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# Exercise-Related Fatigue Change Dynamic Postural Control in Healthy Males

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**Abstract:** The purpose of this study was to examine the effect of exercise-related fatigue on dynamic postural control in healthy male. Thirty healthy male students (age: 21.3 ±1.5 Year, mass: 74.2 ± 14.4 kg, height: 170 ± 5.2 cm) volunteered to participate in this study. They completed pre-test, then performed a functional fatiguing protocol (20 min and 7station). Their Rating of Perceived Exertion (RPE) was measured before the first station, the end of third station and exactly after completing the seventh station. The post test was given afterward. A two-way repeated measure ANOVA and one-way ANOVA were used to determine the differences between pretest and posttest in SEBT and also in RPE between the three tests. Scheffe Post-hoc was run for all of them. The findings demonstrated a significant interaction between time and direction, significant main effects for time (pre and post of fatigue) and direction of SEBT and a significant main effect for RPE that means decrease in dynamic postural control after functional fatigue. Considering the findings of the research, exercise-related fatigue can affect dynamic postural control in healthy men and can increase the risk of injuries and decline the performance of athletes.

**Key words:** Exercise-Related Fatigue · Postural Control · Balance

## INTRODUCTION

It is imperative to maintain body posture during everyday activities and performing sport skills correctly and its measurement in experimental and clinical settings is used as a tool for assessing stability and neuromuscular control in both healthy and injured individuals [1]. Shumway-Cook [2] defined postural control as the control of the body's position in space for the purposes of balance and orientation [2]. Postural control can be categorized into maintaining a position with minimum movement (static), maintaining a position while the center of gravity (COG) is displaced or perturbed away from the base of support (semi-dynamic) and maintaining a stable base of support while a prescribed movement is performed (dynamic) [3-7]. Meanwhile, dynamic postural controlcan be defined as performing a functional task without involvement of a part of base of support [5-10] that is observed in most skills such as basketball block or vault in gymnastics. This type of postural control is maintained using the information collected by mechanical receptors that exist in lower extremities and the trunk as well as a combination of visual, articular and sensorimotor inputs in order so as to generate proper motor responses for controlling the position of the center of mass within the limits of the base of support [3, 5-7].

Fatigue is defined as the decline in force generation capacity of muscles regardless of the performed action and it is referred to as a phenomenon whose dimensions have not yet been thoroughly understood [11, 12]. McArdle[13] associates fatigue to interruption in the chain of events between the central nervous system and muscle fibers [13]. According to the definition provided by Fitts [14], fatigue is divided into local (peripheral) or general (Central) [14]. Local fatigue appears at the muscular level and encompasses a specific group of muscles that may cause disruptions in the neuromuscular junction, excitation-contraction coupling, the propagation of activation by transverse tubules, the release of calcium and the activation of contractile elements which are responsible for energy and power generation [14]. General fatigue is related to events of neural input to the higher brain centers and recruitment of alpha motor neurons and it is related to the whole body and in particular the central nervous system [14].

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Some factors such as nervous system lesions, dysfunction of the optic nerves, emotional stresses, auricular mechanisms and fatigue can affect postural control [3]. In order to study the effect of fatigue on the postural control system, various fatiguing procedures are applied to the body and extremities, especially lower extremities which include isokinetic contractions [15, 16], repetitive movements [17], isometric contractions [18] and functional exercises for functional fatigue [19, 20]. Although these methods are considered as simple, standardized methods in the context of fatigue protocols, these protocols are not functional and bear no connection or resemblance to real sport and competition; thus, for simulating sports exercises and competitions, researchers have defined the functional fatigue protocol which involves functional exercises [19, 20]. This type of fatigue protocol is more similar to sports exercises and competitions in comparison with other protocols and thus it is more generalizable to fatigue related to sports exercises and competitions. However, the weakness of this protocol is assessment of the level of functional fatigue, for there is no certainty whether the body part to be tested has actually been fatigued or not [19, 20].

Methods such as Time to Stabilization (TTS) [21, 22], Single Leg Hop test [23] and Stability Biodex System [24]are used to assess the dynamic postural control system. Although these tests examine dynamic postural control in functional positions, they fail to assess the stability of the athlete in the sport skill. SEBT is another method for assessing dynamic postural control which presents the results quantitatively and assesses the postural control system in eight directions. Further, the functions performed during this test are very similar to sport skills performed in exercises and competitions. Moreover, Ratty [26] and Olmsted[25]concluded that SEBT is a simple, inexpensive and fast test with validity and reliability which does not require special equipment and shows motor functions, lower extremity functions in different directions and dynamic postural control [25, 26]. Thus, it seems more appropriate to use SEBT rather than other postural control assessment tests.

Considering the fact that the effect of fatigue on the postural control system is well-documented, the protocols used in most studies to assess the effect of fatigue on the postural control system are irrelevant to sports exercises and competitions. Moreover, these studies have mostly examined the static postural control system and few researches have been carried out on dynamic postural control using a functional test. It thus appears that due to the lack of research that deals with the relationship between dynamic postural control and exercise-related fatigue and its concepts, it is imperative to carry out a research on the possible relationship and the quality of the interaction between fatigue of the entire body and dynamic postural control using a functional fatigue protocol which is similar to sports exercises and competitions as well as the SEBT functional test for assessing dynamic postural control to study the effect of intensive sports exercises and competitions on the dynamic postural control system. Thus, this research was carried out in order to study the effect of exercise-related fatigue on dynamic postural control in healthy men.

## MATERIALS AND METHODS

The present research is semi-experimental in which the effect of the independent variable of exercise-related fatigue on the dependent variable of dynamic postural control is measured through a pretest-posttest design. This study was approved by the university institutional review board. 40 male non-athletes student (average of 21.3±1.5 years of age, 74.2±14.4 kg of mass and 169.7±8.3 cm of height) who were all healthy voluntarily participated in the research. All participants signed an informed consent document approved by the Institution human subjects review board.

The SEBT test was used to assess dynamic postural control. In this test, 8 directions are drawn on the ground in the shape of a star with 45° angles between each two directions. To perform the test, the actual leg length, i.e. the distance from anterior superior iliac spine to medial malleolus, is measured to normalize the data [5, 6, 8, 11, 27]. After the examiner provides the necessary explanations, each subject practices this test six times in order to learn how to perform the test. The preferred leg of the subject is determined so that if the right leg is the preferred limb, the test will be performed counterclockwise and if the left leg is preferred one, the test will be performed clockwise (Figure 1) [5, 6, 8, 11, 27].

The subject stands in the center of the star on preferred leg (one leg) and performs reaching with the other leg as determined by the examiner as long as there is no error (if the stance leg moves from the center of the star, if the reaching leg is used to provide support, or if the subject falls). Then, the subject returns to the normal position on both legs and the distance between the touch-point and the center of the star is measured as the reaching distance (Figure 2). Each subject performs three

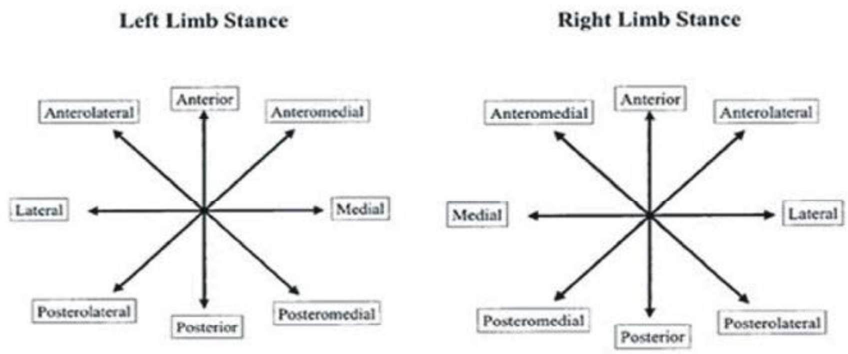


Fig. 1: The outline of SEBT

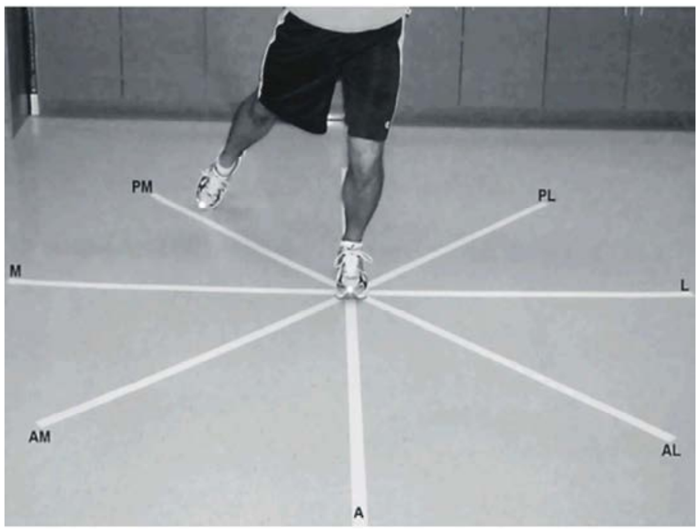


Fig. 2: A subjectperforming SEBT

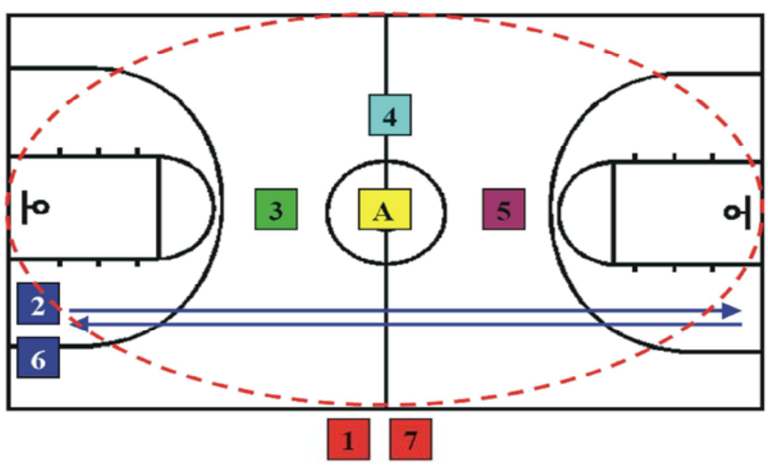


Fig. 3: The diagram of functional fatigue protocol, A is the location of performing the SEBT

attempts in each direction and finally their mean is calculated, divided by leg length (in centimeters) and multiplied by 100 to yield the reaching distance with respect to leg length [5, 6, 15].

To include the fatigue parameter in the research, the seven-station functional fatigue protocol defined by Susco [19] and Wilkins [20] is used (Figure 3 completely illustrates this protocol) [19, 20].

Station 1 involved a 5-minute moderate jog at the subjects self-selected pace; station 2, a 3-minute sprint along a basketball court; station 3, 2 minutes of push-ups; station 4, 2 minutes of sit-ups; station 5, 3 minutes of 30-centimeter step-ups; station 6, 3 minutes of sprints along the basketball court; and station 7, 2 minutes of running with a steady rhythm so that the subject can run with the same speed until the end of the test.

Borg PRE scale was used to determine the level of fatigue in subjects. To measure PRE, the subject was asked to express their true feelings about the intensity of the exercise they performed and its scale was extracted using the table designed by Borg. The minimum scale at the end of the seventh station was 15. PRE measurement was done exactly before the beginning of station 1, after station 3 (i.e. at the middle of the way) and after station 7.

The pretest SEBT was given to the subjects after a brief warming-up (5-10 minutes of moderate jog and stretching out the lower extremities). The first PRE measurement was conducted before the first station of the fatigue protocol; the second and third PRE measurements were conducted after the third and seventh stations respectively and then the subjects took the posttest SEBT.

Descriptive statistics (mean and standard deviation) was used for data analysis for all the eight directions both in the pretest and the posttest. Two-way analysis of variance with repeated measures was applied to determine the effects of fatigue on postural control in the experimental group and to find its difference with the control group in all the eight directions of SEBT. Further, one-way analysis of variance with repeated measures and Scheffe'sposthoc test were applied at the $\alpha \leq 0.05$ significance level to determine the difference between subjects of the control group in PRE and ensuring the occurrence of fatigue.

## RESULTS

Diagram 1 displays the results of SEBT in eight directions both in the pretest and the posttest.

Comparing each direction in the pretest and the posttest reveals that the reaching distance in the posttest has been less than the pretest in all the directions and that this difference is statistically significant at the $P \leq 0.05$ level. The results obtained from the measurements related to two-way analysis of variance with repeated measures (2×8) showed that there is a significant interaction between time (before and after fatigue) and SEBT directions ($F = 9.2$, $\beta = 0.83$. ES = 0.191). Moreover, the main effects of time were significant as well ($F = 554.7$, $\beta = 1$. ES = 0.934 and $P = 0.001$) (all the results are presented in Table 1). The results showed that reaching distance in all directions was less in the posttest in comparison with the pretest. These differences were statistically significant and suggest that fatigue affects and reduces reaching distance.

The results from one-way analysis of variance with repeated measures (1×3) showed significance differences for three PRE tests ($F = 2346/11$, $\beta = 1.000$ ES = 0.885 and $P = 0.003$). These results show that the differences between the three PRE measurements have been significant and that the fatigue of interest has occurred. Diagram 2 displays the results of RPE during three measurements.

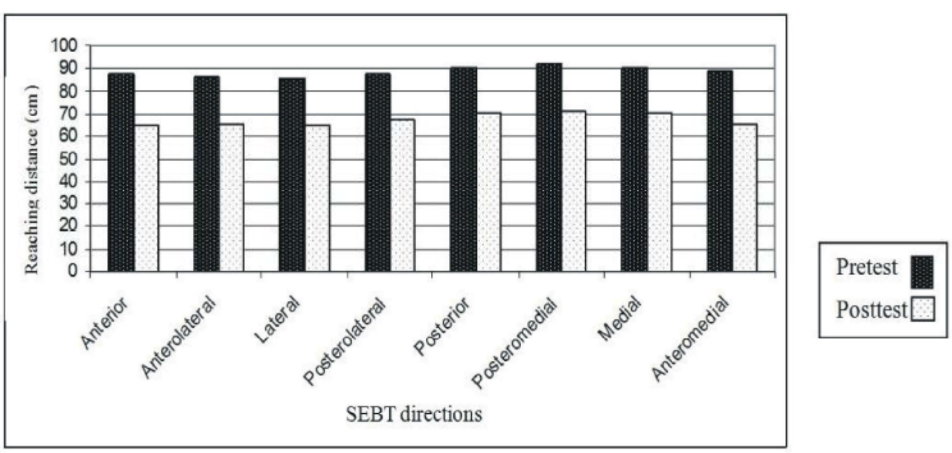


Diagram1: the results of SEBT in eight directions both in the pretest and the posttest

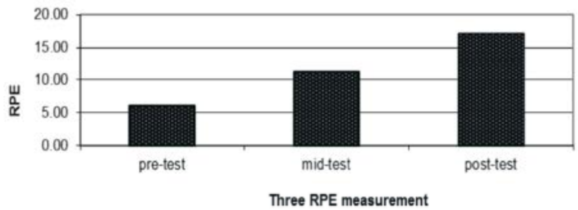


Diagram 2: The results of RPE during three measurements

Table 1: Results of 2-way ANOVA for SEBT

| Parameter | F | P | E.S | β |
|---|---|---|---|---|
| Time | 557.67 | 0.001 | 0.934 | 1 |
| Direction | 49.10 | 0.001 | 0.557 | 1 |
| Direction*Time | 9.2 | 0.003 | 0.191 | 0.83 |

## DISCUSSION AND CONCLUSION

The main purpose of this study was to examine the effect of exercise-related fatigue on dynamic postural control in healthy men. The results suggested a relationship between reaching distance and time (pre-test and post-test) and indicated that reaching distance in the post-test in all SEBT directions have been less than that in the pre-test. Moreover, the results showed a significant difference between pre-test, mid-test and post-test in PRE. The findings of the research supports all the nine research hypotheses that the reaching distance in all SEBT directions (8 directions) was significantly higher in the pre-test than the post-test. Further, the ninth hypothesis states that there is a significant difference between the three testing stages (pre-, mid- and post-test) in PRE and this issue indicates the level of fatigue in the three protocol stages and that the subjects have been fatigued up to the desired level.

Gribble *et al*. [15] studied the effect of fatigue and chronic ankle instability on postural control. They found that both fatigue and chronic ankle instability lead to decreased reaching distance in all direction and decreased knee flexion angle which is consistent with the findings of the present research [15]. To normalize the data obtained from SEBT, the reaching distance to leg length ratio is used; thus, the results can be generalized to a larger population [15]. Suscoe*t al.* [19] and Wilkins *et al.* [20] used a functional fatigue protocol, but they assessed subjects' performance on the Balance Error Scoring System (BESS) which is for measuring static balance. They both reported that using a functional fatigue protocol for 20 minutes leads to a significant decrease in subjects' performance in BESS and our results are in line with these studies [19, 20]. These researchers mentioned some factors for justifying the effect of functional fatigue on postural control and its decrease. They mentioned that the inputs from plantar cutaneous receptors decrease as a result of fatigue which can affect the neuromuscular control of the entire motor chain [28]. Fatigue is followed by the decreased energy production capacity of muscles and during reaching, the individual cannot have proper neuromuscular coordination in the support limb and in the end, it will result in decreased reaching distance or more errors in the posttest [12, 29]. At the local level, fatigue affects the pre- and postsynaptic mechanism and action potential sites including failure to transmit neural signals or failure of the muscle to respond to neural excitation [12]. At the central level, fatigue can affect the nervous system and cause a failure of excitation of motoneurons and in that way it affects postural control [12]. Fatigue protocols affect muscle tissues more greatly than joint receptors and decrease the activity of proprioceptive sensory receptors, in particular muscle spindles and Golgi tendon organs [30]. Perhaps this neuromuscular failure undesirably affected the controlling role of the lower extremities while reaching and consequently led to decreased reaching distance in the post-test in comparison with the pre-test.

SEBT leads to co-contraction of the hamstring and quadriceps while reaching in all the directions; quadriceps is the most active muscle in three SEBT directions (anterior, anterolateral and anteromedial) [5, 6, 31]. The vastuslateralis (VL) muscle has the most activity in reaching in medial and posteromedial directions which may be due to muscular stabilization against various reaching-related forces [31]. Considering the notion that reaching in anterior and medial directions makes use of eccentric control of quadriceps, if the eccentric control or strength of quadriceps (decreased energy production capacity of the muscle) is weak in a subject, it will lead to decreased reaching distance in these directions [31]. In addition, the fatigue protocol can affect the co-contraction of the muscles which is required for correct reaching in SEBT and can disturb the correct, perfect reaching [15, 31].

Moreover, the biceps femoris muscle is very active while reaching in posterior, posterolateral and lateral directions; reaching in these directions leads to eccentric contraction of hamstring to resists the hip flexion moment caused by trunk flexion for extending the leg backward [31]. The applied fatigue protocol included many short sprints which made the hamstring contract eccentrically to slow down the individuals. If these muscles are repeatedly contracted in an eccentric fashion, they will become fatigued and their performance decreases which will disturb reaching. This issue will especially hinder its activity in the mentioned directions.

During the post-test SEBT, it was difficult for the subjects to maintain their stance on one leg between each excursion. Moreover, more errors were reported in the post-test in comparison with the pre-test SEBT [8, 32]. During the fatigue protocol, the subjects were asked to perform various and numerous movements whichrequired both concentric and eccentric control of the quadriceps and the hamstring; for instance, step-ups required eccentric contraction of the quadriceps and thus led to fatigue in this muscle [8, 31, 32].

Many authors have mentioned that reaching in some of the directions of SEBT is easier than some other directions. In particular, posterior, posteromedial and medial directions are identified as the easiest directions; yet the anterior, anterolateral and lateral directions are the most difficult ones [8, 11, 12, 27]. Posthoc tests revealed that the lateral direction is the most difficult direction and that the reaching distance in the anterolateral direction is significantly less than other directions. Posterior and posteromedial directions appear to have the greatest reaching distance and this distance is randomly larger than other directions [8, 11, 27]. In the present research, a significant decrease was observed in all the directions after fatigue; this issue occurred both in the difficult directions (anterior, anterolateral and lateral) and in the easy directions (posterior and posteromedial).

## CONCLUSION

Considering the findings of the research, exercise-related fatigue can affect dynamic postural control in healthy men and can increase the risk of injuries and decline the performance of athletes. Thus, using proper exercise periods for increasing physical fitness of athletes and decreasing the experience of fatigue in an activity is highly recommended.

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