Research Paper: Comparing Neurocognitive Parameters Between Women With Lumbar Hyperlordosis and Normal Women

Sara Fereydounnia[1], Azadeh Shadmehr[1*], Saba Salemi[2]

1. Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.
2. Student Research Committee, School of Rehabilitation, Shiraz University of Medical Sciences, Shiraz, Iran.

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ABSTRACT

Introduction: The prevalence of lumbar hyperlordosis is high in young women. Considering the previous studies on the role of neuro-cognitive skills in preventing musculoskeletal injuries, the goal of the present study was to examine these skills in women with lumbar hyperlordosis.

Materials and Methods: A total of 15 women with normal lumbar lordosis and 15 women with lumbar hyperlordosis participated in this study. Measurements of the visual and auditory reaction time and anticipatory skills were performed by using Speed Anticipation Reaction Time (SART) test. The Independent t-test was used to compare between two groups.

Results: The distribution of all variables in both groups was normal, according to the result of Kolmogorov-Smirnov test. The results showed no significant difference between the two groups (P>0.05).

Conclusion: The participants of our study had no pain, movement limitations or disability. Our study results were not consistent with the findings of previous studies in this topic. It is suggested that in the future studies the individuals with severe malalignments (that affected their lifestyle) be assessed to clarify the reason for these discrepancies among study results.

1. Introduction

Lumbar lordosis is the ventral curvature of the lumbar spine, consisting of the wedging of the bodies of the lumbar vertebrae and their intervertebral disks. The posterior curvature of the vertebral bodies and disks increases the angle of the lumbar lordosis. On the other hand, anterior wedging of these structures (the anterior portion is shorter than the posterior part) reduces the angle of lumbar lordosis. Each of the five vertebrae (the vertebral bodies and their adjacent disks) contribute to the formation of the lordosis. The last lumbar segment forms 40% of the lordosis and the first segment of the spine forms only 5% of the lordosis. The lordosis angle is also related to the orientation of the facet joints. For example, the lordosis is more associated with the posterior slope (horizontally) of the facet angles relative to the

* Corresponding Author:
Azadeh Shadmehr, PhD.
Address: Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.
Tel: +98 (21) 77528468
E-mail: shadmehr@tums.ac.ir

vertebral bodies [1]. Harrison et al. like Troyanovich et al. stated that the normal curvature of the lumbar vertebra is about 39.7° [2].

The prevalence of lumbar hyperlordosis in students is about 49.75%. According to a study on the prevalence of lumbar malalignments in different age groups, 29.5% of the individuals had lumbar hyperlordosis. In addition, the prevalence is higher in adolescents (38.8%) and young women (48.7%) [3].

Researchers believe that in an upright standing position, weakness of the rectus abdominis muscles allow the onset of anterior pelvic tilt and hyperlordosis posture. Some researchers believe that abnormal posture in the lumbar region such as hypolordosis and hyperlordosis, represents a change in muscle activity and stress patterns that reduces the tolerance of certain daily activities in these individuals [2]. Various factors and abnormalities can play a role in increasing the lumbar spine lordosis, including the tightness of iliopsoas, hamstring muscle weakness, and higher anterior pelvic tilt [2].

A review study suggests that weak coordination and slow psychomotor reaction time provide the basis for injury [4]. In a prospective study, it was concluded that individuals with a history of non-contact anterior cruciate ligament injury had a significant reduction in neuro-cognitive scores and increase in the reaction time [5]. Also, in some studies the results indicate that the reaction time of people with chronic low back pain is slower compared to the control group [4, 6, 7]. These findings reveal the importance of better reaction time in preventing musculoskeletal disorders. Therefore, individuals with lumbar lordosis are expected to have longer reaction time and worse performance in anticipatory skill tests than the control group.

Measurement of the reaction time is done for two reasons. First, it is a component of the real life's tasks (such as the start of a fast action). Second and the more important reason is that the reaction time is involved in the identification of the stimulus, the choice of response, the planning for the response, and finally the execution of the response. Besides it is considered as the general indicator of the functional integrity of the central nervous system [8]. On the other hand, anticipatory skill is a strategy for reducing the reaction time or even reducing the processing time, which is naturally applied in response to an unpredictable stimulus [9].

Typically, electromyography and computerized software can be used to measure the reaction time and anticipatory skill. In the electromyography technique, the reaction time is calculated solely for a specific muscle. Therefore, it is not possible to examine the cognition and decision making. But by the computerized methods, the examiner could quickly and easily assess the overall reaction time of a participant.

Since the relationships between the brain function and the motor control strategies and musculoskeletal disorders have already been investigated, our main goal is to study and compare the reaction times and anticipatory skills of women with lumbar hyperlordosis to provide a new perspective into the mechanisms of the brain and neuromuscular control and also to prevent musculoskeletal disorders and injuries.

2. Materials and Methods

This study was performed in the Reaction time Laboratory of the School of Rehabilitation, Tehran University of Medical Sciences.

Study participants

The participants were recruited from School of Rehabilitation via announcement. A total of 15 women with normal lordosis (Mean±SD age=28.07±2.68 years, Mean±SD height=162.20±4.28 cm, Mean±SD weight=59±6.97 kg) and 15 women with lumbar hyperlordosis (Mean±SD age=28.93±3.45 years, Mean±SD height=161.07±8.80 cm, Mean±SD weight=61.53±9.39 kg) were participated in this study.

The participants' age ranged between 18 and 32 years. The participants were included in the normal or control group if they had normal lumbar lordosis (30-40 degree) and in the hyperlordosis group with lumbar hyperlordosis more than 40 degree. Participants were excluded if they had a history of previous neuromuscular and musculoskeletal disorders, taking any medication that affected their motor and cognitive performance, drinking any stimulants such as tea, coffee and alcohol before the test session, and unwillingness to continue study.

Study procedure

Before the study, the examiner explained the objectives and the procedure of the study to the participants. After signing the consent form, participants completed the initial assessment by providing their demographic data via a questionnaire and measurements of their weight and height. After participants were evaluated in terms of the inclusion criteria and the lumbar lordosis angle, the individuals with normal lordosis were matched with the hyperlordosis group according to the age and Body Mass Index (BMI).

Measuring lumbar lordosis angle

Flexible ruler for measuring lumbar lordosis is a reliable, portable, and non-invasive tool with high reliability and validity. To measure lumbar lordosis with a flexible ruler, we need two bony landmarks. In this method, as in the Youdas method, the T12 spinous process was used for the beginning of the lumbar arc [10]. In addition, like many other researchers, S2 spinous process was used for the end of the arc. The reason for using T12, is to cover the entire lumbar arch. To find two bony landmarks, the Hoppenfel method was used.

In this case, the bony landmarks were marked with the sticky removable red points. After identifying these landmarks, the participant was asked to stand on two feet in a comfortable position and look toward the opposite wall and divide her weight between the two feet (the distance between the two feet was 10-15 cm which were marked on the ground). In this situation, the examiner had to wait about two minutes until the participant reaches her normal position. Then two stabilizer arms, whose height and distance are adjustable from the ground, were placed on the xiphoid process of sternum and the upper surface of the pubis symphysis and they were kept fixed until to the end of the measurement.

The flexible ruler was then placed on the lumbar area to form a lumbar lordosis. After the ruler was fixed on the lumbar area, the point in the middle of the two landmarks (S2, T12) was marked with the marker. Without changing the shape of the ruler, it was carefully placed on a white paper. Then the ruler pattern was drawn and the T12 and S2 points were marked. To calculate the lumbar lordosis angle, the T12 and S2 points were measured by a straight line, and the line was drawn perpendicular to the center of the arc. These lines were named respectively L and H. The lordosis angle was calculated by inserting the values in the Formula (1):

(1)
$$\theta = 4\, Arc\tan \frac{2H}{L}$$

Speed Anticipation Reaction Time (SART) test system

During the test, each participant sits on a comfortable chair. The height of the chair is adjusted so that the feet are on the ground. The participant was asked to sit at a 2 m distance from the high-resolution LCD monitor (Samsung 68-2555 A, 24-inch). Measurement of the reaction time and anticipatory skills were done by the SART system. The validity and reliability of this system have already been determined and approved [11]. The system software was installed on a laptop located 2 m away from the LCD, and since the laptop was connected to the LCD by the interface ports, the software content was displayed both on the laptop screen and on the LCD screen (Figure 1). However, the selection of the menu and the determination of the start of each trial was controlled by the examiner behind the laptop and each stimulus was randomly selected by the examiner without being seen by the participants.

The participant was held the joystick with two hands and this situation was the same for all study participants. The output of each trial was a text file and printable. Output report of the reaction time tests are as follows: Average reaction time; and Number of tests in which the error occurred. Output report of the anticipatory tests are as follows: The average of total predictions time that did not result in abnormal response; The difference between the mean real time and the average of the predicted periods of the test; and The number of times that the participant had not responded in 10 seconds, leading to the abnormal message.

In the declared values, the negative value is the sign of the late response and the positive value the sign of earlier response than the real time. On the first page of the software, the test type (reaction time or anticipatory test) is selected by the examiner. In the next menu, an anthropometric data entry table has been designed. If the examiner chooses the reaction time test in the initial menu, the application will open the test window of the reaction time. In this section, visual stimulation is provided by illuminating four lamps in red, yellow, green, and blue on the monitor, as well as the corresponding auditory stimulation of the above colors at frequencies of 500, 1000, 3000 and 7000 Hz (Figure 2).

To perform the test, the examiner chooses one of the visual or auditory modes of the reaction time test. For example, in the visual mode, the examiner chooses the button for each of the four colored lamps and in the auditory mode the button for each of the four different frequencies is chosen on the laptop and the participants has to respond with the corresponding button on the joystick. After subject's familiarization with the system, the test is taken.

The reaction time test is equipped with an incompatible mode, which is enabled by activating it at the beginning of the program and by ticking the reverse key, so it is possible to evaluate the complex choice reaction time

Figure 1. Schematic view of the SART setup

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and the participant has to press the reverse button on the joystick in response to each stimulus. The reaction time tests are repeated in five sets of 10 repetitions, and they are measured with an accuracy of 0.001 s.

By choosing the anticipatory skill test, the participant was in the same previous situation. By pressing the start button in the system, the anticipatory skill test is activated. On the test page, a ball moves horizontally from the right side of the screen to the left side at a constant speed. On the left side, there is a black curtain and the ball is disappeared when it arrives to the curtain. At this moment, the chronometer of the system starts to work.

The participant have to estimate the time when the ball reaches the end of the curtain, according to the visible direction of the moving ball and its speed. The subject have to press the button on the joystick, when it seems that the ball has reached the end of the curtain (Figure 3). At this moment, a lamp is lit at the end of the left-hand side of the screen, and the chronometer stops by the end of the test. In this part of the system, it is possible to perform a two low-speed and high-speed anticipatory skill test, each of them three sets with 10 repetitions. The anticipatory skill of the participants is computed in milliseconds and recorded in its electronic record. The accuracy of this chronometer is 0.001 ms.

Statistical analysis

All obtained data were analyzed in SPSS version 25. A one-sample Kolmogorov-Smirnov test was done to determine normal distribution of all variables ($P>0.05$). Independent t-test was employed to check the demographic variables between the women with lumbar hyperlordosis and the control group. Independent t-test was used to compare the mean reaction time and anticipatory skills between the two groups. $P<0.05$ were used on all statistical tests.

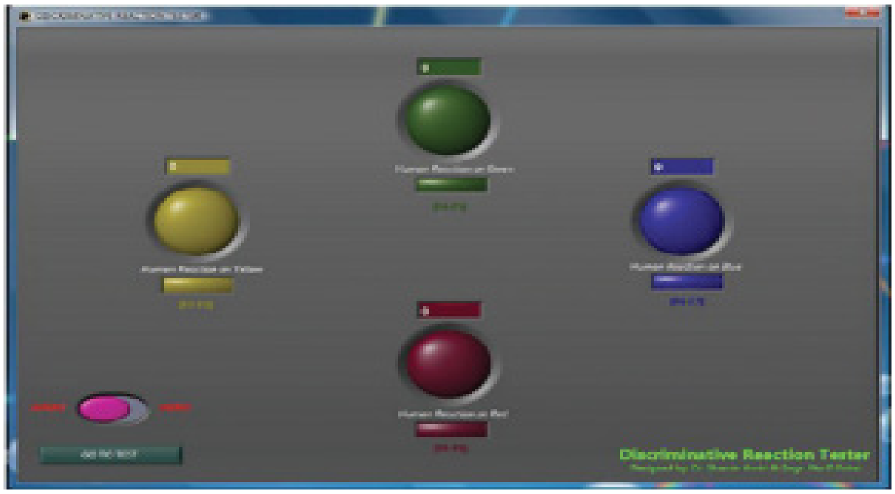

Figure 2. Graphic user interference of the visual and auditory reaction time test

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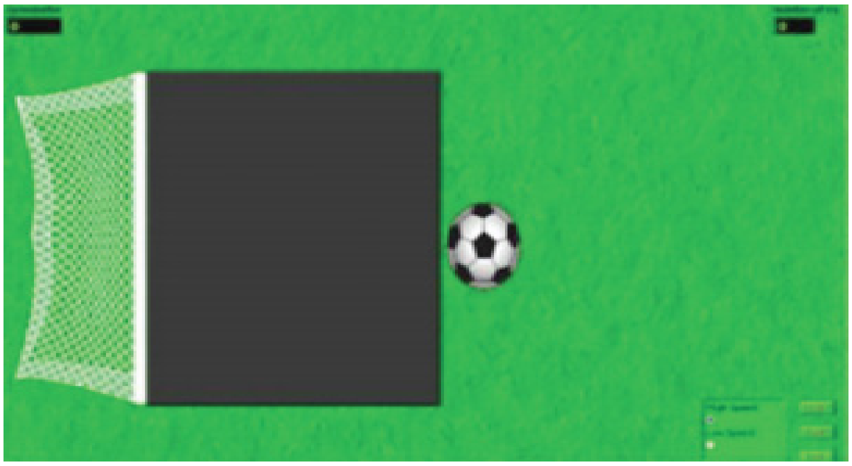

Figure 3. Graphic user interference of anticipatory skill test

3. Results

The distribution of all variables in both groups was normal, according to Kolmogorov-Smirnov test results. There was no significant difference between the two groups with regard to demographic data (P>0.05) (Table 1). According to the Independent t-test, no significant difference was observed in the women with lumbar hyperlordosis and the control group in regards to visual choice reaction time, visual complex choice reaction time, auditory choice reaction time, auditory complex choice reaction time, anticipatory skill with high speed and low speed (P>0.05) (Table 2).

4. Discussion

In this study, neuro-cognitive skills were evaluated by measuring the visual and auditory reaction times and anticipatory skills using the computerized software, called SART-test. As indicated in the results section, there was no significant difference between the two groups of women with normal lumbar lordosis and lumbar hyperlordosis in the visual and auditory reaction times and anticipatory skills.

The reaction time is a common measurement that indicates how much time it takes for a person to get ready to move or start moving. Since reaction time has the central and peripheral components, it is used as a parameter that reflects the cognitive and motor performance. There are three different types of reaction times: simple, choice, and complex choice. These different types of reaction time tasks are used not only in the laboratories and athletic tests, but also in the daily life. The traffic light is a good example of the choice reaction time task that is very common in everyday life. It has three different signals, and each one requires a different response. Therefore, reaction time as a scale of information processing is a very important parameter and is affected by many factors such as age, gender, arousal, fatigue, and physical activity [12].

In a prospective study, Swanik and colleagues examined the neuro-cognitive function of athletes with a history of non-impact injury to the anterior cruciate ligament using computerized software with four tests: processing speed, visual memory, verbal memory, and reaction time tests. The statistical difference between the case group and the control group was significant in all four tests [5]. Several papers reported that patients with chronic low back pain had a longer reaction time than controls [4, 6, 13]. The method used in these studies were computerized software, but only the simple and choice visual reaction times were investigated.

In a study by Shadmehr et al. they used SART system and examined 10 male soccer players and 10 non-athlete healthy men. The results revealed that soccer players had better cognitive abilities than non-athlete men in all tests of visual and auditory choice reaction times, visual and auditory complex choice reaction times, and anticipatory skills [14].

Khademolhosseini et al. examined the reaction times and anticipatory skills in athletes with and without scapular dyskinesia using SART-test system. Visual complex choice reaction time, auditory choice reaction time, and auditory complex choice reaction time in athletes with and without scapular dyskinesia showed a significant difference. That is athletes with dyskinesia had a longer reaction times compared to those with no dyskinesia. However, there was no significant difference in the visual choice reaction time and anticipatory skills of the ball with high and low speeds [15].

Table 1. Independent t-test for the comparison of the demographic data between women with and without lumbar hyperlordosis (n=15 in each group)

Variables	Mean±SD		Mean Difference	95% CI	P
	Hyperlordosis	Control			
Age (y)	28.93±3.45	28.07±2.68	0.87	-1.45-3.18	0.45
Weight (kg)	61.53±9.39	59.00±6.97	2.53	-3.02-2.53	0.41
Height (cm)	161.07±8.80	162.20±4.28	-1.13	-6.31-4.04	0.66
BMI (kg/m²)	23.71±3.10	22.44±2.62	1.27	-0.87-3.41	0.23

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The results of the present study were not consistent with the findings of the previous studies. One of the reasons for this inconsistency could be related to samples in the mentioned studies who were mostly athletes whose neuro-cognitive abilities vary from the non-athletes. In addition, the participants in this study were not aware of their own musculoskeletal disorder, and their lumbar hyperlordosis had not caused pain, movement limitations and disability, or affected their lifestyle. In addition, they became aware of it during the evaluation of this study. Moreover, the lumbar lordosis angle in the participants in the hyperlordosis group was not severe.

Neuro-cognitive skills are considered as a prerequisite for teamwork [16]. According to the theory of information processing, a complex task requires the use of all mental processes, understanding of the stored information in the short-term memory, recalling information from the long-term memory, deciding and adjusting movements. Most researchers believed that complex tasks activate large portions of the brain, and especially the prefrontal cortex [17, 18]. Therefore, the type of neuro-cognitive tests (simple, choice, or complex choice) is undoubtedly an important factor in demonstrating the neuro-cognitive skill differences between individuals.

Although few studies have examined cognitive skills among soccer players and non-athletes, most studies have examined the effect of sport exercises on athletic decision-making abilities in sport teams. The researchers concluded that competitive sport environments improved their decision-making abilities and cognitive skills. The study of Shadmehr and colleagues also revealed the relationship between cognitive ability and the better anticipatory skill of the ball, which is very similar to the playing field for soccer players [14].

Athletes need a wide attentional field to continuously monitor the environment, filter out unrelated informa-

Table 2. Independent t-test for the comparison of neurocognitive parameters between women with and without lumbar hyperlordosis (n=15 in each group)

Variables (ms)	Mean±SD		Mean Difference	95% CI	P
	Hyperlordosis	Control			
Visual choice reaction time	436.19±68.33	444.47±50.68	-8.28	-53.28-36.72	0.71
Visual complex choice reaction time	529.47±56.20	548.30±92.28	-18.88	-75.98-38.22	0.50
Auditory choice reaction time	886.61±146.71	932.83±315.75	-46.21	-230.36-137.93	0.61
Auditory complex choice reaction time	1114.16±298.29	1120.64±394.88	-6.48	-268.22-255.26	0.96
Anticipatory skill with high speed	437.36±381.98	674.94±684.13	-246.78	-656.96-163.41	0.23
Anticipatory skill with low speed	1035±765.71	1175.44±894.13	-140.44	-763.06-482.17	0.65

ms: millisecond

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tion, and at the same time they require a complex motor program. An increase in arousal or anxiety reduces the concentration of athletes as well as changes in their muscle activity that can interfere with coordination and result in their poor performance [19].

Many studies have shown that the response to the auditory stimulus is faster than the response to the visual stimulus [20]. The difference in reaction time between two types of stimuli depends on the simplicity or complexity of the response [21]. In our study, all participants had a faster reaction to visual stimulus in comparison to auditory stimulus. This may indicate a simpler visual tasks in this study. Cognitive abilities (reaction time and anticipatory skills) are important for the successful performance of many daily activities. For example, drivers have higher cognitive abilities and better understanding of their surroundings and could survive from hazardous situations while driving [14].

Lower mental ability and longer reaction time may be related to general musculoskeletal complaints [4, 8]. A small deflection at the onset of reaction and processing speed can make a person vulnerable to small errors in judgment or losing coordination in dealing with complex issues during sports competition [16]. It has been proven that a slight error can undoubtedly interfere with coordination and muscle activity.

This study had some limitations. The number of the participants were too small to fully reflect the reaction time. Many factors, such as fatigue, intelligence, stress, life events, emotional control, and personality characters, can affect the reaction time and the neuro-cognitive function. Also, the selection of study groups was a challenge in this study like other case control studies. Although random selection reduced the bias, the results of the present study should be considered with caution until the results of future prospective studies be provided. The authors suggest that the larger sample of participants be assessed. The study samples with severe lumbar hyperlordosis and signs and symptoms of pain and limitation in their lumbar areas. It is also advisable to assess participants from athletic population for whom the reaction time and anticipatory skill are vital.

Ethical Considerations

Compliance with ethical guidelines

This study was under supervision of Ethics Committee of Research of Tehran University of Medical Science (Grant No.: 95-02-32-32253).

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Authors contributions

Azadeh Shadmehr supervised all stages of the study, including the planning, study design, interpretation the data, editing the manuscript and etc. Sara Fereydounnia contributed to the study design, collecting data, statistical analysis and writing the manuscript. Saba Salemi contributed to the subject selection and data analysis. All authors critically reviewed and revised the manuscript for important contents. All authors have read and approved the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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