Reaction Time and Anticipatory Skill of Overhead Athletes With and Without Scapular Dyskinesia

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ABSTRACT

Scapular dyskinesia is a change in position or movement of scapula, which is highly prevalent in athletes with overhead activities. In addition to biomechanical changes in shoulder complex, neurocognitive impairments can have a significant role in its creation. Thus, this study aimed to compare neurocognitive scores between athletes with and without scapular dyskinesia. In this study, 30 athletes with overhead activities participated. Caliper and SART (Speed Anticipation and Reaction Time) sets were used for assessing subjects' scapular dyskinesia, reaction time, and anticipation skill. Athletes with scapular dyskinesia had significantly a slower visual and auditory complex choice of reaction time, and a lower auditory choice of reaction time compared to athletes without scapular dyskinesia. No significant difference was seen between two groups in terms of visual choice of reaction time and anticipation skill. Thus, athletes with scapular dyskinesia had poorer performance in more complex neurocognitive tests compared to athletes without it.

1. Introduction

Scapular dyskinesia is a change in the position or movement of the scapula during the coupling movement of scapulohumeral and glenohumeral joints. In the other words, it often results from inhibition or imbalance in the activity pattern of stabilizer muscles of scapula [1]. The possibility of scapular dyskinesia in athletes such as volleyball and basketball players is high compared to other fields of sport because the most activities of these athletes are done overhead, and throwing is performed as an extra load on dominant shoulder [2]. Most of studies done in overhead athletes focused on biomechanical and neuromuscular characteristics of shoulder complex so far [2, 3, 4]. Although deficit in these characteristics may predispose subjects to musculoskeletal disorders in shoulder complex, the underlying influence of neurocognitive processes on determining the motor behavior is very important.

New insights into the mechanisms of the brain and neuromuscular control can be obtained by neurocognitive tests. Measuring the process of speed and reaction time has been used as a neurocognitive test in several studies [5, 6]. Computational methods can quickly and easily calculate a person's overall reaction time that indicates the stimulus identification, response selection, response planning, which is considered a general indicator of functional integrity of central nervous system [7, 8].

In a recent prospective study, the relationship between low performance of neurocognition in athletes and the nontraumatic injury of the anterior cruciate ligament has been shown [9]. In a review study, it was also noted that poor coordination and slow psychomotor speed provide

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the background of injury [10]. The results of the two studies showed that people with chronic low back pain had longer choice reaction time compare to the control group [11,12]. These findings revealed the importance of better reaction times in preventing musculoskeletal impairments. As maintaining the dynamic stability of scapula needs complex neuromuscular strategies, this study aimed to compare the reaction time and anticipatory skill of athletes with and without scapular dyskinesia to provide new perspective in connection between neurocognitive function and brain mechanisms to control the motor program.

2. Materials and Methods

This study used a descriptive–analytical method. Thirty (15 with and 15 without scapular dyskinesia) volunteers were selected among students of physical education. Each group comprised 10 female and 5 male athletes. Participants were invited to cognitive laboratory of Rehabilitation School of Medical Sciences. They first signed informed consent forms. Then, they underwent the initial assessments, including filling a questionnaire related to demographic characteristics and measurements of height and weight. All stages of the research had been approved by the Ethics Committee of University of Medical Sciences. Inclusion criteria consisted of age between 20–35 year old, sport history of regular participation in overhead fields (volleyball, basketball) 3 d/wk for at least two years, being right-handed, ability to move shoulder in full range of abduction, and scaption and internal rotation.

Exclusion criteria consisted of history of surgery or trauma to the shoulder (dislocation, subluxation, or joint sprain) in recent 6 months , any postural deformity such as kyphosis or scoliosis, pain, chronic or acute disease like neurological, cardiac and metabolic disease, serious problems related to hearing, vision or color blindness, taking any medication or having any particular disease, which may affect the movement/cognitive performance , taking any stimulant drinks (such as tea, coffee, alcohol, or chocolate) before the tests session, unwillingness to continue the trial, people with education lower diplomas [2,13].

Each volunteer was assessed for the presence of scapular dyskinesia by a lateral scapular slide test that would be described in the following section. Accordingly, we enrolled a group of athletes with scapular dyskinesia. Then, the second group was selected among those volunteers without scapular dyskinesia that was matched with respect to age, sex, body mass index (BMI), type of exercise, and sports history with the first group.

Figure 1. GUI of the Audio and Video Reaction time Test.

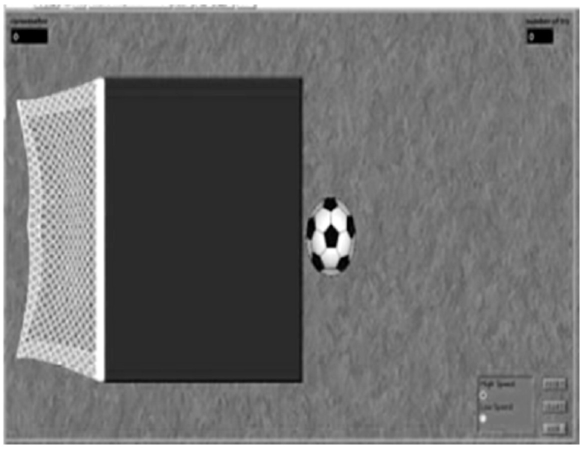

Figure 2. GUI of Anticipatory Skill Estimation Test

The evaluation of scapula dyskinesia was performed based on Kibler method (Lateral Scapular Slide Test) by a digital caliper (Mitotuyo company, Japan) [14]. The reliability and validity of tool were investigated in several studies and reported to be moderate to high [15,16]. Spinous process of the seventh thoracic vertebra and inferior angle of scapula were determined by palpation and marked. The order of right or left scapular distance measurement was randomly determined.

This test was performed in three functional positions: 1) hands were along the body, 2) hands were on iliac crest so that the thumb finger was in the back and other fingers were in front, and 3) 90º of shoulder abduction and internal rotation so that the thumb finger was perpendicular to the ground. In each of these positions, the distance between inferior angle of scapula and spinous process of the seventh thoracic vertebra (scapular distance) was measured by a digital caliper with an accuracy of 0.01 mm (so that the outer arm of caliper was placed on inferior angle and inner arm on spinous process). The volunteers were asked to be comfortable and focus on a point that was marked in

Table 1. Comparision of means of demographic data in athletes with and without scapular dyskinesia (n=30).

Variables	Athletes with dyskinesia	Athletes without dyskinesia
Age (y)	23.66 ± 2.25	24.84 ± 3.86
Height (cm)	169.33 ± 8.95	167.80 ± 10.05
Weight (Kg)	64.93 ± 14.28	66.06 ± 15.07
Athletic history (y)	4.73 ± 3.41	5 ± 4.2

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front of them during test. Resting interval between each position was 30 seconds. Measurements were duplicated and the average was used for analysis. The difference of 1.5 cm or more between right and left scapular distances was diagnosed as scapular dyskinesia [17].

To test reaction time and anticipatory skill, participants were seated on a chair with adjustable height so that their feet were placed on the ground, in front of a 24 inch monitor (Samsung, Korea), which is located at the distance of 2 m from them. Measuring reaction time and anticipatory skill was done by handmade software called Speed Anticipation Reaction Time Test (SART). Reliability and validity of this software was already determined [18].

The software was installed on a laptop (Dell Vostro 1510) to see the content on the monitor. Menu selection and determining the start of tests were only controlled with proofer. In this setup, the possibility of creating visual stimulation by light bulbs to four colors, red, yellow, green, and blue, on the monitor and the corresponding auditory stimulation with frequencies of 500, 1000, 3000, and 7000 Hz was provided (Figure 1).

Volunteers activated the corresponding key (response) as soon as possible after proofer randomly activated any of stimulants (stimulations). Before test, they became familiar with software by self–training for a short time. Incompatible mode in this software could have been activated by pressing the "REVERSE KEY" at the beginning of the program. In this mode, the chassis of reaction acted non–corresponding with Graphical User Interface (GUI) enabled us to evaluate complex choice of reaction time. Above-mentioned tests were repeated in 5 sets with 10 stimulants in each set and the reaction times were recorded with accuracy of 1 ms by the system. In a test window of anticipatory skill, a ball was moved horizontally from the right to left side of the window at a constant speed.

A curtain was embedded in the left side. The ball was disappeared when it got the curtain and the chronometer of the system started to work at this point (Figure 2). The subject should press the key when the ball hit the final point of curtain with watching ball way carefully before it was disappeared, and the ball speed was calculated. The chronometer got stopped and a lamp would light at this point. The anticipatory skill was tested in both high and low speed. The test was repeated 3 times in each speed, and each time contained 10 trials. Finally the average was recorded by the system with the accuracy of 1 ms.

Descriptive statistics was used for calculating indexes of central tendency (mean) and dispersion (standard deviation). The normality was determined by Kolmogorov-Smirnov test. To test the hypothesis, parametric statistics and an independent t test were used. The level of significance was considered at 0.05.

3. Result

In this study the information of 30 overhead athletes in two groups (15 with and 15 without scapular dyskinesia) was analyzed. Mean and standard deviation of age, height, weight, and athletic history for all participants are shown

Table 2. Comparision of means of scapular distance differences in athletes with and without scapular dyskinesia (n=30).

Positions	Athletes with dyskinesia	Athletes without dyskinesia
0 degrees of abduction (mm)	8.05 ± 5.80	4.57 ± 4.08
45 degrees of abduction (mm)	15.38 ± 5.89	4.85 ± 4.25
90 degrees of abduction (mm)	12.53 ± 7.45	5.63 ± 4.43

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Table 3. Comparision of means of neurocognitive tests in athletes with and without scapular dyskinesia (n=30).

Test	Athletes with dyskinesia	Athletes without dyskinesia	P value
Visual choice reaction time (ms)	389.60 ± 32.28	383.64 ± 34.42	0.62
Visual complex choice reaction time (ms)	554.47 ± 55.63	510.21 ± 52.79	0.03*
Auditory choice reaction time (ms)	854.45 ± 132.61	713.67 ±111.58	0.004*
Auditory complex choice reaction time (ms)	1087.73 ± 259.75	884.92 ±124.45	0.01*
Anticipatory skill with high speed (ms)	239.01 ± 61.71	263.11 ±67.93	0.45
Anticipatory skill with low speed (ms)	439.80 ± 113.55	550.59 ±142.16	0.70

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in table 1. There were no significant differences between two groups with respect to age, height, weight, and athletic history (P > 0.05). Table 2 shows the differences of right and left scapular distances in each test position in athletes with and without scapular dyskinesia.

There were significant differences between athletes with and without scapular dyskinesia in 3 neurocognitive tests. Athletes with scapular dyskinesia had significantly longer visual complex choice of reaction time (P = 0.03), auditory choice of reaction time (P = 0.004), and auditory complex of choice reaction time (P = 0.01) compared to athletes without scapular dyskinesia. No significant differences between two groups were seen in terms of visual choice of reaction time and anticipatory skills (P > 0.05). Table 3 shows the time of all neurocognitive tests in both athletes with and without scapular dyskinesia.

4. Discussion

This was the first study that investigated neurocognitive skills in overhead athletes with scapular dyskinesia. We compared visual and auditory reaction times as well as anticipatory skills in overhead athletes with and without scapular dyskinesia. Based on the results of this study, athletes with scapular dyskinesia had a longer visual complex choice of reaction time, auditory choice of reaction time, and auditory complex choice of reaction time compared to the athletes without scapular dyskinesia. As also shown at the prospective study, athletes with a history of non-traumatic injury of anterior cruciate ligament had a significant reduction in neurocognitive scores [9]. In another study, the relation between long choice reaction time and history of accidental fracture in young man was shown [19].

Several studies reported that patients with chronic low back pain compared to the control group had longer choice reaction times [11,12, 20]. It seems that poor coordination and slow psychomotor speed cause musculoskeletal injuries [21]. Various authors have attributed scapular dyskinesis to scapular muscle imbalance rather than absolute strength deficit [22-24]. Especially, increasing activity of upper trapezius, along with reduced control of lower trapezius and serratus anterior, can cause abnormal the scapular motion [23, 25].

In other words, lack of coordination between scapular muscles can lead to scapular dyskinesia. Situational awareness and arousal resources may affect neurocognition or brain function [21]. Thus, deficit in complex coordination between different levels of processing information (Cortical, Subcortical, Somatosensory) affects motor control strategies. In fact, motor control and coordination are based on interaction of cortical, subcortical, and somatosensory levels. Complex and high-speed movements of athletes need pre-activation of muscles, which is programmed cortically, as well as reflex contractions.

The cerebral cortex function is based on feed forward processing to start motor program for coordinated implementation of the task. Then, the feedback mechanism provides the motor reflex responses for unexpected events after contact. Although there are many segmental and peripheral reflex pathways, all these motor control processes are eventually planned and regulated with the cerebral cortex [10]. Therefore, imbalance of scapular muscles in overhead athletes with scapular dyskinesia may be related to changing in cerebral and neurocognitive processes.

In our study, there were no significant differences between athletes with and without scapular dyskinesia in term of visual choice of reaction time and anticipatory skills. Information processing theorists consider decision-making in sport games as the player' ability to accurately perceive the situation, hold what they perceive in short-term memory and compare the present situation with past experiences stored in long-term memory. This is the exact role of working memory [26].

The positron emission tomography study has revealed that working memory activates the prefrontal cortex, anterior cingulate cortex, hippocampus, and probably the basal ganglia and cerebellum [27]. Therefore, cognitive skills are prerequisite for team sport activities [28]. Based on our results, it seems that athletes with scapular dyskinesia are different with athletes without it just in tasks that have a certain complexity. Based on the information processing theory, a complex task requires the use of all mental processes, perception of information maintained in short-term memory, recalling information from long-term memory, decision-making, and regulating the movement. Most researchers claim that the complex tasks activate great areas of the brain particularly in the prefrontal cortex [29, 30].

Hence, the type of neurocognitive test (simple, choice, or complex choice) is undoubtedly an important factor to show the neurocognitive skill differences between subjects. Therefore, one reason that there was no difference between two groups in term of visual choice reaction time, and anticipatory skills can be attributed to the simplicity of these tests in our study. Many studies have shown that reaction to sound is faster than reaction to light [31, 32]. Differences in reaction time between these types of stimuli are related to whether the response is simple or complex [13]. In our study, all participants had significant faster visual choice reaction time than auditory reaction time tests. It could be assumed that the response to visual tests is easier than auditory tests. Thus, the lack of significant difference in visual choice reaction time test between two groups might be due to the lack of sufficient complexity.

In addition, recent studies [33] have shown that even for tasks which there is evidence that activate prefrontal cortex, the exercise does not affect all aspects of the task evenly. So there is a possibility of a positive effect of exercise on one aspect of the task and its negative effects on the other aspects. In each group, we will not see any effect on the output. The motor behavior includes reflexive movements (lowest level) up to voluntary movements (highest level). Voluntary movements involve a lot of nonsteryotyped motor activity that are often guided with sensory information from the outside world and with the motor strategies, form previous experience [34].

Athletes need a wide attention field to continuously monitor the environment, filter irrelevant information, and simultaneously perfor complex motor programs. Increasing arousal or anxiety, reducing concentration of athletes and minimizing the attention field, and also alter muscle activity that causes poor coordination and low performance [35]. Regarding athletes, our results were consistent with the previous studies that showed mental ability and long reaction time may associate with overall musculoskeletal complaints [10, 21]. A small deficit in reaction time and processing speed can make people susceptible to small errors in judgment or loss of coordination faced with complex surrounding issues during sports competitions [26]. Undoubtedly, a small error can impair muscle activity and coordination. In athletes with overhead activities, it could be the underlying cause of scapular dyskinesia.

A number of limitations were found in this study. Measuring the scapular asymmetry for determining a group with scapular dyskinesia was based on 2-dimentional static measurement while the scapular motion has 3-dimentional kinematics. In addition to factors controlled in this study, there were many other factors such as fatigue, intelligence, stressful life events, control of emotions, and personality type that can affect reaction time and overall neurocognitive performance. Furthermore, selection of the comparison groups is a problem in case control studies. Since random selection can minimize the bias, the results of this study should be viewed with caution until prospective studies can be done.

In conclusion, this study showed that athletes with scapular dyskinesia had a lower performance in neurocognitive tests (that had sufficient complexity to activate prefrontal cortex) compared with the athletes without scapular dyskinesia. Therefore, neurocognitive skills have an important role in the prevention of scapular dyskinesia.

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