ORIGINAL SCIENTIFIC PAPER

Static alignment of the upper limb and performance of athletes with spinal cord injuries

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Abstract

In athletes with spinal cord injuries, due to relying on upper limbs and activities such as driving a wheelchair and repeating specific movement patterns, significant structural changes occur in their upper limbs. Those changes lead to muscle imbalance and disorders in the shoulder girdle and upper limb. Investigation of the relationship between forward head angle, round shoulder, and kyphosis with physical capabilities (power, range of motion, wheelchair propulsion and sitting balance) in wheelchair athletes. 15 male and 13 female wheelchair athletes with Spinal cord injury (age 27.64±7.24) in basketball, pétanque and table tennis were selected. The sagittal view photogrammetry method was used to measure the forward head angle and round shoulder angle. A flexible ruler was used to measure the thoracic kyphosis angle. Additionally, a medicine ball throw to measure power, a goniometer to estimate the range of motion, a 20-meter propulsion test to measure propulsion speed, and a sitting balance test to measure balance were used. Descriptive statistics, Pearson correlation coefficient and stepwise multiple regression were applied to analyse the data at the 0.05 significance level. There was only a significant relationship between the round shoulder with the balance in three directions and throwing the ball. However, in other variables, there is no significant relationship with static alignment. Despite the slight difference in the investigated indicators in this study, it is important from a clinical point of view. For coaches, including the necessary preventive and corrective measures in athlete's training programs is better.

Keywords: *Disability, spinal cord injury, correlation, elite athletes*

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PHYSICAL CAPABILITIES IN ATHLETES WITH SPINAL CORD INJURY
http://mjssm.me/?sekcija=article&artid=275

Cite this article: Pooryamanesh, L., Kondrič, M., Rajković Vuletić, P., Blažević, M., and Daneshmandi, H. (2024) Static alignment of the upper limb and performance of athletes with spinal cord injuries. *Montenegrin Journal of Sports Science and Medicine, 20 (1)*, 81–85. https://doi.org/10.26773/mjssm.240310

Introduction

Disability is a long-term, substantial condition that affects all or part of a person's body and impairs or limits physical function, mobility, or skill. Loss of physical capacity decreases a person's ability to perform physical movements such as walking, moving hands and arms, sitting and standing, and muscle control. As a part of society, people with physical disabilities need sports and movement programs. Adopting a continuous

Received: 02 April 2023 | Accepted after revision: 03 February 2024 | Early access publication date: 01 March 2024 | Final publication date: 15 March 2024

Conflict of interest: None declared.

and incredibly inactive posture in a wheelchair can cause the spine to become out of alignment. Disabled athletes with spinal cord injuries have lost part of their ability based on the type of disability. Therefore, they can be exposed to spine abnormalities due to their sedentary life. Any deformity in the trunk and thoracic spinal cord (such as hyper kyphosis) may reduce muscle strength and range of motion and decrease lung volume (Roshani et al., 2018). In addition, disabled athletes with spinal cord injuries who participate in high-level sports activities are continuously exposed to musculoskeletal disorders, which seem to be caused by exercise and the nature of each sport (Fullerton et al., 2003). Athletes with spinal cord injury suffer from muscle fatigue and eventually pain due to relying on the upper limb in the movement of pushing the wheelchair forward and performing repetitive movements for a long time with the upper limb (Samuelsson et al., 2004). Muscle imbalance plays an essential role in the development of musculoskeletal pain when using a wheelchair. It can affect the body's natural alignment and cause a person to suffer from various postural abnormalities (Freitas et al., 2021). People with spinal cord injuries have skeletal abnormalities of the upper body, leading to muscle imbalance (Wilbanks & Bickel, 2016).

On the other hand, people with spinal cord injuries who use wheelchairs adopt the wrong sitting position due to the imbalance of the trunk muscles, which causes kyphosis, rounded shoulder, and forward head angle in the long term (Medicine, 2005). Sahrmann (2010) states that repetitive movements or continuous positions can change the relationship between length-tension, strength, and stiffness of muscles. As a result, these adaptations may cause movement disorders. Among the complications that may occur due to a change in static alignment are a change in the physical capabilities of the upper limb and a decrease in its function. The muscle group of the shoulder girdle movement includes the pectoralis major, upper trapezius, shoulder elevator and upper deltoid (Williams Jr et al., 2020). The group of stabilisers includes rhomboid, anterior, serratus posterior deltoid, supraspinatus, and teres minor, which are the group of moving muscles prone to shortening and the group of stabilising muscles prone to weakness and stretching (Williams Jr et al., 2020). Disturbances in the static alignment of the upper limbs lead to a decrease in the subarachnoid space, rotator cuff and biceps tendonitis, impingement syndrome and other musculoskeletal disorders, which are more common in wheelchair users and athletes who are participating in sports activities (Yazdani et al., 2021).

Clinical theory suggests that changes in the static alignment of the upper body cause a decrease in muscle function (Turbanski & Schmidtbleicher, 2010). Therefore, we hypothesised that the angles of the forward head angle, kyphosis and round shoulder can be related to the physical capabilities of the upper limb. Therefore, the present research aims to investigate the relationship between the static alignment of the upper limb and the movement performance of athletes with spinal cord injuries.

Methods

Participants

15 male and 13 female (age 27.64±7.24) wheelchair athletes with Spinal cord injuries were randomly selected and participated in this study. The criteria for entering the study included: 1- Female and male athletes with spinal cord injuries who are classified in the sitting group in the relevant sports classification of the Federation of Veterans and Disabled Sports of the Islamic Republic of Iran. 2- Willingness to participate in the research. 3- Age above 18 years. 4- Having at least two years of experience in wheelchair basketball, table tennis and pétanque. 5- Having the conditions and requirements listed in the physical activity readiness questionnaire (PARQ).

Design

Table 1 shows the demographic information of the participants. The results of similar previous studies and Gpower software were used to determine the sample size in this research. Tests related to muscle power, sitting balance, range of motion, wheelchair propulsion, forward head angle, rounded shoulder and kyphosis were measured. To prevent fatigue during the execution of each test, a 5-minute rest interval was considered. Seca 664 digital scale (Seca, Germany) was used to measure the subjects' body weight. To measure sitting height, the distance from the base of the head to the base of the sitting surface was calculated. The body profile photography method measured forward head and rounded shoulder angles. This method has good reproducibility and has been used in the research of Rajabi et al. (2008). Using this method, three anatomical signs of the earlobe, the right acromion protrusion, and the spinous appendage of the seventh cervical vertebra should be determined. They are marked with a marker. Then, the subject was asked to sit in his/her wheelchair at the designated place next to the wall at a distance of 23 cm so that his left/right arm was towards the wall. Then, the photo tripod, on which the digital camera is also placed, was placed at a distance of 105 cm from the wall and its height was set at the level of the subject's right shoulder. In such conditions, the subject was asked to bend forward three times and raise his/her hands above his/her head three times and then sit comfortably and naturally on the wheelchair and look at an imaginary point on the opposite wall (eyes in line with the horizon) then, after a five-second pause, the examiner starts taking pictures of the sagittal view of the body. Finally, the mentioned photo was transferred to the computer and using the angle calculation software (Protractor, vers 1.6.1., Google Commerce Ltd), the angle of the line connecting the earlobe and the seventh cervical vertebra with the vertical line (head forward angle) and the angle of the line connecting the seventh cervical vertebra and the acromion appendage with the perpendicular line (rounded shoulder angle) was measured (Cheshomi & Rajabi, 2011; Rostamizalani et al., 2019). A flexible ruler was used to check the amount of back kyphosis. In such a way that the subject is sitting in the wheelchair so that his hands are placed on the wheelchair handles from the forearm and does not use the back support, the spinous process of the second dorsal vertebra T2 was used as the starting point of the arch and the spinous process of the 12th dorsal vertebra was used as the end of the arc. To find the T2 spinous process, the person was asked to put his neck in flexion and identify the most prominent spinous process, which is the C7 vertebra. Two vertebrae below the mentioned process to identify the T2 vertebra. Since the location of the spinous appendage of the T12 vertebra is on the same level as the lower edge of the twelfth ribs on both sides, the edges of these ribs are simultaneously touched with the tips of the thumbs, and their path will be followed upwards and inwards until the soft tissue of the body disappears. By drawing a straight line connecting the tips of two thumbs, the location of the spinous process of

DOI 10.26773/mjssm.240310

the T12 vertebra was estimated. Then, the measurer puts the flexible ruler on the spine and applies gentle pressure so that the ruler takes the shape of the spine. Then, T2 and T12 points were marked on the ruler. The ruler was slowly removed from the spine and placed on the paper, and after drawing the arc on the paper, its marks were determined. In the next step, to obtain quantitative information, two points marked on the arc were connected, the length of this line was recorded, and L was considered. Also, the deepest part of the arch was identified and considered as H. Then, the back-kyphosis angle was calculated using the trigonometric formula θ=4ARCTAN (2H/L) (Rajabi et al., 2008). The range of motion of flexion, extension, internal rotation, external rotation and shoulder abduction was measured by a universal goniometer using the Clarkson method (Clarkson, 2000). To measure balance in a sitting position, a modified functional reach test was used in three directions: front, left and right. The subject performed the movement three times in each direction and recorded all three records. The average of the second and third attempts was considered the overall score of each direction. To measure power, while the subject was sitting in a wheelchair, he threw a two-kilogram medicine ball forward as far as possible. The throw was done twice, and the distance from the launch to hit the ground was measured with a meter, and the longest distance was recorded as a personal record.

Statistical analysis

In this research, descriptive statistics were used to describe the data of each group (age, height, and weight of subjects). Mean index and standard deviation were used to describe the data. The Shapiro-Wilk test was used to detect the normality of the data, indicating a normal distribution in the research data. To check the homogeneity of variances, Levene's test was used to check the homogeneity of variances. Also, the Pearson correlation coefficient and stepwise multiple regression were applied to examine the relationship between the variables at the 0.05 significance. Statistical operations were performed with SPSS software version 23.

Results

To describe the information of the participants, the mean and standard deviation of the research variables, including age, height, weight, kyphosis, and rounded shoulder angles, are presented in Table 1.

Table 1. The demographic information of the participants

	Male (n=15)		Female (n=13)	
	Mean	Std. Deviation	Mean	Std. Deviation
Age	29.86	7.25	25.07	6.57
Weight	80.15	5.60	58.30	5.32
Seating height	84.04	3.53	71.34	4.54
Kyphosis angle	42.68	2.73	43.08	1.98
Rounded shoulder angle	53.34	2.07	56.15	1.16
Forward head angle	46.40	2.08	47.19	3.30

The correlations between research parameters with static alignment, including kyphosis and rounded shoulder angles, are presented in Table 2. As can be seen, there is only a significant relationship between the round shoulder with the balance in three directions and throwing the ball. However, in other variables, there is no significant relationship with static alignment.

Table 2. Pearson correlation between parameters

Parameters	Medicine ball throw	Seated balance front	Seated balance left	Seated balance right	Shoulder flexion ROM	Shoulder extension ROM	Shoulder internal rotation ROM	Shoulder external rotation ROM	Shoulder abduction ROM	20-meter wheelchair propulsion
Kyphosis	0.760	0.667	0.635	0.505	0.948	0.699	0.989	0.952	0.732	0.351
Forward head angle	0.216	0.344	0.595	0.955	0.774	0.824	0.999	0.832	0.199	0.402
Rounded shoulder	0.00*	0.012*	0.009*	0.041*	0.226	0.287	0.339	0.871	0.090	0.374

*Sig p<0.05

According to the output of the stepwise multiple regression test, we observed that only shoulder flexion ROM is entered into the regression equation, and this change alone in the amount of kyphosis is expressed according to the value of R square (.997). Other variables could not pass the desired criterion and were removed from the model. Therefore, the variable shoulder flexion ROM is the best predictor for kyphosis (p<0.05). Also, for the forward head variable, considering R square (0.996), only the shoulder flexion ROM variable can be a good predictor for forward head angle (p<0.05). Finally, the variables of abduction and flexion ROM of the shoulder, power through medicine ball throwing and seated balance on the left side considering R square (.998, .999, .999, .999), were the variables that can predict the rounded shoulder (p<0.05).

Discussion

The purpose of the present research was to study the relationship between the static alignment of the upper limb and the movement performance of athletes with spinal cord injuries. One of the research findings was a significant relationship between the round shoulder and the balance in three directions and power. The shoulder is the most active part of the body, and it is directed under pressure by wheelchair users and sports with repetitive movements in the upper limbs. Wheelchair athletes use their upper body constantly, and many forces are applied to the shoulder complex from various directions every day. The combination of posterior and superior shoulder forces increases the risk of rounded shoulder and its outcomes in wheelchair athletes (Finley & Rodgers, 2004). The rounded shoulder posture is associated with tightness of the serratus anterior, pectoralis minor, pectoralis major, and upper trapezius muscle and weakness of the middle and lower trapezius (Hasan et al., 2023). In the literature, rounded shoulder posture is described as abduction, the elevation of the scapula giving the appearance of a hollow chest (Kendall et al., 2023). Biomechanical studies show that the rounded shoulder posture causes hypertrophy and bulking of the internal shoulder rotator and adductor muscles compared to their antagonists. This will result in muscle imbalance that reduces the stability and efficiency of the shoulder (Ambrosio et al., 2005; Nejati et al., 2014). Muscle imbalance, which should function as one of the risk factors related to protective and stabilising mechanisms in the shoulder, can reduce functional stability in wheelchair users. As a result, lower scores are observed in the balance test. The inefficiency of the sensory-motor system and shoulder proprioceptiveness are other issues that occur after a rounded shoulder. It can cause shoulder instability, reducing achievement in different directions of the sitting balance test (Myers et al., 2006). A rounded shoulder would lead to the shortening of the pectoral muscles and elongating of the scapular retractors. The shortened pectoral muscles might then exhibit increased strength and power, and more importantly, the elongated scapular retractors might become relatively weaker (Kendall et al., 2023). Protruding shoulder posture causes other defective conditions such as kyphosis and forward head, which over time leads to stabilisation of muscle shortness/weakness of antagonistic groups, disturbance in the communication between agonistic and antagonistic muscle groups, and the dominance of synergistic muscle groups (Yip et al., 2008). As a result of shoulder joint instability, the dysfunction of joint mechanical receptors leads to the inhibition of joint stabilising neuromuscular reactions (Barden et al., 2005). It leads to decreased upper limb muscle strength, stability, and balance.

Among the limitations of this study, we can mention the limited number of qualified samples and the impossibility of accurately controlling the mental and motivational state of participants in the research process.

Conclusion

In the present research, which investigated the relationship between the forward head angle, round shoulder, and kyphosis with the physical capabilities of athletes with spinal cord injury, we concluded that the rounded shoulder angle is related to upper limb balance and power. In addition, the round shoulder is related to other disorders and injuries. Therefore, with some considerations, this can reduce the probability of damage. These actions include screening and evaluating the alignment of the upper limbs, teaching the correct movement patterns of the upper limbs of wheelchair athletes and providing a suitable exercise program to establish muscle balance in the upper limbs. Despite the slight difference in the investigated indicators in this study, the results are significant from a clinical point of view. Movement performance is improved by improving the alignment of the upper limb by modifying movement patterns and muscle balance. For coaches, including the necessary preventive and corrective measures in athlete's training programs is better.

Acknowledgements

The authors would like to thank the participants enrolled in the study.

Ethical Approval Information

The University of Ljubljana, Committee for Ethical Issues in Sports approved the study (Nr. 10:2023).

Funding

This research received no external funding.

Availability of data and material

All data generated or analysed during this study will be/are included in the published article as Table(s). Any other data requirement can be directed to the corresponding author upon reasonable request.

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