can be seen in Table 3.

Table 3: Mean and standard deviation for training groups in pre-test, post-test, and after four, six and eight weeks of detraining and post hoc test results for the 5-Chair Stand Test

	pretest	posttest	4 weeks detraining	6 week detraining	8 week detraining
ABT	14.30 ± 1.16	12.27 ± 1.31[ac]	12.39 ± 1.31[a]	12.52 ± 1.33[a]	12.82 ± 1.21[a]
WBVT	13.83 ± 1.11	12.41 ± 1.26[bc]	12.82 ± 1.22[d]	13.38 ± 1.16[e]	13.57 ± 1.09[f]
CG	13.97 ± 1.20	13.84 ± 1.16	13.94 ± 1.20	13.87 ± 1.22	13.96 ± 1.14

Significant difference between (a: ABT and CG, b: WBVT and CG, c: pre-test and post-test, d: post-test and 4 weeks detraining, e: post-test and 6 weeks detraining, f: post-test and 8 weeks detraining), all at the p ≤ 0.05.

Repeated-measure ANOVA results on TUG test showed significant interaction between time (five tests) and groups (3 experimental groups) ($F_{8, 168}$ = 34.05, P = 0.000). Moreover, the main effect of time ($F_{4, 168}$ = 104.21, P = 0.000) and experimental intervention ($F_{2, 42}$ = 14.26, P = 0.000) were significant. The results of repeated-measure ANOVA (within groups) separately for each of the experimental groups in TUG test showed that the effect of time in the ABT group ($F_{4, 56}$ = 178.93, P = 0.000), WBVT group ($F_{4, 56}$ = 145.13, P = 0.000) was significant, but this effect in the control group was not significant ($F_{4, 56}$ = 1.19, P = 0.32).

The result of one-way ANOVA (between groups) for this test showed that the three groups did not have any significant difference in the pre-test ($F_{2, 44}$ = 2.57, P = 0.08), but the performance during post-test ($F_{2, 44}$ = 22.52, P = 0.000), after four weeks of detraining ($F_{2, 44}$ = 22.52, P = 0.000), after six weeks of detraining ($F_{2, 44}$ = 13.70, P = 0.000) and after eight weeks of detraining ($F_{2, 44}$ = 25.17, P = 0.000) had significant differences in three groups. Mean and standard deviation in each group during pre-test, post-test, and detraining periods and also the Post Hoc test results can be seen in Table 4.

Table 4: Mean and standard deviation for training groups in pretest, post-test, and after four, six, and eight weeks of detraining and post hoc test results for the Timed Up & Go Test

	pretest	posttest	4 weeks detraining	6 week detraining	8 week detraining
ABT	7.88 ± 0.23	6.75 ± 0.38[ac]	6.79 ± 0.43[a]	6.87 ± 0.40[a]	6.97 ± 0.36[a]
WBVT	7.80 ± 0.31	6.72 ± 0.24[bc]	7.07 ± 0.25[d]	7.48 ± 0.27[e]	7.71 ± 0.34[f]
CG	7.66 ± 0.28	7.59 ± 0.52	7.59 ± 0.53	7.73 ± 0.32	7.75 ± 0.25

Significant difference between (a: ABT and CG, b: WBVT and CG, c: pre-test and post-test, d: post-test and 4 weeks detraining, e: post-test and 6 weeks detraining, f: post-test and 8 weeks detraining), all at the $p \leq 0.05$.

DISCUSSION

The aim of this study was to comparatively examine changes in balance and neuromuscular performance following WBVT and ABT in elderly subjects. The main hypothesis was that adults who participate in WBVT and ABT for eight weeks would significantly improve balance and neuromuscular performance compared against the control group, which will be preserved after four, six and eight weeks of detraining. The results of this study confirm the effect of these training programs on aforementioned factors on the adult samples.

The time of 5CS and TUG tests for post-test in comparison with the pretest declined 10.2 / 13.85 percent in WBVT group and 10 / 14.13 percent in ABT group respectively. Reduce in time of TUG and 5CS tests represent improvement in balance and neuromuscular performance in training groups [21-23]. Although time decline percent in training groups was different for TUG and 5CS tests, these differences were not statistically significant. It shows that balance and neuromuscular performance levels in the posttest compared against pretest significantly improved for two training groups.

Our finding in WBVT group is similar to former studies that have reported improvement in balance and neuromuscular performance after WBVT [12-14, 25, 26]. These effects of WBVT have been diagnosed immediately after exercise [25] and it seems that these results will be more conspicuous in professional athletes than amateur ones [12, 26]. A possible reason for improvement in neuromuscular performance observed in the WBVT group in the present study is the increase in simultaneous recruitment of motor units. It is reported that WBVT increase all identifiable pressure indicators (RPE and blood lactate levels). This process can improve neuromuscular irritability as well as recruitment of more motor units [27, 28]. In addition, simultaneous activity of synergist muscles or increased inhibition of antagonist muscles in lower limbs due to activation of stretch reflex may also justify our results. In this study, subjects stood on the vibration platform with flexed knee (110 degrees); hence, activation in quadriceps muscles (agonist) and inhibition in hamstring groups (antagonist) through stretch reflex increases. This posture can lead to an increase in the recruitment of motor units of synergist muscles through increased involuntary contraction and improve neuromuscular performance.

The results of TUG and 5CS tests showed significant improvement in neuromuscular performance and walking ability in ABT group, which is similar to the results in former studies that examined effect of hydrotherapy among elderly subjects [1, 11, 16, 17, 19, 29]. However, functional tests and intervention programs in these studies were different and a little find it difficult to compare the results. Our findings indicate that resistive nature of water may have increased lower limb muscle strength and it has improved balance and neuromuscular performance in adult groups [30, 31]. On the other hand, water has viscous property that slows down the movement and delays falls in adult subjects; during failure in balance, it provides more time to restore balance [1, 29]. Floating property of water also acts as a supporting factor, which increases self confidence and reduces fear of falling. Using this exercise, we enable the adult subjects to exercise beyond their limit of support without fear of falling [32]. These physiological properties of water have probably improved neuromuscular performance and walking ability in adult subjects. Our findings, however, challenge the results of Chu and colleagues study (2004) [33]. They reported that eight-week training in water had no significant effect on balance in patients with heart attack, while significant improvements in cardiovascular preparation, walking speed and lower extremity strength were observed. However, in their study, balance system was not considered and researchers were of the opinion that the buoyancy of water and use of flotation devices have not challenged balance systems effectively [33].

Detraining is a period after the training intervention when no training is performed. As shown in tables, the times in 5CS and TUG tests reached their initial and before training values in the WBVT group after six weeks of detraining, and there were significant differences between posttest with six and eight weeks of detraining. While in ABT groups, there were not any significant differences in amounts of post-test with four, six, and eight weeks of detraining. The findings imply that the effect of WBVT on balance and neuromuscular performance has returned to its original levels after discontinuation of the training; however, these factors remained to their high levels after discontinuation of the training in ABT. Since the goal of athletic training programs is to maintain their effects on the body, it is likely to say that the effect of ABT is more enduring on balance and neuromuscular performance in adult subjects.

From the physiological perspective, increases in strength due to resistance exercise occur in two phases. At the beginning of exercises, increase in strength is obtained through neuromuscular coordination in the muscles, and then the structural changes and hypertrophy occur in muscles that are considered as increase in strength [28, 34]. WBVT causes activation of vibration tonic reflex [35]; this reflex causes an increase in muscle strength by improving neuromuscular coordination, but the first factors which affect and reduce in detraining period are neuromuscular adaptations. This is the reason why muscle structural adaptations (e.g. muscle hypertrophy) decrease with less speed and lower rates during detraining period. It can justify the cause of fast reduction of neuromuscular performance and walking ability in WBVT group as well as maintenance of training effects in ABT.

CONCLUSION

The results of this study showed that ABT with an emphasis on several senses involved can improve balance. Multi-sensory trainings, which manipulate senses involved in balance, both in stable and unstable levels, may also be an effective tool to improve balance and walking ability in adults. Meanwhile, the use of ABT, due to low-risk nature, providing challenging conditions for balance systems can be an effective way to improve balance and prevent subsequent falls among adults. According to the findings of this study, exercise in water can be recommended as a training method to improve balance and neuromuscular performance for male adults with no history of regular exercise. Meanwhile, probably WBVT can be recommended as complementary training besides ABT.

Acknowledgments
The authors also acknowledge the formal consent and willingness of the adult subjects participated in this study.

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