ABSTRACT

Good postural control provides inherent protection against lower limb joint injuries and several studies have been implemented in order to examine the effect of fatigue as an unavoidable component of daily activities and sport exercises on neuromuscular control and lower limb stability but none of them have dealt with the impact of fatigue resulting from the simulated activities of the matches. Thus, the purpose of this study is to examine the effect of the fatigue related to functional and simulated activities of Badminton players on dynamic postural control. Twenty healthy students of the major of physical education who had played badminton for at least two years (age: 21.4 ± 1.63 Yr, weight: 72.1 ± 5.2 kg, height: 175.12 ± 3.5 cm) volunteered to participate in this study. Pretest of Y balance test (YBT), the protocol of functional fatigue composed of six stages, and post-test of YBT were performed. A Multi-variable variance analysis (MONOVA) and paired t-test were used in order to analyze the data. The findings demonstrated a significant difference between the performance of the subjects of the two groups in three directions and the total score of YBT that indicated a decrease in the dynamic postural control after functional fatigue. The results of the study support the hypothesis of the effect of functional fatigue on the decrease in the dynamic postural control of Badminton players. Therefore, they may be in danger of lower extremity injuries.

KEY WORDS: sport exercises, neuromuscular control, limb stability.
INTRODUCTION

Athletes may bother from lower limb injury in all levels of sport events. The main reason of the injuries is unknown; however, good neuromuscular control has been introduced as one of the most important factors in order to prevent the injuries of the lower limbs (1). All of the aspects of neuromuscular control are important in order to prevent and rehabilitate the injuries; nevertheless, it has been shown that postural control can be very important in this field. Postural control has been defined as the process of maintaining and controlling body in the space in order to achieve stability and orientation through complicated coordination between sensory and motor system (2). Postural control can be classified into three groups: static, semi dynamic, and dynamic (3,4). Here dynamic postural control can be defined as performing a functional task without compromising any part of the supporting leg (5) which can be observed in many skills such as: backhand in tennis and badminton and there are a large variety of test to evaluate dynamic postural control system for example: time to stabilization (6,7) (TTS), single-leg hop test (8) and biodex stability system (9). Although these tests assess dynamic postural control in functional situations, they do not evaluate athlete’s stability in sport skills. Star excursion balance test (SEBT) is another way of evaluation of dynamic postural control which is a simple, cheap test having reliability and validity that does not need special equipment and shows the ability lower limb performances in different directions that similar to sport skills (10,12). But because of some limitations (13,15), the test was modified in 2006 and was presented as Y balance test (15).

It has been recommended that even healthy athletes may suffer from lower limb injuries during sport events as a result of muscular fatigue which leads to a decrease in neuromuscular control (1,16). Fatigue is defined as a reduction in force production capacity regardless of the movements performed which is called a phenomenon whose dimensions are not yet thoroughly known (17,18). In order to investigate the effects of fatigue on postural control system, different techniques have been used to exhaust body and limbs, specially lower limbs which include isokinetic contractions (19,20), repetitive motions (17,21), isometric contractions (22,23). Although these techniques are simple and standard methods in relation to fatigue protocols, but they are not practical and relevant or similar to any kind of sport. For this reason, researchers have defined functional fatigue protocol which includes functional activities in order to simulate sport exercises and investigate the effects of fatigue on postural control (1,24,25). Some of the functional protocols have very similar patterns with special sport courses, for example functional fatigue protocol defined by Wikstrom (2003) is very similar to tasks performed in a badminton match (1). Therefore, its’ generalization to the fatigue resulting from sport exercises and events is more suitable. Most of the studies which have
used isokinetic contraction fatigue protocols (19,20), repetitive motions (17,21,26), isometric contractions (17,23), and functional fatigue (1,24,24,27) in order to investigate the effect of fatigue on postural control concluded that fatigue resulted in a reduction in postural control.

Performing of badminton skills in a better way during a match requires an advanced function of lower limbs and dynamic postural control. Considering that the effect of fatigue on postural control is shown, most studies have utilized irrelevant protocols for studying the effects of fatigue on postural control, these studies have mainly examined dynamic postural control by using decorative tests and few studies have been implemented on dynamic postural control by using functional tests. Therefore it seems that there is a lack of researches which have been involved in proving the relation between dynamic postural control and sport induced fatigue. It is necessary to examine the probable relationship between the whole body fatigue and dynamic postural control by using a functional fatigue protocol similar to the badminton and its' events, also using YBT as a functional test to estimate dynamic postural control in order to investigate the effects of exercise and intense sport competitions on dynamic postural control system. Consequently this research is performed in order to examine the effects of functional fatigue resulting from sport on dynamic postural control of badminton players as measured by YBT.

MATERIAL AND METHODS

The present research has studied the effects of fatigue induced by functional exercises on dynamic postural control which has been done measured pre test and post test. The subjects consisted of 20 students of physical education who had played badminton for at least 2 years (age 21.4 ± 1.63 yr, weight 72.1 ± 5.2 kg and height 175.12 ± 3.5 cm), that they were healthy and participated in this research voluntarily. The whole stages of data collection were performed in three days. On the first day YBT was taught to subjects and the fatigue group got familiarized with the performing and practiced it. In second session, fatigue group performed a complete cycle of 6 stages in maximum speed and the record was registered to estimate the fatigue rate accordingly. In third session, pre test of YBT was done And then fatigue group did fatigue protocol after a brief warm-up (5 - 10 minutes of smooth and slow running and lower limb stretching) in a way that every subject did the six stages and the time was registered and they continued doing the next cycle until the time of doing one cycle didn’t exceed one and a half times of the maximum time of a cycle. In other words the subject was tired and the repetition of the cycles was stopped when the time of doing the last cycle was more than one and a half times of doing a cycle with his maximum effort (1). Then YBT post-test was performed.
Dynamic postural control was evaluated by YBT (Y Balance Test™) in anterior, postomedial and postolateral directions (28). Before starting, subjects’ dominant leg was determined in order that if right leg was dominant, the test would be counter-clockwise; on the contrary, if the left one was dominant, the test would be clockwise (29,31). Participants stood on the dominant leg on a centre of Y-Junction shape surface. Then as long as they had no error, they did the reaching via indicators movement in a direction which was randomly selected by examiner, and finally, they returned to standing on double leg position. The errors included leg stance movement, lean on the leg that did reaching and falling. Amount of displacement of indicators was their reaching distance. In introductory test, they practiced each direction six times in order to remove learning effect. In main test, they performed each direction three times; then the average of three attempts in each direction was computed. Finally, it was divided by the length of leg (cm) and multiplied by 100 to obtain the reached distance as a percentage of leg length (29,31).

![Figure 1](image_url)

**Figure 1:** *Figure 1, whole scheme of Y Balance test for right and left foot.*

In YBT, in addition to considering the three directions separately, a total score was also calculated for dynamic postural control by using the following formula:

$$\text{Composite Score} = \frac{(\text{Anterior} + \text{Posteriomedial} + \text{Posterolateral})}{(3 \times \text{Limb Length})} \times 100$$

In this research six phases of functional fatigue protocol have been used in order to exert fatigue parameters from the fatigue protocol by Wikstrom (2003) that consisted of the following stages (1):

1. Agility drill: A series of forward sprints, diagonal back-pedaling, and side stepping within a 12’ × 12’ area. (3 times).
2. Box jumping: A drill that mimics the rapid jumping and landing that could be experienced in athletic competition. This drill is a series of 3 boxes of 24” in height 18” apart. You will jump onto the first box, stabilize and jump down, immediately jumping back up onto the second box, stabilize and repeat onto the third box. (3 times).
3. Two-legged hop sequence: A series of markers spaced over a ten foot distance, must be jumped onto and immediately left for the next marker. You need to jump and land using both feet for each marker. (3 times).
4. Side-to-side bounds: An area 5' wide in which you will jump sideways from a center marker to the one side and back to the center to the opposite side. (30 times).
5. Mini-tramp: You will be asked to jump onto a mini-trampoline, stabilize and jump off on to the floor on the opposite side. (30 times).
6. Resistance arc: You will be asked to resist the tension of an elastic cord as you side shuffle around semi circle. (10 times).

After normalizing the data and computing the total score of every subject, the descriptive (M ± SD) statistics of MANOVA and paired t-test were employed in order to analyze the data.

RESULTS

The results of MANOVA did not show a significant difference between the two groups from three directions and YBT total score in pre-test: (F3,16 = 0.796, wilks lambda = 0.870, P = 0.514). Representing an absence of significant difference between performance of the two groups in pre-test.

To compare performance of the two groups, at first the difference between the pre-test and post-test of the two groups in three YBT directions and also the total score were calculated. Then the performance of the two groups was compared using MANOVA. The results demonstrated a significant difference between a combination of the function of the two groups in three directions and YBT total score. (F3,16 = 24.339, wilk’s lambda = 180%, P ≤ 0.05). The results of MANOVA post hoc tests are presented in table 1.

Table 1. MANOVA post Hoc tests for the function of the two groups in three YBT directions and total score

<table>
<thead>
<tr>
<th>SEBT directions</th>
<th>df</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>1,18</td>
<td>36.361</td>
<td>0.000*</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>1,18</td>
<td>9.628</td>
<td>0.006*</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>1,18</td>
<td>34.483</td>
<td>0.000*</td>
</tr>
<tr>
<td>Total score</td>
<td>1,18</td>
<td>78.416</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

* indicates a significant difference between fatigue and control group (P < 0.05).
Table 2. shows the descriptive data and the results of comparing fatigue group’s pre and post test pairs using paired t-test. The results showed a reduction in the quality of the function of both the three directions and the fatigue group’s total score in post-test.

**Table 2.** Descriptive Data (Mean ± SD) for reaching distance (as a percentage of leg length) in three directions and total score and the results of the comparing pairs of the fatigue group’s pre and post tests

<table>
<thead>
<tr>
<th>SEBT directions</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>t(df = 9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>101.16 ± 3.1</td>
<td>94.84 ± 2.9</td>
<td>16.48</td>
<td>≤ 0.001*</td>
</tr>
<tr>
<td>Posteromedial</td>
<td>118.90 ± 3.4</td>
<td>112.37 ± 3.5</td>
<td>8.90</td>
<td>≤ 0.001*</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>131.26 ± 4.92</td>
<td>126.62 ± 4.14</td>
<td>6.50</td>
<td>≤ 0.001*</td>
</tr>
<tr>
<td>Total score</td>
<td>117.5 ± 4.08</td>
<td>110.31 ± 3.65</td>
<td>9.74</td>
<td>≤ 0.001*</td>
</tr>
</tbody>
</table>

* indicates a significant difference between pre and post test of fatigue (P < 0.05).

**DISCUSSION AND CONCLUSION**

The main purpose of this study was to consider the effects of fatigue induced by functional exer on dynamic postural control. The results showed both the reaching distance in post-test in three directions and the total score of dynamic postural control have been lesser in comparison with pre test. Also a significant difference was observed between the postural control of the two groups after exerting the fatigue. Generally, results demonstrated the negative effect of fatigue on dynamic postural control. There were more errors in reaching in post-test in comparison with pre-test after fatigue which is a hint of a falling in the quality of subjects’ performance and an absence of any suitable neuromuscular control. These increases in the number of errors are consistent with Susco et al (24) and Wilkins et al (25). They utilized functional fatigue protocol but evaluated subjects’ performance on balance error scoring system which is a static balance measurement. Both of them reported that doing functional fatigue protocol for 20 minutes, resulted in a significant decrease in the quality of the subjects’ performance on BESS. These researchers stated some factors in order to justify the effect of functional fatigue on dynamic postural control and its weakening. They stated that the inputs of
the subcutaneous receptors of the sole decreases as a result of fatigue which can influence the neuromuscular control of whole kinetic chain (32). The fatigue may be followed by a decrease in the capacity of muscle force production and the person can’t have a good neuromuscular coordination while executing the reaching task and finally causes a decrease in reaching distance or more errors in post test (17,18). In the local fatigue, it affects pre-post synaptic mechanism and the action potential places which resulted in weakness in transferring neural signals or weakness in reply of the muscle to neural excitation (17). The fatigue in central level may result in a weakness in the simulation of kinetic neurons through influencing neural system and thus influence postural control (17). The fatigue protocols affect muscular tissue more than joint receptors and decrease the activity of proprioceptive receptors especially Golgi Tendon Organ and muscle spindle (33). In SEBT and YBT the strength of the surrounding muscles and acting on the joints and their co-contraction to stabilize lower limb joints of the stance leg, suitable range of motion, active and sensitive proprioceptive, neuromuscular control are very important to maintain balance and postural control while performing the reaching (10,11). Thus the neuromuscular inefficiency resulting from fatigue has an undesirable effect on the control role of the lower limb muscles and finally decrease the reaching distance in all directions and in knee flexion angle.

Eral and Hertel (2001) demonstrated that YBT is directly dependant on the activity of the lower limb muscles except gastronomies (34). YBT causes contraction in hamstrings and quadriceps while doing the reaching in all directions. Quadriceps has a lot of activity in anterior direction (34) as to do anterior direction, the person has to lean back and the trunk must be in extension in order to preserve his balance (34). In this position, gravity acting on the trunk causes high flexion moment in knee which should be controlled by the extension moment produced by quadriceps (eccentric contraction). Hamstrings has the greatest amount of activity in postomedial and postolateral direction (34). To perform posterior directions the person should have trunk flexion to be able to open the foot backward and in this position hamstrings should be contracted eccentrically to resist thigh flexion moment (34).

Supposing that performing the reaching in anterior direction uses quadriceps eccentric control and in postolateral and postomedial directions uses hamstrings’ eccentric control, if the eccentric control of the lower limb muscles is weak (decreasing production capacity of the muscle force), this results in a decrease in reaching distance in YBT (34). Fatigue protocol used included a great amount of short speed running and various jumpings that caused
the hamstrings to contract eccentrically to reduce the speed of the person and quadriceps to contract concentrically while jumping and to contract eccentrically to control the person descending and these muscles contracted repeatedly in the fatigue protocol. As a consequence they became tired and their performance on YBT decreased. Moreover fatigue protocol can affect muscles’ co-contraction which is necessary in performing reaching in YBT and it can create some disorders in doing the act of reaching (19,34).

Except muscles that act on knee and thigh joints, during fatigue protocol dorsi flexions and plantar flexions performed a lot of concentric and eccentric contractions, these may resulted in their fatigue. The fatigue of the involved muscles in the ankle can be another reason of the subjects’ weak performance in post-test.

Considering the research findings, the fatigue resulting from functional performances can influence dynamic postural control, and may be followed by the possibility of the lower limb injury and a reduction in the quality of the athletes’ sport performance. Whereas the actions performed during fatigue protocol used in this research were very similar to the actions in the badminton; therefore, applying good exercise bouts which are conformed to the involving models during a badminton match are recommended in order to improve the physical fitness of badminton players, reduce fatigue experience in a match and reduce the possibility of lower limb injuries.

REFERENCES


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