Research Article

Physiotherapy

Comparative Analysis of Upper Extremity Performance Variables in Elite and Novice Recurve Archers: A Cross-Sectional Observational Study

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Abstract: Scapular stability, grip strength, and fine motor skills are found to be the important variables to achieve the highest performance in precision tasks. Archery being one of the precision games, understanding these variables in archers is crucial as they can influence shooting performance. Therefore, the purpose of the present study was to compare the fine motor skill, hand grip strength and scapular stability in elite and novice recurve archers.50 Novice and 50 Elite recurve archers in the age group of 15-25 years were recruited. Scapular stability was assessed by Scapular dyskinesis test, hand grip strength by baseline hydraulic hand dynamometer for both upper limbs (bow arm and draw arm) & fine motor skill was assessed by Purdue pegboard. The results were analysed using SPSS software, version 16.00. Independent T-test and Mann Whitney U test were performed for between-group comparisons. Elite archers [draw arm (27.02±7.08), bow arm (26.16±7.31) CI- 95%] showed statistically significant greater hand grip strength [draw arm (p=0.039), bow arm (p=0.008)] than novice archers [draw arm (23.92 ±7.73), bow arm (22.04 ± 7.86) CI-95%]. In assembly tasks for fine motor skill, elite archers [(34.44 ±3.92) CI-95%] showed significantly better coordination (p=0.011) than novice archers [(31.78±6.14) CI-95%]. For scapular stability, elite archers showed significant scapular dyskinesia on the draw arm (p=0.005) and bow arm (p=0.012)] than novice archers. Elite recurve archers had significantly better hand grip strength and fine motor skill than novice recurve archers. However, 52% subtle and 18% obvious scapular dyskinesia was observed in elite archers than novice archers who showed 38% subtle and 8% obvious scapular dyskinesis. The results of the study indicate that elite archers had statistically significant hand grip strength for both arms, fine motor skills, and a greater presence of obvious and subtle scapular dyskinesis than novice archers.

Keywords: Archers, Dyskinesia, Grip Strength, Upper Extremity, Variables.

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1. INTRODUCTION

Archery has developed from bow and arrow weapons used in wars and hunting into the competitive and recreational game, and it became more popular ever since being included in the Olympic games[1]. It requires skills of precision, control, focus, and repetition. An archery shot consists of 3 phases (i) the stance phase; (ii) the arming phase, during which the archer pulls the bowstring and pushes the bow; and (iii) the sighting phase, which involves the final stretching of the bow while focusing on the target[2]. Game performance in archery is the score an archer accumulates as a result of the combination of their physical, technical, and tactical factors and requires technically interrelated and harmonious behaviours among these factors. Existing literature supports some performance factors like hand grip strength [3,4], eye-hand coordination[5], and scapular stability [6,7,8] found to affect the archery performance. In the movement of shooting an arrow, there is a large amount of neuromuscular involvement[9]. Being a static sport, archery requires good muscular endurance particularly in the upper body, and less cardiovascular endurance [10]. In the athletic population, handgrip strength is an indicator of the whole physical power of the body. In archery, because both hands are used to grab the bow and arrow, the grip strength of both the hands significantly impacts the performance. Hence to keep the arrow right on the target, archers must have control on the arm, wrist, and especially the fingers. Therefore, having good hand grip strength to grab and to feel the control over bow and arrow is important during shooting[11]. Once the archer attains the full drawing position and aims for the target, a synchronized movement of hand and visual sensory stimuli should occur to achieve the highest performance. Aiming and firing at something that eyes are focused on is the basis of the game. Therefore, eye-hand coordination where the visual system, brain, and hands interact with each other is required as an important perceptual-motor skill [5] as it accounts for optimal speed, smoothness and accuracy of movement.

In competition/practice, an archer adopts a stance position, inserts the arrow, holds the bowstring, and creates a pressure point on a bow grip. During the sighting phase, archers are required to maintain certain angles of shoulder abduction, horizontal extension, and elbow joint flexion for several seconds[12]. To hold the desired position to aim at the target before shooting an arrow, archers require repeated use of the shoulder and scapular muscles[6]. Asymmetric forces are produced on the shoulder girdle due to repeated drawing and releasing of the arrow[13]. Thus, when drawing an arrow, shoulder joints are subject to a great deal of force from the bow limb. Also, while holding the static position of the shoulder joint during shooting, scapular mal-alignment and impingement syndrome occur as a result of sustained contraction and overuse of shoulder muscles[7]. Studies have shown a high prevalence of scapular dyskinesis in the asymptomatic general population[14]. 43% greater risk of developing shoulder pain was observed in athletes with scapular dyskinesis than those without scapular dyskinesis[15]. However, it is unclear whether dyskinesis is a sports-specific protective mechanism against injury and potentially beneficial adoption for maximal performance or it may be a risk factor that helps to identify athletes who are at greater risk of injury, requiring preventive rehabilitative strategies. A mismatch of these aforementioned variables can influence athletic performances directly. Hence, there arises a need to measure each factor affecting the performance; as such information can have a direct impact on archer's performance[16]. It is necessary to prepare the training plan and program in line with these measured values. Despite this, there is a dearth of literature on a comprehensive assessment of these variables, which are found to be responsible for performance in archers. But without scientific data, it is difficult to compare how athletes with different levels of expertise perform. Thus, the primary aim of the study was to compare upper extremity performance variables in elite and novice recurve archers. The objectives of the study were to compare hand grip strength, eye-hand co-ordination and scapular stability in elite and novice recurve archers.

2. MATERIALS AND METHODS

2.1 Study Design and Participants

A cross-sectional study design was conducted. The purposive sampling method was used for the selection of archers. Ethical approval for this study was obtained from the Institutional ethics committee of Padmashree Dr. D Y Patil Medical College, Hospital and research center, Navi Mumbai on 10th May 2019 [DYP/IEC/01-003/2019]

2.1.1 Eligibility Criteria

The inclusion criteria for participating in the study were archers aged between 15 to 25 years involved in target archery. Archers playing sport at district, state, and national levels were considered elite archers, whereas novice archers should have a minimum of one year of archery experience. All those with a previous history of upper extremity trauma, visual impairments, neurological deficits, and known medical conditions were excluded from the study. Based on the eligibility, archers were recruited from various archery clubs and sports associations in Mumbai and Navi Mumbai. Each participant after being advised of the purpose, method of the study, and potential risks of the study, signed an informed consent form.

2.2 Outcome Measures

2.2.1 Hand Grip Strength

Hand grip strength was measured using a Baseline® (Fabrication Enterprises, Inc., Irvington, NY, USA) Hydraulic Hand Dynamometer[17]. Archers were positioned as per the guidelines of 'The American Society of Hand Therapists (ASHT)[18] for each of the tests of hand strength. The Jamar and Baseline hydraulic dynamometers have acceptable inter-instrument reliability and concurrent validity (i.e., they measure grip strength equivalently) and can be used interchangeably. As shown (Figure.1) the archers were seated on a chair with a straight back, without armrest with the feet flat on the floor and their shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in a neutral position, and wrist between 0° to 30° flexion and between 0° to 15° ulnar deviations. They were asked to squeeze the dynamometer with maximum isometric effort, and maintain it for 3 seconds. No other body movements were allowed. Three attempts for each archer were conducted, alternating dominant and non-dominant hands. All the archers were evaluated in the same position and under the same protocol. Before each reading of grip strength, the dynamometer was rearranged to zero. The maximum value obtained was

recorded in kilograms(kgs). The average grip strength was taken for both the dominant and the non-dominant hand.

2.3. Fine Motor Skill (Eye-Hand Coordination)

Fine motor skill (Eye-hand coordination) was measured by Purdue pegboard, Lafayette Instrument Company, Inc. USA [19,20]. Reliability of Perdue pegboard with various groups and scores ranges from 0.60 to 0.91 and validity coefficients ranges from 0.07 to 0.76, depending on the score used the job, and the criterion[19]. It is a neuropsychological test of manual dexterity and bimanual coordination. The test involves two different abilities: gross movements and fine motor dexterity. The Purdue pegboard test (Figure.2) consists of a board with two parallel rows with 25 holes into which cylindrical metal pegs are placed by the examinee. The test involves a total of three trials. The subsets for preferred, non-preferred, and both hands require a person to place the pins in the holes as quickly as possible, with the score being the number of pins placed in 30 seconds /assembly 60 seconds. The test subject sits at a table and follows instructions from a test administrator. The subset of assembly is the most important from the point of view of fine motor skill, as the assembly task more comprehensively evaluates the subject's coordination. A combination of pins, washers, and collars was used to perform the assembly test. A person has to pick up one pin with the right hand from the right hand cup and placed it in the top hole in the right hand row, simultaneously pick up a washer with the left hand. As soon as the pin has been placed, the washer is dropped over the pin, while the washer is being placed over the pin by left hand pick up a collar with the right hand, while the collar is being dropped over the pin, pick up another washer with the left hand and drop it over the collar. This completes the first assembly consisting of pin, washer, collar and washer. While the final washer for the first assembly is being placed with the left hand, the second assembly is started by picking up another pin with the right hand, placing it in the next hole, droping the washer over it with the left hand, and so on completing another assembly till 1 min. Each assembly is of 4 points. If the subject made eight complete assemblies, the score is 8 multiplied by 4 (parts), or 32. If there are additional parts that are properly placed at the end of the minute after the completion of assemblies, they are also added to the assembly score. Both the groups of archers performed three trials of the assembly subset and the average score of trials was considered for statistical analysis.

2.4. Scapular Stability

Scapular dyskinesis test (SDT)[21] was used to assess scapula stability. Reliability of scapular dyskinesis test ranged from 0.48 to 0.61 within upper limb athlete[21]. Each participant performed 5 repetitions of bilateral, active, weighted shoulder flexion and bilateral, active, weighted shoulder abduction (frontal plane) while they were videotaped from the posterior views. These 2 weighted elevation tests constituted the tasks for the SDT (Figure.3). After demonstrating the movements, the archers were instructed and briefly practiced each movement. Testing started with arms at the side of the body, elbows straight, and shoulders in neutral rotation; tester observed from the back, 2 to 3 meters away. Archers were asked to simultaneously elevate their arms overhead as far as possible to a 3-second count using the "thumbs up" position and then lower to a 3-second count. Tests were performed with archers holding the dumbbells according to body weight, 1.4 kg (3 lb) for those weighing less than 68.1 kg (150 lb) and 2.3 kg (5 lb) for those weighing 68.1 kg or more. Each test movement (flexion and abduction) rated as- a] Normal motion: no evidence of abnormality b] Subtle abnormality: mild or questionable evidence of abnormality, not consistently present c] Obvious abnormality: striking, clearly apparent abnormality, evident on at least 3/5 trials (dysrhythmias or winging of 1 in [2.54 cm] or greater displacement of the scapula from thorax). The final rating is based on combined flexion and abduction test movements. Normal: Both test motions are rated as normal or 1 motion is rated as normal and the other as having a subtle abnormality. Subtle abnormality: Both flexion and abduction are rated as having subtle abnormalities. Obvious abnormality: Either flexion or abduction is rated as having an obvious abnormality. On the completion of the test, the inference was drawn based on the abnormality noted in two test movements for both dominant and non-dominant side scapular motion.

2.5. Study Size

The power calculation was based on the primary outcome variables like hand grip strength, fine motor skill, eye hand co-ordination and scapular stability; assuming a significance level at 5% and a power of 80%. Using a scientific formula it was estimated that 50 archers should be allocated in each group.

Hand grip strength	Eye hand coordination and scapular dyskinesis test
$$\eta_c = \frac{[Z_{1-\alpha/2} + Z_{1-\beta}]^2\,[\delta_1^2+\delta_2^2]}{(\mu_1-\mu_2)^2}$$	$$\eta_c = \frac{[Z_{1-\alpha/2}\sqrt{2\overline{p}\,\overline{q}} + Z_{1-\beta}\sqrt{p_1q_1+p_2q_2}]^2}{[p_1-p_2]^2}$$

Where,

$Z_{1-\alpha/2} = 1.96$	P1=approximate proportion of subject in the elite group
$Z_{1-\beta}=0.84$	P2= approximate proportion of subject in the novice group
μ1= mean of elite group	q1=100-p1
μ2=mean of novice group	q2=100-p2
δ1= SD of elite group	$\bar{p}$= (p1+ p2)/2
δ2= SD of novice group	$\bar{q}$ =100- $\bar{p}$ if N_1 =N_2

3. STATISTICAL ANALYSIS

Kolmogorov-Smirnov test was used to verify the normality of data. Based on the normality test an unpaired two-tailed t-test was used to analyse parametric data and Mann Whitney U test for non-parametric data. The characteristics of the archers and their outcomes are presented as frequencies, means, and standard deviations for parametric distributions of data, and mean rank for non-parametric distributions of data. A probability level of $P < 0.05$ was used as an indicator of statistically significant results in these analyses. As shown in the flow chart.1 score/results obtained from each test were further used for statistical analysis. The analysis was performed using the SPSS software statistical package (version. 16.0, SPSS Inc., Chicago, IL).
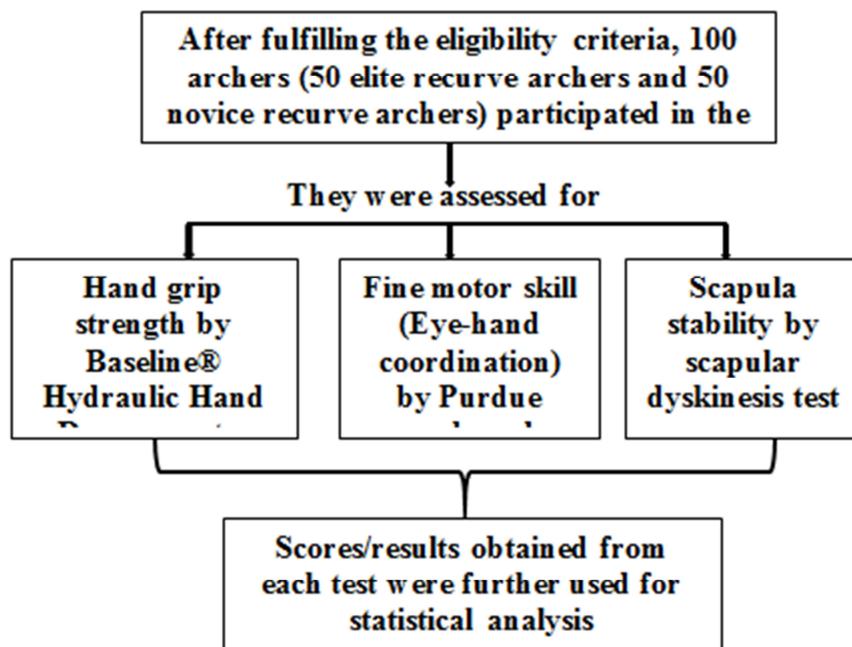
Flow chart.1 Methodology of the study

4. RESULTS

Table 1. Descriptive statistics of Elite (N=50) and Novice (N=50) recurve Archers		
	Elite Archers	**Novice Archers**
	Mean ± SD	
Age (years)	19.46 ± 2.91	18.16 ± 2.98
Height(cms)	162.28 ± 9.98	151.57 ± 12.08
Weight (kgs)	54.32 ± 9.64	46.46 ±12.76
BMI (kg/m²)	20.5 ± 2.57	20 ± 4.17
Years of experience	4.3 ± 2.19	1.89 ± 0.74

values are Mean ± SD, N= 100, Abbreviation: BMI –Body mass index

Table 2. Cross tabulation- Level of Scapular Dyskinesis (%) on draw arm and bow arm between elite and novice recurve archers				
SDT Interpretation (%)	**Draw arm**		**Bow arm**	
	Elite	**Novice**	**Elite**	**Novice**
Normal	30	58	40	54
Subtle	52	34	42	38
Obvious	18	8	18	8

Abbreviation: SDT = Scapular Dyskinesis; N=100

Table.1 depicts the archer's demographic characteristics. Occurrence of scapular dyskinesis according to the level of SDT interpretation as shown in Table.2 suggests that respectively on draw arm and bow arm 18% obvious scapular dyskinesis was noted in elite archers than novice archers (8% draw arm,8% bow arm). 52% and 42% Subtle scapular dyskinesis was present on the draw arm and bow arm individually in elite archers, whereas novice archers showed 34% draw arm and 38% bow arm subtle scapular dyskinesis.

Table.3 Comparison of hand grip strength and fine motor skill between elite (N=50) and novice recurve archers (N=50)								
Performance Variables		Elite Archers	Novice Archers	T	df	P-value	95% Confidence Interval of the Difference	
		Mean ± SD					Lower	Upper
Hand grip strength [kgs]	Draw arm	27.02±7.08	23.9±7.73	2.091	98	0.039[*]	0.159	6.041
	Bow arm	26.16±7.31	22.04±7.86	2.713	98	0.008[**]	1.106	7.134
Fine motor skill [eye-hand coordination-No. of peg inserted /secs]	Assembly task	34.4±3.92	31.78±6.14	2.581	83.281	0.011[*]	0.615	4.705

Values are Mean± SD, P-value < 0.05 indicates significant differences between groups.; *** Extremely significant, **Very significant, * significant; N=100

Table.4 Comparison of scapular stability between elite (N=50) and novice recurve archers (N=50) by scapular dyskinesis test				
Performance Variables		Elite Archers	Novice Archers	P-value
		Mean Rank		
Scapular stability	Draw arm	57.99	43.01	0.005**
	Bow arm	57.17	43.83	0.012*

P-value < 0.05 indicates significant differences between groups.; *** Extremely significant, **Very significant; * significant; N=100

For the between-group analysis of handgrip strength, the result (Table.3) of the present study shows that elite archers had significantly better handgrip strength for draw arm (P=0.039) and bow arm (P=0.008) than novice archers. Assessment of fine motor skill for assembly tasks (Table.3), elite archers had statistically significant eye-hand co-ordination (P=0.000) than novice archers. For Scapular stability between two groups (Table.4), the analysis of obtained data showed that as compared to the novice archers, elite archers had statistically significant scapular dyskinesis present in both the draw arm (P=0.005) and bow arm (P=0.012).

Fig.1 Assessment of hand grip strength by Baseline® Hydraulic Hand Dynamometer

Fig.2 Assessment of fine motor skill [eye-hand coordination] by Purdue pegboard

A- Weighted active bilateral   B- Weighted active bilateral
shoulder abduction   shoulder flexion

Fig.3 Assessment of scapular stability by Scapular dyskinesis test

5.   DISCUSSION

The results of the study indicate that for the draw arm and bow arm, elite archers had statistically significant hand grip strength and greater presence of obvious and subtle scapular dyskinesis than novice archers. For the assembly task of Purdue pegboard, elite archers had statistically significant fine motor skill than novice archers. The main aim of gripping the bow and arrow in archery is to stabilize the arrow at the desired point on the target scoreboard and to keep the arrow stable until it leaves the bow[3]. Superior hand grip strength of draw arm and bow arm in elite archers (Table.3) could be the effect of regular physical exercises[22] that they undergo as part of their training program through neural adaptation, as it plays an important role in the dramatic improvement of muscular strength and power[23]. Strength performance is a motor act, which challenges the nervous system. It is the product of a partnership between the muscles and the nervous system[24]. Therefore, statistically significant hand grip strength in elite recurve archers due to training could be the result of adaptations either in the muscles or in the nervous system. These results are also following the results obtained by Shyamal Koley et al.[25] with the study conducted in cricketers. Another possible reason

for better hand grip strength in elite archers could be their level of expertise and years of training, which might have also influenced the results, as it has been seen that cognitive mechanisms governing task execution are dependent on the level of expertise[26]. Eye-hand coordination is a complex psychomotor skill with an essential role in adaptation, which involves synergistic action of sensory and motor function[27]. The nature of the task performed and the stage of the learner have a direct impact on the processes of skill acquisition. As defined by Schmidt (1988) motor learning is "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for responding"[28]. Therefore, as shown in Table.3 statistically significant fine motor skills observed in elite recurve archers could be the effect of the motor learning process, as the elite recurve archers in the present study have more years of experience of playing archery as compared to novice archers due to their level of expertise. Also, it has been seen that the level of movement coordination is influenced by the level of knowledge of the motor skills and the level of automation of the same[27]. Similarly, in the current study, elite archers were involved in target archery from the district level and above. Thus, their superior knowledge of game skills owing to their years of training and participation in tournaments may have

led to the obtained results. During an archery tournament or while practicing archery, an archer has to take a large number of shots while drawing a high-poundage archery bow which weighs about 2-3 kgs[9]. Though the shooting action of archery does not involve overhead activity, it does places tremendous stress on the shoulder in the extreme of horizontal abduction and extension [29], subsequently, application of such high energy forces in a repetitive manner predisposes the static and dynamic stabilizers of the shoulder joint to chronic injuries and attenuation following which a mild instability pattern develops that sets increased demand on rotator cuff muscles[30]. Further these repetitive concentric and eccentric loading of the shoulder girdle and upper back muscles during draw and stance may cause fatigue of the surrounding muscles[31]. Repeated use of shoulder and scapular muscles to hold the upper limb position might have led to positional and mechanical changes in the shoulder girdle in elite recurve archers. Thus, fatigue and repetition of the movement could be the reason for the significant presence of scapular dyskinesis (Table.4) in elite archers[32]. These notions are supported by prevailing literature which shows that immediate (short-term) fatigue[33,34] and excessive increase in training load [35,36], can induce scapular dyskinesis without shoulder pain and independently can also induce shoulder pain. However, existing literature has shown scapular dyskinesis as an indirect collective risk factor and it is not a risk factor in isolation but increases the risk of shoulder pain in the presence of excessive increases in load[15]. Also, as shown in Table.2 higher percentage of obvious and subtle scapular dyskinesis in elite archers as compared to novice archers could be the effect of long years of training and sporting activity, as elite archers in the present study are involved in sporting activity for a prolonged time and they undergo extensive shooting training to excel at higher competitive levels as compared to the novice archers. In the present study, the elite archers were categorized as archers playing archery at the district level and above. Therefore, how top-level archers differ in these performance variables from the national level and the state level archers is not understood. To date, there are no studies available for normative data of these parameters in archers irrespective of the level of participation. Also, the present study was limited to only the target form of archery, thus reducing the generalizability of the obtained results. Archers other than age groups of 15-25 years were not included in the study. Hence, further studies should focus on the assessment of the aforementioned parameters in top-level archers as compared with others including the other form of archery.

6.   CONCLUSION

Findings of the present study suggest that as compared to novice recurve archers, elite archers had a significantly better hand grip strength and fine motor skills. However, elite archers showed more subtle and obvious scapular dyskinesis than novice archers. Therefore, the present study implies that these performance variables are crucial and need to be assessed in each archer. These results may be useful to coaches, physiotherapists, and to athletes themselves for optimizing the performance by developing sport-specific training strategies that bring about the desired requirement of the sport. Also, scapular rehabilitation exercises should be incorporated in the routine exercise program as a preventive strategy in shoulder pain related to archery.

7.   ACKNOWLEDGMENTS

8.   AUTHORS CONTRIBUTIONS STATEMENT

Dr. Pranita D. Ganave carried out the study design, data collating, data analysis, and interpretation, and drafted the manuscript; Dr. Ajit S. Dabholkar conceived the study, participated in its design, helped to draft the manuscript; provided a critical review of the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

9.   CONFLICT OF INTEREST

Conflict of interest declared none.

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