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ORIGINAL RESEARCH

Physical characteristics of the pulling and stabilization arm in archers, examination of posture and injury risk

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Abstract

This study aimed to evaluate the physical characteristics, posture, and musculoskeletal problems of the stabilization and pulling arms in archers. Thirteen licensed athletes aged 11–18 years, each with at least two years of experience, were assessed for muscle shortness, flexibility, scapular dyskinesia, muscle strength, posture, and musculoskeletal complaints. Significant differences were found between the pulling and stabilization arms in shoulder flexion, abduction, adduction, elbow flexion, and various grip strengths ($p<0.05$), as well as in shoulder and hip anterior tilt ($p<0.05$). Musculoskeletal pain was most frequently reported in the back and lower back, followed by the knee and neck. These findings suggest that archers may develop postural alignment issues, particularly on the pulling arm side, and highlight the importance of archery-specific postural exercise programs for injury prevention.

Introduction

Archery is a non-contact and static sport that particularly requires the strength of the shoulder, shoulder girdle, and forearm muscles (Ertan et al., 2003). This sport demands a high level of motor control and the maintenance of a consistent sequence of movements. In shooting technique, the non-dominant arm typically serves as the “stabilization arm,” whereas the dominant arm functions as the “drawing arm” (Nishizono et al., 2008). The shooting process was described in archery in six distinct stages (Nishizono et al., 2008): bow holding, drawing, full draw, aiming, release, and follow-through. Therefore, archery performance is not solely limited to the ability to hit the target but represents a complex construct shaped by the interaction of multiple physical, psychological, technical, and environmental variables. In this context, upper extremity muscle strength, maintenance of correct posture, and balance control stand out as fundamental physical determinants of successful shooting performance (Ertan, 2009; Kim et al., 2016). Moreover, biomechanical efficiency, the achievement of intermuscular coordination, and a smooth release technique are critical components in determining shot accuracy. In addition, psychological factors such as focus, mental resilience, and stress management have a direct influence on performance under competition conditions (Mann & Littke, 1989; Ko et al., 2010; Landers et al., 1994).

Due to its repetitive and unilateral loading patterns, archery can lead to the development of a condition referred to as arm asymmetry. Arm asymmetry is defined as differences in strength, flexibility, muscle volume, and motor control between the dominant and non-dominant arms (Kikuchi & Nakazawa, 2016a; Sanchis-Moysi et al., 2010a). In the drawing arm, repetitive movements induce muscle hypertrophy, increased strength, and enhanced proprioceptive sensitivity, whereas the stabilization arm primarily serves to maintain posture and balance. Over time, this functional differentiation can result in structural and functional asymmetries in the shoulder girdle and back musculature (Sanchis-Moysi et al., 2004). Such asymmetries affect not only muscle mass but also joint

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stability, scapular mechanics, and trunk alignment, thereby predisposing athletes to overuse injuries (Ertan et al., 2003). Previous studies have reported that unilateral sports can influence postural development in young athletes, sometimes correcting pre-existing asymmetries but, in other cases, exacerbating them (Sanchis-Moysi et al., 2010b; Kikuchi & Nakazawa, 2016b). While a mild degree of asymmetry may contribute to technical skill, excessive asymmetry may compromise the integrity of the kinetic chain, impair motor control, and ultimately hinder performance (Sterkowicz-Przybycień et al., 2017).

Furthermore, repetitive anterior scapular rotation in archery has been associated with shortening of the pectoralis muscles and weakening of the scapular stabilizers, which, in turn, increases the risk of injury in the shoulder, elbow, and wrist of the drawing arm (Ludewig & Reynolds, 2009; Sarro et al., 2021; Niestroj et al., 2018). For this reason, comparing the musculoskeletal characteristics of both arms is essential for identifying postural deviations, reducing injury risk, and designing performance-enhancing training programs tailored to the specific physical demands of archery.

Method

Study Design

The study was a cross-sectional study.

Participants

Licensed archery athletes between the ages of 11-18 were included in the study. The sample size of the study was calculated using G*Power 3.1.9.7 program. In the calculation, the number of samples required to determine the difference between the right and left arm was calculated as 13 for the t-test with a medium effect level ($d = 0.86$), 5% margin of error ($\alpha = 0.05$) and 80% power ($1\text{-}\beta = 0.80$). For the study, 15 licensed archery athletes were reached. Since 1 of them refused to participate in the study and 1 did not meet the inclusion criteria, the study was completed with 13 athletes. The inclusion criteria were being between 11-18 years of age, being a licensed archery athlete, practicing archery for at least 2 years and agreeing to participate in the study. Exclusion criteria were having a musculoskeletal injury and treatment within the last 3 months, having any diagnosed neurologic or rheumatologic disease, and having undergone surgery on the extremities before. Written informed consent was obtained from all participants and their families. This study was conducted after obtaining the approval of Bolu Abant İzzet Baysal University, Clinical Research Ethics Committee numbered 2023/153.

Procedure

Firstly, gender, age, body mass index (BMI), dominant side, eyeglass use, and type of bow were recorded for all participants. The pectoral, shoulder internal and external rotator muscles were assessed for muscle shortness. Trunk rotation, lateral flexion and hyperextension, and horizontal flexibility of the arms were assessed and a sit-lie test was performed. For scapular evaluation and scoliosis assessment, the distance between the mastoid process and acromion and the distance between the wall and acromion when leaning against the wall were measured. The distance between the upper, middle and lower points of the medial part of the scapula and the spinous processes of the vertebrae was measured. Lateral Scapular Slide Test (LSST) was performed to evaluate scapular dyskinesia. Shoulder flexion, abduction, elevation and elbow flexion and extension muscle strengths of the participants were evaluated with the MF2 Microfet 2 Manual Muscle device for right and left extremities. Hand grip strength was measured with Jamar hand dynamometer, which is accepted as the gold standard. The circumferences of both extremities of the participants were measured 10 cm above and 10 cm below the elbow joints. The Side Bridge Test was used to assess the endurance of the lateral trunk flexor muscles of the participants. Cornell Musculoskeletal Disorders Questionnaire (CMDQ) was used to assess the injury risk of the participants. Posture assessment of the participants was performed with "Posture Screen Mobile (PSM)" (posture analysis/body composition/movement assessment software). This application is a valid and reliable application developed to evaluate posture with the help of a camera system on devices with iOS and Android systems (Hopkins et al., 2019). The participants were photographed from the front, back, right and left laterally with their upper torso and clothes that were open below the knees. The photographs were evaluated with PSM by determining anatomical reference points on the photograph. According to these marked points, postural disorder values and the degree of disorder were calculated as the degree of deviation from normal posture for each individual through the software (Szucs & Brown, 2018).

Statistical Analysis

Statistical analysis of the study was performed with the SPSS program. For descriptive statistics, mean (Mean) and standard deviation (SD) values were used for continuous variables and number (n) and percentage (%) values were used for categorical variables. Whether the data were normally distributed or not was decided according to the skewness and kurtosis values. Since the data were not normally distributed, the difference between the tensile arm and stabilization arm was analyzed with the Wilcoxon Test, a nonparametric test.

Results

When the demographic characteristics of the 13 licensed archers who participated in the study were examined, the average age was 15.07 ± 1.81 years, the average height was 162.64 ± 7.33 cm, the average weight was 54.00 ± 7.33 kg, and the body mass index was 20.33 ± 2.22 kg/m2. 57.1% of the archers were male, 42.9% were female, 21.4% wore glasses, all of them were right-handed, and their educational status was middle school 21.4% and high school 71.4%.

In our study, a significant difference was observed between the pulling and stabilization arms in the acromion–wall distance, whereas no difference was found for the acromion–mastoid distance ($p>0.05$). Regarding scapula–spinous process measurements, a significant difference was detected only at the upper edge of the scapula ($p<0.05$). Additionally, scapular lateral shift tests revealed a significant difference exclusively at 45° ($p<0.05$). Clinically relevant effect sizes (≥0.40) were observed for scapula upper-spinous process distance (d = 0.44), scapula lateral shift at 45° (d = 0.43).

Table 1
Comparison of anthropometric measurements of pulling and stabilization arms of archers.

		Min	Max	Mean ± SD	p	Cohen d
Acromion-Mastoid	Pulling	7.50	21	16.57 ± 3.11	.219	0.21
	Stabilization	8	20	15.89 ± 3.43		
Acromion-Wall	Pulling	7	13	11.17 ± 1.62	.044*	0.36
	Stabilization	6	14	10.57 ± 1.75		
Scapula Sub-Spinous Process	Pulling	7	11	9.71 ± 1.32	.529	0.18
	Stabilization	7	12	9.46 ± 1.47		
Scapula Mid-Spinous Process	Pulling	5	9	6.91 ± 1.09	.238	0.24
	Stabilization	3	8	6.60 ± 1.43		
Scapula Upper-Spinous Process	Pulling	6	10	7.67 ± 1.21	.026*	0.44
	Stabilization	4	10	7.10 ± 1.37		
Scapula Lateral Shift Neutral	Pulling	7	11	9.71 ± 1.26	.469	0.21
	Stabilization	7	12	9.42 ± 1.50		
Scapula Lateral Shift 45°	Pulling	8	15	10.53 ± 1.86	.015*	0.43
	Stabilization	7	14	9.75 ± 1.75		
Scapula Lateral Shift 90°	Pulling	6	14	10.96 ± 2.07	.785	0.02
	Stabilization	6	14	10.92 ± 2.00		

*Min: Minimum; Max: Maximum; SD: Standard deviation; * p<0.05.*

Table 2
Comparison of archers' pulling and stabilization arms in terms of muscle shortness and flexibility.

Muscle Shortness and Flexibility (cm)		Min	Max	Mean ± SD	p	Cohen d
Pectoralis Minor Shortness	Pulling	6	17	9.89 ± 2.71	.031*	0.36
	Stabilization	7	17	8.96 ± 2.49		
Short Shoulder Internal Rotators	Pulling	4.50	17	11.89 ± 3.70	.231	0.33
	Stabilization	6.50	15	10.78 ± 2.93		
Shoulder External Rotators Shortness	Pulling	2	20	10.60 ± 5.14	.003*	0.75
	Stabilization	0	15	6.60 ± 5.50		
Flexibility of Trunk Rotation	Pulling	18	38	26.35 ± 5.75	.041*	0.30
	Stabilization	17	37	24.46 ± 6.82		
Trunk Lateral Flexion Flexibility	Pulling	16	32	21.42 ± 3.91	.171	0.23
	Stabilization	14	29	20.50 ± 3.97		
Trunk Hyper-Extension Flexibility		20	39	26.35 ± 4.86		
Sit Lie Test		-24	13	0.28 ± 9.50		

*Min: Minimum; Max: Maximum; SD: Standard deviation; * p<0.05.*

In our study, a significant difference was observed in pectoralis minor muscle shortness and shoulder external rotator length between the pulling and stabilization arms of archers (p<0.05), whereas no significant difference was found for shoulder internal rotators or trunk lateral flexion flexibility (p>0.05). Trunk rotation flexibility differed significantly between sides.

Trunk hyperextension flexibility and sit-lie test analyses are given in Table 2. The effect size of the Shoulder External Rotators Shortness value is 0.75.

In our study, archers' pulling arms exhibited significantly greater shoulder flexion, abduction, and adduction forces, as well as elbow flexion strength, compared to the stabilization arms (p<0.05). Similarly, hand, palmar, fingertip, and lateral grip strengths were higher in the pulling arm (p<0.05). No significant difference was observed in right versus left lateral trunk endurance (p>0.05). Above-elbow circumference was significantly larger in the pulling arm (p<0.05), whereas below-elbow measurements showed no difference (p>0.05). Alongside p-values, effect sizes (Cohen's d) were calculated to quantify the magnitude of between-group differences. Clinically relevant effect sizes (≥0.40) were observed for shoulder abduction strength (d = 0.46), elbow flexion strength (d = 0.59), palmar grip (d = 1.31), finger tip grip (d = 1.07) and lateral grip (d = 1.72). The values indicated indicate that, beyond statistical significance, this parameter exhibits differences of potential clinical importance.

Table 3

Comparison of archers' pulling and stabization arms in terms of force.

		Min	Max	Mean ± SD	p	Cohen d
Shoulder Flexion Strength	Pulling	129.90	268.70	180.04 ± 42.74	.030*	0.2
	Stabilization	112.10	259.80	171.57 ± 40.75		
Shoulder Abduction Strength	Pulling	129	273.60	182.78 ± 38.39	.004*	0.46
	Stabilization	115.60	221	166.30 ± 32.65		
Shoulder Adduction Strength	Pulling	135.70	306	211.55 ± 52.74	.001*	0.37
	Stabilization	122.70	285	192.37 ± 49.95		
Elbow Flexion Strength	Pulling	137.30	290	224.70 ± 47.39	.001*	0.59
	Stabilization	105	260.80	196.62 ± 48.34		
Elbow Extension Strength	Pulling	82.30	190	138.62 ± 38.50	.009*	0.26
	Stabilization	76.50	185	129.41 ± 33.11		
Hand Grip	Pulling	19	50	30.42 ± 8.03	.011*	0.21
	Stabilization	17	45	28.78 ± 7.30		
Palmar Grip	Pulling	4.80	7	6.05 ± 0.66	.001*	1.29
	Stabilization	4.20	6.30	5.22 ± 0.63		
Finger Tip Grip	Pulling	4.20	6	5.18 ± 0.54	.001*	1.07
	Stabilization	3.20	5.70	4.55 ± 0.63		
Lateral Grip	Pulling	6.30	8.40	7.35 ± 0.73	.001*	1.74
	Stabilization	5	7	6.09 ± 0.72		
Lateral Trunk Endurance	Pulling	5	115	63.14 ± 33.50	.258	0.11
	Stabilization	4	22	59.42 ± 34.29		
Above Elbow Circumference	Pulling	19	29	23.71 ± 2.79	.012*	0.16
	Stabilization	18	28	23.25 ± 2.80		
Below Elbow Circumference	Pulling	16.50	25.50	21.89 ± 2.75	.206	0.12
	Stabilization	*17*	*25*	*21.57 ± 2.45*		

*Min: Minimum; Max: Maximum; SD: Standard deviation; * p<0.05.*

Table 4

Lateral posture analysis in archers.

		Min	Max	Mean±SD	p	Cohen d
Head Anterior Tilt		0.81	5.35	2.93±1.48		
Head Anterior Angle		2.11	17.70	8.83±5.23		
Shoulder Anterior Tilt	Pulling	0.36	8.16	2.80±2.29	.001*	0.2
	Stabilization	0.30	6.52	2.39±1.80		
Hip Anterior Tilt	Pulling	-1.19	5.13	2.24±1.81	.009*	0.23
	Stabilization	-1.01	4.48	1.86±1.53		

*Min: Minimum; Max: Maximum; SD: Standard deviation; * p<0.05; + Value: Right Tilt; - Value: Left Tilt.*

Table 5
Anterior posture analysis in archers.

	Min	Max	Mean ± SD
Head Lateral Tilt	-1.20	2.48	0.81 ± 1.15
Shoulder Lateral Tilt	-0.90	1.80	0.77 ± 0.83
Hip Lateral Tilt	0.06	3.30	1.52 ± 0.87
Chest Lateral Tilt	-0.40	1.11	0.49 ± 0.41

Min: Minimum; Max: Maximum; SD: Standard deviation; + Value: Right Tilt; - Value: Left Tilt.

There is a significant difference between the shoulder anterior tilt of the archers' pulling arm and stabilization arm ($p<0.05$). There is a significant difference between the anterior hip tilt of the archers ($p<0.05$).

Head, shoulder, hip and chest tilt analyzes of the archers are given below (Table 5).

In the musculoskeletal pain frequency scoring with CMDQ, the most common pain was in the back and lower back, followed by the knee and neck.

Discussion

Our study demonstrated pronounced asymmetries between the pulling and stabilization arms in elite archers. The acromion–wall distance was shorter on the stabilization arm, indicating a more anterior position, whereas the distance from the upper edge of the scapula to the spinous processes was greater on the pulling arm. Furthermore, increased displacement was observed in the pulling arm during the 45° scapular lateral shift test, which may reflect altered scapular kinematics associated with unilateral loading patterns. Such asymmetries are consistent with adaptations induced by repetitive and direction-specific movements in unilateral sports, leading to differences in flexibility, muscle shortness, and strength between sides, which, if not addressed through targeted interventions, may predispose athletes to overuse injuries.

Shortening of the shoulder external rotators and lateral and anterior trunk tilts toward the pulling arm are likely consequences of the arrow-shooting posture and the stabilization demands after release. The literature indicates that flexibility influences muscle balance and injury risk, and that increased flexibility is inversely related to muscle strength (Alonso et al., 2009; Brockett et al., 2004). In our sample, differences in trunk rotation flexibility and pectoralis minor length between sides further support the role of repetitive and asymmetrical arm positioning in developing side-dominant adaptations (Lopes et al., 2017)

The observed difference in scapular upward rotation during the 45° sliding movement may reflect overactivity of the serratus anterior on the pulling arm side. Unilateral sports often induce imbalances among scapular stabilizers, with reduced serratus anterior activation and increased upper trapezius activation, thereby altering glenohumeral–scapulothoracic motion ratios (Kikuchi & Nakazawa, 2016b). In our cohort, differences in both acromion–wall distance and scapula–spinous process measurements between arms reinforce the importance of asymmetry-focused training in archers to mitigate injury risk.

Although archery is considered a low-injury-risk sport compared to high-contact activities such as boxing, football, or rugby (Niestroj et al., 2018; Demiroğlu et al., 2017), upper extremity pain was reported more frequently than lower extremity pain in our study. This is likely due to the dominant role of the upper limbs in both bow stabilization and arrow release, whereas the lower limbs primarily serve a supportive stance function. Therefore, preventive and rehabilitative programs should prioritize the upper extremity musculature—particularly the shoulder complex—while also addressing muscular balance in the lower limbs, hips, knees, and feet.

Strength assessments revealed higher values on the pulling arm side for shoulder flexion/abduction, elbow flexion, and various grip types, as well as greater arm circumference above the elbow. These findings are attributable to the concentric–eccentric activity of the muscles used continuously during arrow shooting, as well as the fact that most participants used their dominant arm for pulling, which aligns with the literature showing that the dominant limb typically exhibits greater strength (Nishizono et al., 2008).

In addition to p-values, effect sizes (Cohen's d) were calculated to better interpret the magnitude of these differences. Several variables—including shoulder abduction ($d = 0.46$), elbow flexion ($d = 0.59$), palmar grip ($d = 1.31$), finger tip grip ($d = 1.07$), and lateral grip ($d = 1.72$)—demonstrated effect sizes exceeding the threshold for clinical relevance (≥0.40). This suggests that the observed asymmetries are not only statistically significant but also likely to have practical implications for performance and injury prevention in archers.

Postural analysis using PostureScreen® (Hopkins et al., 2019) indicated more pronounced anterior and lateral tilts of the head, shoulders, and hips on the pulling arm side. This finding is consistent with the requirements of the shooting stance, in which the pulling shoulder and hip are positioned more anteriorly. Shortening of the pectoralis minor and hip external rotators on the pulling side may contribute to these postural deviations.

Finally, although some data were obtained via participants' self-reported responses, which may limit reliability, objective measurements confirmed our primary findings. Overall, the results emphasize the critical importance of early detection and correction of asymmetries in archers to prevent chronic overuse injuries and maintain optimal performance.

Conclusions

These results indicate that archers may experience postural alignment problems, especially on the pulling arm side, due to the arrow shooting position. An exercise program that includes strengthening and stretching exercises is recommended for archers, especially in order to prevent posture disorders and related injuries that may occur due to the posture in the arrow shooting position. Future studies should examine the muscle structures of male and female archers and investigate their specific injury risks.

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Authors' Contribution

Study Design: PNS, RÇ, TÇ; Data Collection: PNS; Statistical Analysis: PNS, RÇ, TÇ; Manuscript Preparation: PNS, RÇ; Funds Collection: PNS, RÇ, TÇ.

Ethical Approval

The study was approved by the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee (2023/153) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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