Effects of Water and Land-based Sensorimotor Training Programs on Static Balance among University Students

Abdolhamid Daneshjoo 1*, Ashril Yusof 2

1. Department of Sports Injuries and Corrective Exercises, Faculty of Physical Education and Sport Science, Shahid Bahonar University of Kerman, Kerman, Iran., 2. Sports Centre, University of Malaya, Kuala Lumpur, Malaysia

ABSTRACT: This study examined the effect of sensorimotor training on static balance in two different environments; in water and on land. Thirty non-clinical university male students (aged 22±0.85 years) were divided randomly into three groups; water, land and control groups. The experimental groups performed their respective sensorimotor training programs for 6 weeks (3 times per week). The Stork Stand Balance Test was used to examine the static balance at pre- and post-time points. Significant main effect between group (P=0.001, η=0.78), and also time (P=0.001, η=0.72) were found. The post-hoc test showed significant differences between training in water compared to control group (P=0.001), while no difference between training on land compared to the control group (P=1.000). The water-based exercises significantly improved balance in the dominant leg with eyes opened (EO; test in water 10.4%, test on land 7.7%), and eyes closed (EC; test in water 8%, test on land 1.7%). Similarly in the non-dominant leg, the water group showed improvement in all conditions (EO; test in water by 10.7%, test on land 6.8%, EC; test in water by 8.8%, test on land 1.6%). However, the land-based exercise just showed improvement of 0.7% in the dominant leg with EO condition. It is concluded that the sensorimotor exercises in water can improve static balance more than on land. We suggest using water-based exercises instead of land-based for improving static balance in the collegiate population.

KEY WORDS water; land; sensorimotor; balance; Stork Stand Balance Test

INTRODUCTION

Researches support that having a good balance is essential to reduce musculoskeletal injuries and improve functional daily activity [1, 2]. American College of Sports Medicine (ACSM) position stand on balance is neuromotor exercises which included balance, coordination, gait, and agility, and sensorimotor training performed; ≥2-3 d week⁻¹, 20-30 min day⁻¹ [3]. Generally, balance could be divided
Effect of water and land-based programs on static balance

into static and dynamic components, and by definition static balance is the ability to maintain the body's center of gravity vertically over the base of support during quiet standing with minimal movement [4].

The relationship between balance ability and sport injury risk among young athletes has been established in many cases, where a decline in balance function is commonly seen followed by injuries e.g. in anterior cruciate ligament tear of the knee and may predispose to recurring injury [5]. So assessment of balance function is important in identifying balance deficits and the subsequent planning of appropriate preventative programs [1, 6]. Static balance may be assessed by having an individual to maintain a motionless position while standing on one or both legs using Flamingo test or Stork Stand Balance Test (SSBT) [1]. SSBT is a functional assessment which is quick to administer, convenient, and low expense, and is a common balance test used by physical educators, sports and exercise science specialists and physiotherapists. The control and regulation of balance depend on continuous feedback systems of processing visual, vestibular and proprioceptive inputs and executing neuromuscular actions [1, 5]. In order to reduce the balance impairment, prevention by exercise training which improves balance seems to be essential. Actually, it is well recognized that physical training permits a decrease in risk factors linked with balance by providing an improvement in static balance [4].

It had been reviewed that exercising in water provides improvement in afferent stimulations, reduction in weight bearing, less fearful of movement, more independent upright postures and facilitate vestibular inputs [7]. Several studies have compared the effect of different water-based and land-based exercises on some physiological factors such as heart rate, blood lactate [8, 9], oxygen uptake [8], lumbar motion and level of physical disability [10]. Few studies focused specifically on comparing the effects of certain exercise program in water and land on static balance. Results by Douris et al. (2003) indicate that both water and land-based program enhanced static balance after 6 weeks of activities (walking, toe raises, heel raises, marching in place, etc.) [11]. A later work also confirms these hypotheses where an 8-week balance specific training program (such as; one leg standing, tandem walking, overhead lifts, kickbacks, shoulder rows, squats, and lunges) carried out in both environments; in water and on land improved static balance [12]. In a related study, an aquatic program improves balance in female with rheumatoid arthritis [13]. In addition, water exercises such as walking, marching, sidestepping, kicking, and twisting have shown improvements in balance among healthy elderly people [14].

Little information has been published regarding the effectiveness of improving stability by sensorimotor training in water and on land. Furthermore, most researches focus on investigating the effects of training in water mainly on elderly and clinical populations, and there is limited research on younger healthy population. Ageing has been associated with decline in sensorial function and muscular weakness of the lower extremities which consequently leads to postural instability and body sway [16]. Since there are vast differences between young and elderly populations; physiological, physical and life style, more attention on young people is merited [15]. Although there has been few studies addressing the issue of whether training in water is better than on land in improving static balance, the findings remain equivocal with few reporting the former is better [14, 17] or no change [11, 18]. This is further complicated by the different methodologies employed by the researchers in their studies; the training program administered, testing protocols employed, age group and health status of participants. In other words it is unknown which exercise program, water-based and land-based exercises, has maximum advantage in improving static balance in the young population. So the aim of this study was to investigate effects of water and land sensorimotor program on static balance in healthy college age population.
Effect of water and land-based programs on static balance

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METHODS

Thirty (n=30) non-clinical male students (moderately active) were randomly divided into 3 groups as listed in Table 1; water group (WG, n=10), land group (LG, n=10) and control group (n=10). All participants were students at the University Malaya. Those without any history of major injuries or diseases participated in this study, while those involved in any sport, which may influence balance abilities, were excluded from this study. The participants were encouraged to maintain similar eating habits and sleeping patterns. All the participants were informed orally about the procedures they would undergo and their written consents were taken. The study was approved by the ethical committee of the Institute of Research Management and Monitoring, University of Malaya and the Sports Centre Research Committee.

Table 1. Demographic Characteristics of the Participants (Values Are Mean ±SD)

<table>
<thead>
<tr>
<th>Groups</th>
<th>WG</th>
<th>LG</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>21.9(0.87)</td>
<td>22.0(0.82)</td>
<td>22.1(0.87)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.72(0.02)</td>
<td>1.67(0.05)</td>
<td>1.71(0.06)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.2(7.95)</td>
<td>63.9(7.5)</td>
<td>64.1(6.31)</td>
</tr>
</tbody>
</table>

y= year; m= meter; kg= kilogram; WG= water group; LG= land group

Procedure

Participants in each group attended a workshop separately to discuss the prescribed training and were instructed on how to perform the exercises correctly. All training sessions were supervised by the same researchers at same time of the day (between 16.00-20.00) to ensure their compliance with the programs. The WG performed sensorimotor training program in water, and LG carried out the same program, but on land. The WG performed the exercises in a swimming pool of shallow water (about; 0.8 m). All participants were encouraged to just perform their respective program and should not be involved in any other activities. Before commencement of the study, the control group was assured that they would receive the sensorimotor training program 6 weeks later.

Before starting the sensorimotor program all participants participated in two familiarization sessions. The pre-test was conducted one day prior to the first day of training, and the post-test 6 weeks later (1 day after the last training session). The static balance testing was performed by a different member of the researcher team who was blinded to the treatment received by the participants (Figure 1).

The sensorimotor training program

The sensorimotor training program followed the same routine for every session. Before starting the sensorimotor training program, the participants carried out a 5-min warm-up. The sensorimotor training program was performed 3 times per week (total of 18 sessions). The training program groups consisted of 50 min specific sensorimotor exercise. In each session 5 min rest was given between different types of exercises. Some of these varied exercises consisted of changing arm position, opening/closing eyes, moving in a different direction or modifying the base of support (Table 2).

Static balance test

Static balance was measured using the Stork Stand Balance Test (SSBT). This test is a standard test with high test re-test reliability (r =0.87), and an inter-rater type of reliability (objectivity; r = 0.99) in terms of assessing static balance among healthy people adopted from Johnson and Nelson (1986) [19]. Moreover, Suni et al. (1996) reported inter-rater ICC values of 0.76 (SEM 13.3 seconds) over a week for 510 healthy male/female adults [20]. The participants were instructed to remove their shoes and placed their hands on their hips (at iliac crests). Then they were asked to lift and hold the opposite leg against the medial side of the knee of the stance leg. The timer was started to record at the time the subjects raised the heel. The trial ended when the heel of the involved leg touched the floor, the hands came
off of the hips, or the opposite foot was removed from the stance leg. This test was conducted with eyes opened (EO) and eyes closed (EC) for dominant leg. The participants performed three attempts and the best time was recorded for analysis [1, 21]. All balance assessments performed by a single investigator.

**Statistical analysis**

To compare the balance between times (pre-and post-tests), groups (WG, LG and control), test environment (water, land), legs (dominant, non-dominant), eyes (eyes opened, eyes closed) the 2×3×2×2 (time vs group vs environment vs leg vs eye) repeated measures mixed design ANOVA was used as described by Holcomb et al. [22]. In case of statistical significance, the post-hoc Bonferroni test was also conducted. Levene's test was employed for assessing homogeneity of variance among groups (P>0.05). Further, the Kolmogorov-Smirnov test was employed for assessing normality of the distribution of scores (P>0.05). The partial eta (η) squared (0.01=small effect, 0.06=medium effect, and 0.14=large effect) was used to tests effect sizes of each variable [23, 24]. The level of statistical significance was set at P <0.05.

**Statistical results**

The means of static balance in pre-and post-tests of the groups are presented in Table 3. The mixed ANOVA indicated significant main effect between group (F_{2,27}=49.23, P=0.001) with large effect size (0.78). The results showed significant main effect in time (F_{1,27}=69.78, P=0.000, η=0.72), leg (F_{1,27}=5.68, P=0.024, η=0.17), eye (F_{1,27}=179.91, P=0.001, η=0.87) and environment of test (F_{1,27}=26.45, P=0.001, η=0.49). Significant interactions between time with group (F_{2,27}=63.33, P=0.001), and environment with group (F_{2,27}=13.48, P=0.001) time with eye (F_{1,27}=34.86, P=0.001) were found. But the results did not show significant interaction between leg with group (F_{2,27}=2.30, P=0.119) and time with leg (F_{1,27}=0.047, P=0.830).

The Bonferroni post-hoc test indicated significant differences between WG compared to control group (P=0.001) and LG (P=0.001). But the results did not show significant difference between LG compared to the control group (P=1.000). The results showed that water-based exercises significantly improved balance in the dominant leg in all conditions (P<0.05). In the non-dominant leg also water group showed improvement in all conditions (P<0.05). But land-based exercise just showed improvement by 0.7 % in the dominant leg of EO condition. No significant improvement were found in the control group (P>0.05) (Table 3).

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**Figure 1. Sequence of actions of testing and training sessions**

Familiarization  ➔  Pre-test  ➔  5-min warm-up + 50-min exercise (18 sessions) on 4-8 pm; supervised by a researcher  ➔  Post-test
Table 2. Exercises, Duration and Intensities of the Structured Sensorimotor Program

<table>
<thead>
<tr>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1:</strong> Toe walk (3 item, each item 20m; straight ahead, toes-out, toes-in), 1 leg partial squat (2 set, each set 15 repetitions), forward backward swing (2 set for each leg, each set 30 repetitions), static high knee (2 set, each set 1 min), 1 leg stand (2 set, each set 1 min), static kick-back(2 set, each set 1 min)</td>
</tr>
<tr>
<td><strong>Week 2:</strong> 1 leg partial squat with weight (2 set, each set 15 repetitions), high knee run (2 set, each set 1 min), toe walk speed (3 item, each item 20m; straight ahead, toes-out, toes-in), max forward backward leg swing (2 set for each leg, each set 30 repetitions), kick-back run (2 set, each set 1 min), static across body swing (2 set, each set 15 repetitions)</td>
</tr>
<tr>
<td><strong>Week 3:</strong> Blind advanced 1 leg balance (3 set, each set 1 min), toe skipping (3 item, each item 20m; straight ahead, toes-out, toes-in), cross body swing and hand swing (2 set, each set 15 repetitions), advanced 1 leg balance (3 set, each set 1 min), 1 leg partial squat with dumbbell swing (2 set, each set 15 repetitions), indo board 2 leg stance (2 set, each set 30 sec)</td>
</tr>
<tr>
<td><strong>Week 4:</strong> 1 leg balance on a wobble board (2 item in AP and ML, each item 1 min for each leg) 1 leg squats with lateral hop (2 set, 10 rep at each set for every leg), blind advanced 1 leg balanced with dumbbell fly (2 item, each item 1 min for each leg), 1 footed heel raise (2 set, each set 15 rep), 1 leg partial squat with adding weight (2 set, each set 15 repetitions), indo board 1 leg stance (2 set, each set 1 min)</td>
</tr>
<tr>
<td><strong>Week 5:</strong> Blind advanced 1 leg balance (3 set, each set 1 min), 1 leg partial squat with dumbbell swing (2 set, each set 15 rep), toe walk speed (3 item, each item 20m; straight ahead, toes-out, toes-in), 1 leg partial squat with adding weight (2 set, each set 15 repetitions)</td>
</tr>
<tr>
<td><strong>Week 6:</strong> Blind advanced 1 leg balance (3 set, each set 1 min), 1 leg partial squat with dumbbell swing (3 set, each set 15 rep), toe walk speed (3 item, each item 25m; straight ahead, toes-out, toes-in), 1 leg partial squat with adding weight (3 set, each set 15 repetitions)</td>
</tr>
</tbody>
</table>

AP= anterior posterior; ML= medial lateral; rep= repetition, sec= second, min= minute

Table 3. Static Balance Test (Values Are Mean ± SD), and Percentage of Change (Δ) [Values Are Mean (95% CI)] From Pre- to Post-Test.

<table>
<thead>
<tr>
<th>Table 3. Static Balance Test (Values Are Mean ± SD), and Percentage of Change (Δ) [Values Are Mean (95% CI)] From Pre- to Post-Test.</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Δ% (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>3.4±2.4</td>
<td>11.1±1.8</td>
<td>7.7(5.6 to 9.8) **</td>
</tr>
<tr>
<td>EC</td>
<td>0.3±0.2</td>
<td>2.0±1.2</td>
<td>1.7(0.9 to 2.5) **</td>
</tr>
<tr>
<td>Land group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>2.2±1.5</td>
<td>2.9±2.2</td>
<td>0.7(0.007 to 1.4) *</td>
</tr>
<tr>
<td>EC</td>
<td>0.3±0.1</td>
<td>0.4±0.2</td>
<td>0.05(-0.08 to 0.2)</td>
</tr>
<tr>
<td>Control group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>2.3±1.3</td>
<td>1.8±1.0</td>
<td>-0.6(-1.3 to 0.1)</td>
</tr>
<tr>
<td>EC</td>
<td>0.4±0.2</td>
<td>0.8±0.9</td>
<td>0.4(-0.2 to 1.0)</td>
</tr>
</tbody>
</table>

EO= eyes opened; EC= eyes closed; *= p<0.05; significant difference when compare pre- to post-tests; **=p<0.01; significant difference when compare pre- to post-tests.
DISCUSSION

The aim of this study was to investigate the effects of water and land sensorimotor programs on static balance in healthy college age population. The study showed that a 6-week sensorimotor training program in water was associated with a significant improvement in static balance from baseline compared to training on land or control among university students. In other words, water-based exercise could be useful to affect the aspects of static balance in healthy male students. Buoyancy and hydrostatic pressure offered by water promote body support and reduce the velocity of falls which might improve learning by providing more time to perform compensatory motor programs [25]. These findings are conflicting with those that reported balance ability could be improved equally through of land-based or water-based exercises [11]. This may be due to the differences in the types of intervention programs and age of our participants (22±0.85 years) to those in the reported study (aged 79±11.8 years). Ageing has been associated with decline in sensorial function and muscular weakness of the lower extremities which consequently leads to postural instability and body sway.

In agreement with our results, Simmons and Hansen (1996) showed that water-based exercise can improve balance more than land-based exercises. The buoyancy of water, exercises can be carried out without overloading the joints, provides extra support for the participant to perform the movement and can be less painful and much easier, which leads to increased subjects compliance with exercise [21]. In addition, the effects of water resistance (i.e., drag forces) may increase energy expenditure due to hydrostatic pressure against the movement [26] and decrease mechanical loads on lower extremities due to no gravity force in the water [27]. The reduced fear of falling in water is another important aspect to be considered [25]. Due to the supportively buoyant environment of the water, participants are able to accomplish skills in the water that would be difficult, too painful, or impossible to perform on land [28]. Because water is more viscous than air, there is resistance to most movement in the water regardless of buoyancy. Viscosity is only noticeable when there is motion through the liquid and acts as resistance to movement because the liquid molecules adhere to the surface of the body [7]. Water provides a low load-bearing form of supplementary training that can be used for recovery and rehabilitation [29]. The influence of the water-based training program is more than land-based on the ability to enhance static balance could also be explained by the fact that exercising in the water require more strength to propel the body forward [30]. There seems to be a positive relationship between strength and balance [31]. This was further substantiated by Bento and co-workers who showed that a 12-week water-based program which included; forward and backward jogging with arms pushing, pulling, and pressing; and leaps, kicks, leg crossovers, improved hip strength [32]. These are the most plausible explanations for the greater improvement of static balance in water- than land-based exercises Based on our results we suggest using water-based intervention exercise instead of land-based programs for improving balance.

The results of present study also showed significant differences between static balance with eyes opened and eyes closed, where static balance was better with opened eyes. These results are in agreement with finding of Daneshjoo et al. (2012) who reported more control in static balance with eyes opened condition than eyes closed in soccer players. Stones and Kozma (1998) also reported better static balance in healthy sighted people compared to blind people [33]. Moreover, Giagazoglou and co-workers (2009) compared static balance between blind and sighted women, and confirmed that vision plays an important role than the coding and processing of other sensory information such as vestibular
and proprioception [34]. It is reported that visual input affected neural control of body sway and that imbalance increases in the absence of vision inputs [34-36].

The present study examined the SSBT time with a stopwatch. Therefore, a limitation of this study was time measuring device. To account for this, time was measured by an experienced researcher, which generated the high reliability of all tests in the present study.

The main finding of present study was that water based exercise is more useful than land based exercise to enhance static balance in male university students. Additionally, the results showed greater improvement in EO than EC conditions. It can be suggested that the sensorimotor exercises in water is appropriate program to improve static balance. This study increases the available data base on the positive effects of sensorimotor program in water on static balance. This information may be useful for college age students to know how they can improve their static balance. The different levels of difficulty of present program may also improve the program’s efficiency which enables coaches and players to individually adapt to the program.

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Conflict of interest: The authors have declared that no competing interests exist.
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