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The effects of neck muscular fatigue on static and dynamic postural control in elite male volleyball players

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Original Article

Abstract

Introduction: Muscular fatigue is a common phenomenon in daily sports activities and is worsening motor performance. The aim of this study was to determine the effect of neck muscular fatigue on static and dynamic postural control in elite male volleyball players.

Methods: For this study, 30 elite male athletes with mean age of 23.3±3.5 years old, height of 184.1±7.7 cm, and weight of 76.6±3.1 kg were selected in the available form and divided randomly into control and experimental groups. Fatigue protocol was induced on both sides via maximal exhausting protocol by instructing the subjects in experimental group to perform a “Dumbbell Shrug Trap Exercise” commonly used in fitness training to specifically involve Levator Scapulae and Trapezius superior muscles. The subjects’ dynamic and static postural control ımmediately after fatigue were assessed by Biodex System (level 4 and 3). For statistical analysis paired and sample t-test ($\alpha \leq 0.05$) were used.

Results: The results of this study showed that in the level 4 of Biodex system there were significant differences in Ant-Post (P=0.030), Med-Lat (P=0.020), Limit of stability (P=0.012) and dynamic balance (P=0.011). In the level 8 of Biodex system there were significant differences in Ant-Post (P=0.022), Med-Lat (P=0.020), Limit of stability (P=0.011) and dynamic balance (P=0.021). With respect to study results, there were significant differences in static balance(P=0.012) in experimental group but there were not significant differences in control group (P=0.214).

Conclusion: Based on this study results, we concluded that neck muscle fatigue affects stability indexes, static and dynamic postural control so it seems that increasing the endurance of neck muscles to prevent early time fatigue, should be considered.

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Introduction:

Postural control has an important role in the daily activities of individuals ranging from simple tasks and high-level performances in sports based on their nature as of the essential components of participating in various sports (1). Due to the nature of movement, athletes must maintain their balance on the supporting surface for optimal execution of movement skills. Fluctuations of body are superimposed by muscle contractions and using sensory information in central nervous system and balance is maintained. The researches have shown that high-level athletic performances will improve physiological and sensory-motion abilities involved in Postural control.

Based on research results, Postural control is associated with the occurrence of injuries in athletes (2). Thus, identification of factors associated with postural control is helpful in reducing injuries in athletes. Many factors have been identified in the field of postural control thus far and impairment of these factors leads to defects in postural control, one of which is muscle fatigue. Based on the result of some of the researches, lower extremity muscle fatigue reduces postural control (3).

Muscle fatigue is a common phenomenon that occurs during sports activities and causes impairing in the motor function of individuals (2) and is defined as any decrease in power generation capacity (3). Start of voluntary muscle activities involves many steps which starts with cortical control of brain and ends in cross bridges inside the muscle fibers. Hence, it should be said that muscle fatigue may occur as a result of any failure in muscle contraction (3). Fatigue depends on the type of exercise (1), the type of contraction, intensity and duration of exercise (2). Potential factors that contribute to fatigue include: central factors (which cause fatigue by disrupting neuromuscular transmission between central nervous system and muscle membranes) and environmental factors (Which cause changes within the muscle) (3).

Muscle fatigue leads to changes in muscle proprioception and thus balance.

Volleyball is among those sports where athletes have dire need of proper functioning of neck muscles in addition to other muscles of body parts for successful results and have easy access to ball and being in conditions and opportunities for implementing their techniques (4). Neck muscles are among those muscles which have the most proprioceptive receptors relative to other parts of the body and due to this important feature, have an important role in the control and spatial orientation. Placed in repetitive and boring positions such as Volleyball (Volleyball players require contraction of the neck muscles to achieve successful outcomes, proper positioning to get the ball and proper spatial orientation) leads to fatigue in this group of muscles (4) and postural control of person may become impaired due to engaging proprioceptive receptors.

There are many receptors in the muscles of the neck which create reflex and central multi-channel communication with vestibular, visual and physical postural control systems. These receptors are concentrated especially in deep sub-occipital muscles and are considered as a key point in central and reflex communication (1). For example, change of neck joint proprioception, balance disturbances, change of eye movements' control, change of postural activity of neck and change of posture control have been seen (3). These disorders in postural control have been attributed to cervical afferent inputs (3). Also, impaired postural control has been seen in individuals with a history of whiplash injury and those who have not been injured who have activities with reduction and increase of acceleration (Such as urban bus drivers and drivers of racing cars) (5). Schieppati et al (2003) also reported increased Center of Pressure (COP) changes after muscular fatigue (6).

Koskimies et al (1997) observed a significant increase in Center of Pressure but did not report any increase in speed of swinging (7). Wierzbicka et al (1998) reported such observations in patients with cervical abnormalities (Idiopathic Torticolli) to be without cause (8). Gosselin et al. (2004) also reported the increased the displacement of Center of Pressure changes after muscles fatigue to be neck extensor (5). Gosselin et al. (2014) stated that neck muscle fatigue results in reduced balance. The results of some other studies suggest that adopting the head extension position affects proprioceptive receptors and will reduce postural control of the body (9).

In Over Head Sports, the head extension position may cause neck muscle fatigue and this fatigue probably affects postural control (9).

Impaired balance will be doubled in these athelets due to adopting extension position and the impact on information of proprioceptive receptors and being associated with muscular fatigue.

Static postural control has been defined as the ability to maintain the level of support with minimal movement and dynamic postural control has been defined as the ability to perform a specific task while preserving a stable condition. Factors affecting the balance are sensory information received from somatosensory, visual and vestibular systems and motion responses affect coordination, range of motion and strength (3).

Based on evidences the balance in upper extremity significantly takes form due to repeated training experiences which affect motor responses and are not related to further sensitivity of vestibular system (10,11). There are also research on this issue that balance in the upper extremity is a result of training experiences which affects and imporves person's ability to make good use of proprioceptive and visual targets (7,12). There is consensus on the mechanism but these researches suggest that changes in both sensory and motor systems cna affect balance performance (3).

Based on the results of researches, neck muscle fatigue may casue static postural control deficits in non-athletes but this issue seems to be compensated with training experiences and more muscular strength and endurance in athelets. The impact of neck muscle fatigue on postural control and it being along with adoption of the head extension and further disrupt in postural control cna cause impaired postural control and injuries in athletes. Given the fact that the effects of neck muscle fatigue static and dynamic postural control of elite volleyball players has not been studyed yet, researchers intend to study the effecct of neck muscle fatigue on static and dynamic postural control in elite volleyball players in this research.

Methods:

The statistical population of the study were college volleyball players. This is a kind of pretest-posttest study with control group. This is a quasi-experimental research with applied purpose. Subjects of the present research were 30 elite male volleyball players with an average age of 23.3±3.5 years, height of 184.1±7.7cm, and weigh of 76.6±3.1kg who had more than 7 years of sports experience and were selected using targeted and available method and were divided into two control and experimental groups. After selection, written informed consent was obtained from all subjects, and their height and weight were measured then. The next day, static and dynamic balance of the subjects were measured using the Biodex balance system. Then, subjects participated in the fatigue protocol, and finally, static and dynamic balance of the subjects were measured as in pre-test, and the obtained data were statistically analyzed.

Since muscle for lifting of shoulders are used in most of the movements of athelets who are doing ovver the head activities, these muscles wete selected for protocol of fatigue (13). Fatigue protocol was done on muscle for lifting of shoulders until exhaustion using exersice for lifting of shoulders using dumbbells (which is done to strengthen the muscles for lifting of shoulders). Subjects held a pair of dumbbells and standed staight with feet shoulder-width open and raised thier shoulders as much as possible and performed this move with the a frequency of 40 times per minute uisng metronome with verbal encouragement of examiner (to ensure maximum effort). Weight used for each subject was determined to be 30% of one maximum repetition. Fatigue was considered to be when the person was unable to complete exersice (Fatigue protocol of Wheeler et al. 2005) (13). Determining a maximum repetition and familiarity with balance tests we done before the test. The site for executing fatigue protocol was adjacent to Biodex machine so that there is no time interval between executing protocols and balance test. static and dynamic postural control of subjects was evaluated uissng Biodex Model SW 45- 30 D- E 6N in unsustainable levels of 4 and 8 before and immediately after the fatigue protocol. Static postural control test of subjeccts was alos done with Biodex.

Subjects did not receive any drug that affect the neuromuscular system and were not addicted to cigarettes and did not have heavy physical activity 24 hours before the measuremnet. Measurements were done 2 to 3 hours after the last meal so that digestion does not interfere in the process of testing.

Also, research subjecct had no history of injury in the head and neck, neurological disease, physical abnormalities and disorders related to the vestibular system. People with diseases, injuries and musculoskeletal system injuries in the past year were excluded from the study.

Procedure of the balance tests

Biodex Stability System (Model S w 45- 30 d- e 6 N). This device has a 8 degree circular screen which meassures stability variables and other indicators related to posture control. In order to run postural control test in the Biodex Stability System, subjects were asked to stand on force screen in locked mode (while hands were beside the body and legs were in the desired mode). by pressing the test start button, screen iss unlucked and the person was asked to keep the sign observed on the screen at the intersection of two perpendicular lines (horizontal and vertical). The person could move his feet at this poit if needed and placed those in good condition to keep the balance. There was focuse on the distance between two feet not exceeding shoulder width at this point (1). After this step, the status of foot of the person was recorded and was maintained until the end of the test. Next, the main tests were conducted (in the present reserach, dynamic postural control at levels of 4 and 8 and static postural control on Biodex were carried out). Instability of level 4 is more while level 8 is almost stable. Biodex Stability System consists of two concentric circles and four equal squares (AM, ML, PM, PL) which calcuates the time of stauing at each part and expresses as a percentage. The higher time of staying in A region indicates more balance of a person. All calculations are the responsibility of computer software and the results are displayed on a screen. In fact, Biodex meassures the center of pressure of body which measn the point where ground reaction force is applied on foot through it and can indicate fluctuation of body center during standing.

Compressed data considered was considered after each test which was calcuated by PC software in the device and was printed using a printer (1).

Statistical method

Descriptive and inferential statistical methods were used to analyze the data. Data normality was evalauted using K-S test and paired and dependent t-tests in 17 SPSS software were used to compare static and dynamic postural control before and after the fatigue protocol ($\alpha \leq 0.05$).

Results:

Profile of subjects are presented in Table 1. There was no significant statistical difference between the mean age (P=0.321), height (P=0.245), weight (P=0.318), and sports experience (P=0.411) of the two groups.

Mean and standard deviation of Biodex balance variables in the control and experimental groups are listed in Table 2.

The results of paired t-test for comparison of the scores of the two groups are listed in Table 3.

Table 1. Mean and standard deviation of profile of subjects

Variable group	Weight (kg)	Height (cm)	Age (years)	Sports experience (years)
Experimental group	75.8±3.2	183.4±8.1	23.6±2.6	4.7±2.3
Control group	77.4±3.1	184.8±7.3	23.4±4.4	5.8±1.4

Table 2. Mean and standard deviation of Biodex Balance variables in control and experimental groups

Group	Variables	Control group		Experimental group	
		Pre test	Post test	Pre test	Post test
Stability variable of 4	Anteroposterior stability	1.65 ±0.09	2.59±0.08	1.64 ±0.08	1.63 ± 0.09
	Lateral stability	1.43 ±0.06	1.42 ±0.07	1.42 ±0.07	2.14 ±0.38
	Range of stability	15.80 ±1.42	15.86 ±1.18	15.53 ±1.40	11.33 ±1.11
	Static balance	55.33 ±1.58	55.80 ± 1.52	54.66 ±1.87	29.13±2.94
	Dynamic balance	40.20±4.64	40.80±4.49	37.93±5.33	21.73±1.16
Stability variable of 8	Anteroposterior	1.05±0.04	1.04±0.08	1.04±0.03	1.21±0.04
	Lateral stability	1.33±0.06	1.32±0.07	1.12±0.08	1.8±0.90
	Range of stability	15.14±1.13	15.11±1.10	15.13±1.50	13.42±1.60
	Static balance	12.03±1.13	12.10±1.14	19.06±1.15	21.17±2.23
	Dynamic balance stability	40.18±1.13	40.19±1.15	41.22±1.21	39.13±1.29

Table 3. Results of paried T test about variables measured in the study (P=0.05)

Dynamic balancr		Anteroposterior stability		Anteroposterior or stability		Anteroposterior or stability		Variables	
Statistics	**Group**	**t**	**sig**	**t**	**Sig**	**t**	**sig**	**t**	**sig**
Stability variable of 4	Control group	-2.100	0.521	-2.111	0.133	0.213	0.231	-0.341	0.132
	Experimental group	-3.143	0.030	-2.592	0.044	-2.209	0.012	-2.342	0.011
Stability variable of 8	Control group	-2.182	0.423	0.413	0.123	-2.009	0.330	-3.102	0.201
	Experimental group	-3.121	0.022	-2.301	0.020	-2.042	0.011	-1.310	0.021

Based on the results of Table 3, there was significant difference in Biodex level of instability of 4 btween scores of anterior-posterior stability (P=0.030), lateral stability (P=0.044), range of stability (P=0.012) and dynamic balance (P=0.011) of the experimental group. there was significant difference in Biodex level of instability of 8 between anterior-posterior stability (P=0.022), lateral stability (P=0.020), and dynamic balance (P=0.011) of the experimental group while no significant difference was observed in the control group in measured variables stability.

Based on the results obtained from static Biodex postural control test, there was no significant difference btweeen static postural control of the control group (P=0.214) while this difference was statistically significant in the experimental group (P= 0.012).

Conclusion:

The aim of this study was to investigate the effect of muscle fatigue on static and dynamic postural control in elite volleyball players. The results showed that neck muscular fatigue leads to a reduction in the static and dynamic balance in volleyball players.The obtained results are in line with the results of Caroline et al (2003), Shpaty (2003), Wilmer et al (2005). Kazvlyn et al (2003) reviewed the effect of neck extensor muscles fatigue on balance after 5% and 25% of maximal voluntary contraction of neck extensor muscles while eyes were open andobserved increased displacement in y axis but no displacement was observed in x axis (5).

Wilmer et al. (2005) evaluated the effects of neck muscle fatigue on balance in various sensory conditions and reported that, increase in displacement of the center of gravity cna be observed in all directions after the fatigue protocol (13). Sheibani and colleagues (2003 evaluated tje effect of neck muscle fatigue on balance and reported that Fatigue of this muscle group can affect central nervous system's control mechanism by production of abnormal sensory input and cause instability, they also reported that eyesight can somewhat compensate these effects (6). All of these researches evaluated the effect of neck muscle fatigue on static postural control. Chamid and colleagues (2006) evaluated the effect of muscle fatigue on spatial orientation while walking in situ and reported that head position and walking do not change after muscle fatigue but spatial orientation is affected and in subjects with closed eyes leads to back and forth movement during walking (14).

Cervical spine has a complex network of muscles which is derived from the anterior and posterior muscles. Upper cervical region has more muscle spindles than other parts of the spine. Some of the sesearchers have examined cervical afferent function using vibration training on healthy subjects or with certain neurological problems (15). For example Ledin and colleagues (2003) reported that neck flexion and extension affects the level of swinging during use of vibration on twin leg muscles and reported this change to be related to changes of neck muscles and changes in thier interaction with the vestibular system (16).

Eyvanakey et al (2004) also reported that Afferent posturals are process from neck muscles using visual field parameters (17). These affects are related to relation of cervical proprioceptive inputs to brain stem nuclei controlling the posture (such as Vestibulospinal Deiters) (15).

Wilmer et al (2002) also observed during researches that using vibration on muscles of the lower leg increases swinging but when they used vibration on tired muscles, increased swing was not observed and they reported that Central nervous system does not pay attention t information from tired muscles and uses other postural control mechanisms such as eyesight and vestibular system (18). Burak et al (2004) also reported that using vibration on upper neck muscles activates compensatory postural more than lower spine muscles. Also, the interaction between cervical receiver, visual and vestibular systems through Cervicoocular, Cervicocollic and vestibuloocollic reflexes will affect sensory receptors in the neck muscles and posture control (19-21).

Local fatigue of neck muscles propably affect the central control posture mechanisms by generating inputs to the central nervous system with regional variations along with fatigue. Such adjustments in sensory inputs may be the result of increased flow in nerve endings after metabolic changes (Increasing intracellular potassium or insufficient oxygen due to reduced blood flow) (21).

In addition, inputs from receptors related to pain in the cervical region of the spine can affect the posture control (6). Input received from pain receptors can lead to changes in vertical spatial perception ability (1). Fatigue can also affect the discharge of a lot of sensory receptors such as muscle spindles (10). On the other hand, muscle spindle discharge may be influenced directly by fatigue (2). Muscle spindle discharge may be also affected by changes related to changes in the alpha motor neurons discharge (1). Such unnatural flows of muscle spindles cna cause impaired postural control. Accumulation of metabolites will change the threshold of receptors and sensitivity of receptors. Thus, sending false information reduces postural control (10,1).

The following two notes be noted that previous studies have reported that deep neck muscle fatigue affects more on postural control but it was observed in the present study that using fatigue protocol on muscles lifting the shoulders (due to the fact that volleyball players continuesly use this muscle during the game) reduces the static and dynamic postural control (22). This issue is probably related to the role of small sub-occipital muscles becuase these muscles are responsible for spinal stability during contraction of the levator scapula and upper trapezius muscles (22). Levator scapula and upper trapezius muscles become tired when those are used a lot. This will make stabilizer muscles tired after a while and thus affects on the reduction of postural control more. Result of researches have shown reduced performance of trapezius muscle after wiplash hits due to damages caused to these stabilizer muscles (23-28).

Subjects of this study carried out postural control tests with open eyes in order to evalaute the effect of neck muscle fatigue on postural control in functional form and under the same conditions as matches. Although the resukts of researches have shown effect of visual inputs on postural control after the neck muscle fatigue and have reported that visual inputs can somewhat compensate the effect of this balance reduction.

According to the results of this study, we suggest that exercises to increase neck muscle endurance and make these muscles resistance to fatigue to be considered in training programs of these athletes and athletes who perform overhead activities in order to counter the effects of neck muscle fatigue. We also suggest future studies to be carried out using electromyography in order to determine the fatigue in order to obtain more accurate information in the field of fatigue and its effect on postural control.

In the end, based on the results obtained from this reserach, we can say that neck muscles fatigue leads to defects in static and dynamic postural control in volleyball players. Given that muscle fatigue is one of the factors affecting the shoulder and neck proprioception, and also upper limb function, and these factors are influential factors in volleyball players, we recommend volleyball trainers and professionals to pay serious attention to this issue. Since neck muscle fatigue could possibly cause loss of upper limb and shoulder function, and these organs are very important for athletic performance of this group of athletes, we recommend sports coaches to use field tests to measure fatigue and prevent the subsequent damage, and take effective steps to increase neck muscle endurance by presenting appropriate solutions. It is also suggested to examine the athletes' balance in real conditions and at different stages of volleyball. One of the limitations of this study was that a highly valid criterion was not used to determine the exact neck muscle fatigue, so it is recommended to determine the fatigue using electromyography index in the future research.

In this study, the fatigue protocol was mostly in the form of a simulation; ıt is recommended to measure the balance of actual fatigue of volleyball players during the game in the future studies.

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تأثیر خستگی عضلات گردن بر کنترل وضعیتی ایستا و پویای والیبالیست‌های نخبه‌ی مرد

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مجله پزشکی هرمزگان سال بیستم شماره ششم ۹۵ صفحات ۳۸۹-۳۸۱

چکیده

مقدمه: *خستگی عضلانی طی فعالیت‌های ورزشی پدیده معمولی است که باعث اختلال در عملکرد حرکتی می‌شود. هدف پژوهش حاضر، تعیین تأثیر خستگی عضلات گردن بر کنترل وضعیتی ایستا و پویای والیبالیست‌های نخبه بود.*

روش کار: *برای انجام این پژوهش، ۳۰ والیبالیست مرد با میانگین سن ۳/۵±۲۳/۳ سال، قد ۷/۷±۱۸۴/۱ سانتی‌متر و وزن ۳/۱±۷۶/۶ کیلوگرم به صورت در دسترس انتخاب و به صورت تصادفی به دو گروه کنترل و تجربی تقسیم‌بندی شدند. پروتکل خستگی بر روی عضلات بالابرنده کتف با استفاده از تمرین بالا بردن کتف همراه با دمبل انجام شد. کنترل وضعیتی ایستا و پویای آزمودنی‌ها بلافاصله بعد از خستگی، به وسیله بایودکس در سطوح ناپایداری ۴ و ۸ ارزیابی شد. برای تجزیه و تحلیل آماری از آزمون تی همبسته و وابسته در نرم‌افزار SPSS 17 استفاده شد ($\alpha <$ ۰/۰۵).*

نتایج: *با توجه به نتایج تحقیق در درجه ناپایداری ۴ بایودکس، تفاوت معنی‌داری بین مقادیر ثبات قدامی - خلفی (P= ۰/۰۳۰)، ثبات طرفی (P= ۰/۰۴۴)، محدوده‌ی ثبات (P= ۰/۰۱۲) و تعادل پویای (P= ۰/۰۱۱) گروه تجربی یافت شد. در درجه ناپایداری ۸ بایودکس تفاوت معنی‌داری بین مقادیر ثبات قدامی - خلفی (P= ۰/۰۲۲)، ثبات طرفی (P= ۰/۰۲۰)، محدوده‌ی ثبات (P= ۰/۰۱۱) و تعادل پویای آزمودنی‌ها (P= ۰/۰۲۱) مشاهده شد. همچنین تفاوت معنی‌داری بین کنترل وضعیتی ایستای گروه کنترل مشاهده نشد (P= ۰/۲۱۴)، درحالی که در گروه تجربی تفاوت از لحاظ آماری معنی‌دار بود (P= ۰/۰۱۲).*

نتیجه‌گیری: *در نهایت با توجه به نتایج به دست آمده از این پژوهش نتیجه‌گیری می‌شود که احتمالاً خستگی عضلات گردن موجب کاهش در متغیرهای ثبات، کنترل وضعیتی ایستا و پویا می‌شود، از این رو پیشنهاد می‌شود افزایش استقامت عضلات گردن برای جلوگیری از خستگی زودرس این عضلات مورد توجه قرار گیرد.*

کلیدواژه‌ها: *کنترل وضعیتی ایستا، کنترل وضعیتی پویا، والیبالیست‌های نخبه*

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