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# Angular kinematics analysis of the Final Release position of elite Archers

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**Abstract:** The purpose of the study was Angular kinematics analysis of an Elite archers. In present study total sample five Indian International level male Recurve category Archers was selected by Purposive sampling technique from SAI Archery training Center Sonipat. The age of the subjects was between 24 (± 5) years, hight of the subjects 6.0` (± 5 Inch), participation year between 2016-2022, shooting FITA score between 650-720 in archery was selected as a subjects for the study. According to Casio EX-F1 high speed camera was used, which have frequency from 60-300 frames per second (f/s).  The data were recorded from Superior view, Lateral view, Anterior view and Medial view. The distance between shooting line and target is 70 meter. Shooting line is passed horizontally through the Center of Gravity box, Center of Gravity box is a square box drown with the measurement of 1×1 m, Center of Gravity box is equally divided into 4 parts. A straight line is passed vertically on it and a horizontal line which is shooting line and is drawn 70 meter apart from the target. The distance between bull eye of the target and the floor surface is 5 feet. Siliconcoach Pro8 update motion analysis software and Tracker motion analysis software was used for Angular kinematics of at the time of final release position in archery. Descriptive statistic was used. To find out multi correlation between dependent variable performance on target 1-10 (bull eye) in points and independent variables (selected linear variables). There is an insignificant relationship between the angle of bow vertical alignment and performance in archery. The study reveals that specific joint angles, especially those related to shoulder, elbow, and wrist joints, play a crucial role in archery performance. Extremely high correlations (e.g., projectile angle) indicate critical joint configurations that significantly impact the success of the archery motion. The study concludes that there is a highly significant positive relationship between the angle of the shoulder joint for the draw hand and various angular kinematical variables in archery. These relationships suggest the importance of the shoulder joint position in determining the overall biomechanics of the archery motion. The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles. The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles. The significant positive correlations indicate that changes in the angle of the elbow joint for the draw hand are associated with corresponding changes in these other joint angles and projectile angles. The significant positive correlations indicate that changes in the angle of the wrist joint for the bow hand are associated with corresponding changes in these other joint angles and projectile angles. The study concludes that there is a highly significant positive relationship between the angle of the draw forearm line and various related angles, emphasizing the coordination of these variables during archery. The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in holding the bow and drawing the bowstring. The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in aiming and releasing the arrow. The study concludes that there is a highly significant positive relationship between the angle of the draw forearm line and the force line, as well as between the angle of the draw upper arm line and the shoulder line, and the angle of the line of force and the bow arm line. The study concludes that there is a highly significant positive relationship between the angle of the draw upper arm line and the shoulder line, as well as between the angle of the draw upper arm line and the line of force, and the angle of the line of force and the bow arm line.

**Keywords:** Angular kinematics, Release position, elite Archers

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## INTRODUCTION

Since their predynastic and Pre-Kerma beginnings, bows and arrows have been a part of Egyptian and adjacent Nubian cultures. In the Levant, there are artefacts dating back to the Natufian culture (c. 10,800–8,300 BC) that may represent arrow-shaft straighteners. It's possible that the PPN A and Khiamian shouldered Khiam-points are arrowheads.

Numerous archers were present in the armies of classical civilizations, including the Assyrians, Greeks, Armenians, Persians, Parthians, Romans, Indians, Koreans, Chinese, and Japanese. According to the victory stele of Naram-Sin of Akkad, the Akkadians were the first people to use composite bows in battle.Zutterman (2003) The Nubians were renowned to be skilled archers, and by the sixteenth century BC, the Egyptians were employing the composite bow in combat, therefore they were called "Ta-Seti," or "The Land of the Bow," by the Egyptians.(W.E. McLeod, 1962) Beginning in the fifteenth century BC, the Bronze Age Aegean Cultures were able to use a variety of state-owned, specialised bow makers for hunting and fighting. (Spyros and Bakas, 2016) It was during the Battle of Crécy that the Welsh longbow made its debut in Continental warfare. (2016) Bow Evolution At the time of European contact, archery was very common throughout the Americas. In 1985, Larry J. Zimmerman

Asia had a highly developed archery culture. The Sanskrit word for archery, dhanurvidya, eventually became the phrase for all forms of martial arts. One of the Three Kingdoms of Korea, Goguryeo, was highly known in East Asia for its regiments of incredibly talented archers. Thomas A. Duvernay (2007)

Additionally, recurved limbs may produce more noise during a shot and put more strain on the components that make up the bow. Stringing a bow with extreme recurves causes instability. Many Native American weapons were mistakenly strung backwards and broken when attempts were made to shoot them after being isolated from their original owners and cultures. An unstrung recurve bow might have an unclear shape. (Gladys and Reginald Laubin, 1980) In a 2002 test, Hepworth and Smith found that a preparation made from pearl glue and bovine tendon, which is used in traditional Asiatic recurve bows, "was found to absorb 18 MJ/m3 of energy to failure, comparable to carbon fibre composites, spring steel, and butyl rubber."(D.G. Hepworth and J.P., 2002)

To help with aim, mechanical sights can be mounted on the bow. They may use optics with magnification, or they may be as basic as a pin. Additionally, they typically have a peep sight (rear sight) integrated into the string to help provide a reliable anchor point. Whereas traditional bows allow for significant variance in draw length, modern compound bows (Sung, LokMan; Kesha, 2017) automatically limit the draw length to provide a constant arrow velocity. Certain bows employ mechanical techniques to maintain a constant draw length.

The measurement of the kinematic quantities needed to characterise motion is known as kinematic analysis. For example, in engineering, kinematic analysis can be used to determine a mechanism's range of motion, and kinematic synthesis can be used to create a mechanism with a desired range of motion. McCarthy, J. M., and Soh, G. S. (2010) A mechanical system or mechanism's mechanical advantage is also studied by kinematics, which employs algebraic geometry in this process.

The study of rotational motion without external forces is known as angular kinematics. The angular kinematics equations bear a striking resemblance to the standard kinematics equations, with the substitution of angular displacements for displacements and velocities for velocities. The equations of angular kinematics apply to the majority of rotating physical systems, just as kinematics is frequently used to characterise the trajectory of nearly any physical system moving linearly.

"Line of force" is a term that is frequently used in this discussion. This is the bow's line of force. This force vector runs directly from the bow hand's pressure point on the grip to the string's nocking point. Both the force that the archer applies to the bow and the force that the bow applies to the archer are represented by this line, which is drawn from the direct points of contact between the archer and the bow.

## METHODOLOGY

### The selection of subjects

Sampling is a crucial research procedure, particularly when data collection from a specific or limited population is required. In present study total sample five Indian International level male Recurve category Archers was selected by Purposive sampling technique from SAI Archery training Center Sonipat. The age of the subjects was between 24 (± 5) years, hight of the subjects 6.0` (± 5 Inch), participation year between 2016-2022, shooting FITA score between 650-720 in archery was selected as a subjects for the study. (**H. Ertan et al. 2005**)

### Collection of Data

The following describes the subjects' performance in the archery, filming protocol, and analysis. To see the effect of accurate pull push technique of archery on the scoring of the performance of the each subject measured by using the standard procedures of (WAF). Three trials given to each subject and after that all attempt considered.

### Filming Protocol

Raw data was gathered using the video graphic technique. Under the guidance of an expert, a professional photographer would capture the video graphics. A high-speed camera, the Casio EX-F1, with a frequency of between 60 -300 frames per second (f/s), was reportedly employed. (**Saptadeep debnath et. Al., 2016**) The data were recorded from Superior view, Lateral view, Anterior view and Medial view. The distance between shooting line and target is 70 meter. Shooting line is passed horizontally through the Center of Gravity box, Center of Gravity box is a square box drown with the measurement of 1×1 m, Center of Gravity box is equally divided into 4 parts. A straight line is passed vertically on it and a horizontal line which is shooting line and is drawn 70 meter apart from the target. The distance between bull eye of the target and the floor surface is 5 feet (figure no. 1). (**Euro NCAP, 2020**)

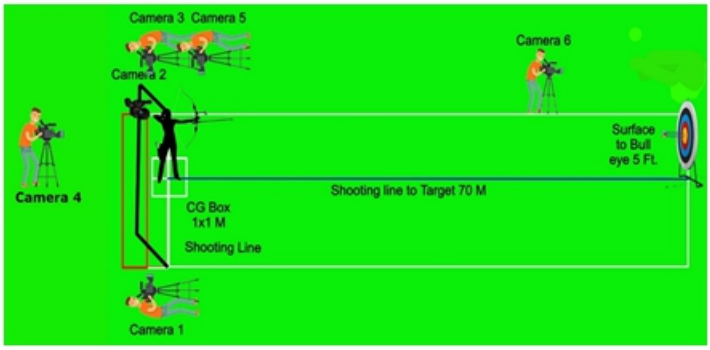



**Figure 1: Diagram of the set-up of collecting data was showed in three-dimensional coordinate system is described.**

**Analysis of Data**

Siliconcoach Pro8 update motion analysis software and Tracker motion analysis software was used for kinematical analysis of at the time of final release position in archery. To analyze kinematical aspect of at the time of final release position in archery, Descriptive statistic was used. Pearson multi correlation was used to determine the multi correlation between the dependent variable—performance on targets 1–10 (bull eye) in points—and the independent variables—selected linear variables—at the moment of the archer's final release position. In order to determine the regression equation between the independent factors (chosen linear variables) and the dependent variable (performance on targets 1–10, or bull eyes), in points, at the moment of the archery final release position, We employed the linear regression entry method. The statistical significance was determined by setting the level of significance at 0.05. Social science statistical software (SPSS 20.0 Version) were used to analyse the data.

**Figure 2: Angular kinematics analysis at the time of final release position in archery.**

## RESULTS

Here, the findings are displayed in tabular form. Three sections, Section 1, and Section 2, include the findings related to the study that was presented. Descriptive statistics, such as mean, standard deviation, minimum, maximum, and total, are covered in Section 1. Section 2 deals with multi correlation statistics in case of the present study has been presented as bellow:

**Section- I**

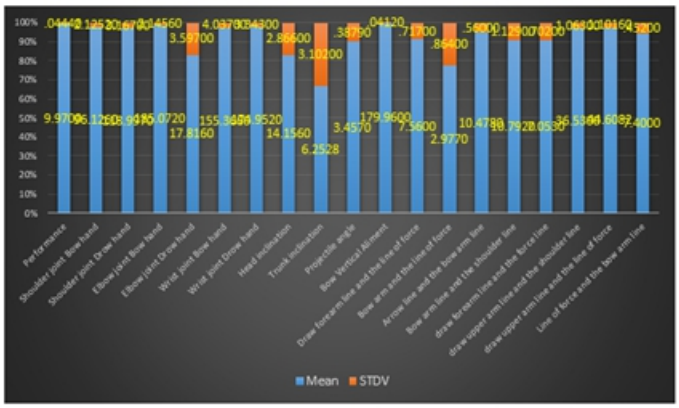
**Table 1: Descriptive Statistic of Performance and Angular kinematics at the time of final release position of elite archers.**

| Variable | Mean | Std. Dev. | Mini. | Maxi. | Range |
|---|---|---|---|---|---|
| Performance on target (1-10 points) | 9.97 | 0.044 | 9.9 | 10 | 0.10 |
| Shoulder joint Bow hand in degree | 96.12 | 2.12 | 93.45 | 98.34 | 4.89 |
| Shoulder joint Drow hand in degree | 118.99 | 3.16 | 114.91 | 122.65 | 7.74 |
| Elbow joint Bow hand in degree | 185.07 | 2.14 | 181.94 | 187.50 | 5.56 |
| Elbow joint Drow hand in degree | 17.81 | 3.59 | 13.61 | 21.43 | 7.82 |
| Wrist joint Bow hand in degree | 155.36 | 4.03 | 151.00 | 159.12 | 8.12 |
| Wrist joint Drow hand in degree | 174.95 | 3.34 | 171.12 | 178.65 | 7.53 |
| Head inclination in degree | 14.15 | 2.86 | 11.93 | 18.79 | 6.87 |
| Trunk inclination in degree | 6.25 | 3.10 | 2.54 | 9.16 | 6.63 |
| Projectile angle in degree | 3.45 | 0.38 | 3.00 | 3.90 | .90 |
| Bow Vertical Aliment in degree | 179.96 | 0.04 | 179.90 | 180 | .10 |
| Draw forearm line and the line of force in degree | 7.56 | 0.71 | 6.40 | 8.09 | 1.69 |
| Bow arm and the line of force in degree | 2.97 | 0.86 | 2.11 | 3.875 | 1.76 |
| Arrow line and the bow arm line in degree | 10.47 | 0.56 | 9.84 | 11.01 | 1.17 |
| Bow arm line and the shoulder line in degree | 10.79 | 1.12 | 9.34 | 11.98 | 2.64 |
| Draw forearm line and force line in degree | 7.05 | 0.70 | 6.12 | 7.86 | 1.75 |
| Draw upper arm line and the shoulder line in degree | 36.53 | 1.06 | 35.33 | 37.81 | 2.49 |
| Draw upper arm line and the line of force in degree | 44.60 | 1.10 | 43.24 | 45.90 | 2.66 |
| Line of force and the bow arm line in degree | 7.40 | 0.45 | 6.90 | 7.83 | .93 |

Table 01 makes clear that the scores' mean and standard deviation of performance and Angular parameters was found as follow: Performance in points (9.97 ± 0.044), Angle of Shoulder joint Bow hand in degree (96.12 ± 2.12), Angle of Shoulder joint Drow hand in degree (118.99 ± 3.16), Angle of Elbow joint Bow hand in degree (185.07 ± 2.14), Angle of Elbow joint Drow hand in degree (17.81 ± 3.59), Angle of Wrist joint Bow hand in degree (155.36 ± 4.03), Angle of Wrist joint Drow hand in degree (174.95 ± 3.34), Angle of Head inclination in degree (14.15 ± 2.86), Angle of Trunk inclination in degree (6.25 ± 3.10), Projectile angle (Angle of Line of force and the arrow line) in degree (3.45 ± 0.38), Angle of Bow Vertical Aliment in degree (179.96 ± 0.04), Angle of Draw forearm line and the line of force in degree (7.56 ± 0.71), Angle of Bow arm and the line of force in degree (2.97 ± 0.86), Angle of Arrow line and the bow arm line in degree (10.47 ± 0.56), Angle of Bow arm line and the shoulder line in degree (10.79 ± 1.12), Angle of draw forearm line and the force line in degree (7.05 ± 0.70), Angle of draw upper arm line and the shoulder line in degree (36.53 ± 1.06), Angle of draw upper arm line and the line of force in degree (44.60 ± 1.10), Angle of Line of force and the bow arm line in degree (7.40 ± 0.45) respectively whereas Minimum and Maximum of scores was found as follow: Performance in points (9.9 & 10), Angle of

Shoulder joint Bow hand in degree (93.45 & 98.34), Angle of Shoulder joint Drow hand in degree (114.91 & 122.65), Angle of Elbow joint Bow hand in degree (181.94 & 187.50), Angle of Elbow joint Drow hand in degree (13.61 & 21.43), Angle of Wrist joint Bow hand in degree (151 & 159.125), Angle of Wrist joint Drow hand in degree (171.125 & 178.65), Angle of Head inclination in degree (11.93 & 18.79), Angle of Trunk inclination in degree (2.54 & 9.16), Projectile angle (Angle of Line of force and the arrow line) in degree (3 & 3.90), Angle of Bow Vertical Aliment in degree (179.90 & 180), Angle of Draw forearm line and the line of force in degree (6.40 & 8.09), Angle of Bow arm and the line of force in degree (2.11 & 3.87), Angle of Arrow line and the bow arm line in degree (9.84 & 11.01), Angle of Bow arm line and the shoulder line in degree (9.34 & 11.98), Angle of draw forearm line and the force line in degree (6.12 & 7.86), Angle of draw upper arm line and the shoulder line in degree (35.33 & 37.81), Angle of draw upper arm line and the line of force in degree (43.24 & 45.90), Angle of Line of force and the bow arm line in degree (6.90 & 7.83) respectively.

**Graphical representation of mean and standard deviation scores of Performance and Angular kinematics at the time of final release position of elite archers.**




**Section-2**

to ascertain the correlation between the archery performance at the final release location and the angular kinematical factors. The multi correlation statistics (Pearson Correlation) was used to analyse the collected data, and the resulting data has been given.

**Table 2: Relationship of Angular kinematics variables with the performance at the time of final release position in archery.**

| | Performance | SJBH | SJDH | EJBH | EJDH | WJBH | WJDH | HI | TI | PA | BVA | DFLLF | BALF | ALBL | BALSL | DFLFL | DULSL | DULLF | LFBAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Performance | 1 | | | | | | | | | | | | | | | | | | |
| SJBH | .919* | 1 | | | | | | | | | | | | | | | | | |
| SJDH | .918* | .995** | 1 | | | | | | | | | | | | | | | | |
| EJBH | .953* | .964* | .981* | 1 | | | | | | | | | | | | | | | |
| EJDH | .916* | .968* | .942* | .900* | 1 | | | | | | | | | | | | | | |
| WJBH | .896* | .974* | .962* | .923* | .982** | 1 | | | | | | | | | | | | | |
| WJDH | .898* | .991** | .989* | .956* | .963* | .989* | 1 | | | | | | | | | | | | |
| HI | .540 | .765 | .799 | .754 | .593 | .656 | .752 | 1 | | | | | | | | | | | |
| TI | .923* | .991** | .980* | .947* | .987* | .994* | .993* | .688 | 1 | | | | | | | | | | |
| PA | .901* | .994** | .994** | .965* | .956* | .982** | .999** | .774 | .990* | 1 | | | | | | | | | |
| BVA | .280 | .615 | .579 | .417 | .622 | .657 | .649 | .609 | .624 | .634 | 1 | | | | | | | | |
| DFLLF | .998** | .920* | .926* | .966** | .901* | .886* | .898* | .580 | .917* | .904* | .267 | 1 | | | | | | | |
| BALF | .821 | .972* | .951* | .877* | .969** | .965* | .963* | .761 | .966* | .962* | .765 | .816 | 1 | | | | | | |
| ALBL | .906* | .873 | .848 | .836 | .950* | .941* | .891* | .372 | .927* | .876 | .473 | .880* | .832 | 1 | | | | | |
| BALSL | .917* | .846 | .861 | .905* | .850 | .893* | .879* | .469 | .883* | .873 | .297 | .913* | .733 | .919* | 1 | | | | |
| DFLFL | .881* | .963* | .934* | .892* | .928* | .884* | .906* | .730 | .924* | .914* | .565 | .881* | .949* | .783 | .692 | 1 | | | |
| DULSL | .885* | .921* | .881* | .828 | .985** | .939* | .905* | .491 | .946* | .895* | .603 | .860 | .931* | .939* | .781 | .918* | 1 | | |
| DULLF | .883* | .802 | .766 | .742 | .910* | .836 | .778 | .246 | .846 | .765 | .360 | .850 | .778 | .934* | .770 | .817 | .962* | 1 | |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficient of correlation required to be significant at 3 degree of freedom = (.878)

Table -2 reveals that in case of Angle of Shoulder joint Bow hand in degree, Angle of Shoulder joint Drow hand in degree, Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree Angle of Draw forearm line and the line of force in degree Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree and obtained value (.919), (.918), (.953), (.916), (.896), (.898), (923), (.901), (.998), (.906), (.917), (.881), (.885), (.883), (.886) is greater than tabulated value of (.878) therefore it shows significant relationship of this independent variable with performance in archery. Whereas, in case of Angle of Head inclination in degree, Angle of Bow Vertical Aliment in degree, Angle of Bow arm and the line of force in degree the obtained values (.540), (.280) and (.821) are lower than tabulated value of (.878) therefore it shows insignificant relationship of these independent variable with performance in archery.

Since the significant relationship was found between Angle of Shoulder joint Bow hand and Angle of Shoulder joint Drow hand in degree, Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.995), (.964), (.968), (.974), (.991), (.991), (.994), (.920), (.972), (.953), (.921), (.986) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Shoulder joint Drow hand and Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.981), (.942), (.962), (.989), (.980), (.994), (.926), (.951), (.934), (.881), (.967) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Elbow joint Bow hand and Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.900), (.923), (.956) (.947), (.965), (.966), (.905), (.892), (.913) is found greater than the required tabulated value of (.878) at .05 level of significance.

Similarly, the significant relationship was found between Angle of Elbow joint Bow hand and Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.900), (.923), (.956) (.947), (.965), (.966), (.905), (.892), (.913) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Elbow joint Drow hand in degree and Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.982), (.963), (.987), (.956), (.901), (.959), (.950), (.928), (.985), (.910), (.989) is found greater than the required tabulated value of (.878) at .05 level of significance.

Similarly, the significant relationship was found between Angle of Wrist joint Bow hand in degree and Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in

degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.989), (.994), (.982), (.886), (.955), (.941), (.893), (.884), (.939), (.987) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Wrist joint Drow hand in degree and Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.993), (.999), (.898), (.963), (.891), (.879), (.906), (.905), (.983) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Trunk inclination in degree and Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.990), (.917), (.966), (.927), (.883), (.924), (.946), (.993) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Projectile angle (Angle of Line of force and the arrow line) in degree and Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.904), (.962), (.914), (.895), (.979) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Angle of Draw forearm line and the line of force in degree and Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree of the subject among independent variables as calculated "r" (.880), (.913), (.881) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Bow arm and the line of force in degree and Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.949), (.931), (.987) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of Arrow line and the bow arm line in degree and Angle of Bow arm line and the shoulder line in degree, Angle of draw upper arm line and the

shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.919), (.939), (.934), (907) is found greater than the required tabulated value of (.878) at .05 level of significance.

It can be seen significant relationship was found between Angle of draw forearm line and the force line in degree and Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.918), (.941) is found greater than the required tabulated value of (.878) at .05 level of significance.

Finally, the significant relationship was found between Angle of draw upper arm line and the shoulder line in degree and Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.952), (.960) is found greater than the required tabulated value of (.878) at .05 level of significance.

## DISCUSSION OF FINDING

The significant correlation was found between In case of angular kinematical variable. The significant correlation was found between Angle of Shoulder joint Bow hand in degree, Angle of Shoulder joint Drow hand in degree, Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree Angle of Draw forearm line and the line of force in degree Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree and obtained value (.919), (.918), (.953), (.916), (.896), (.898), (923), (.901), (.998), (.906), (.917), (.881), (.885), (.883), (.886) is greater than tabulated value of (.878) therefore it shows significant relationship of this independent variable with performance in archery. Whereas, in case of Angle of Head inclination in degree, Angle of Bow Vertical Aliment in degree, Angle of Bow arm and the line of force in degree the obtained values (.540), (.280) and (.821) are lower than tabulated value of (.878) therefore it shows insignificant relationship of these independent variable with performance in archery.

There is a highly significant positive correlation between the angles of the elbow joint for the bow hand and draw hand. This indicates a synchronized movement of the elbows during the archery motion.

There is an extremely high and significant positive correlation between the projectile angle and performance in archery. This implies that the angle between the line of force and the arrow line is a critical factor influencing performance.

Since the significant relationship was found between Angle of Shoulder joint Bow hand and Angle of Shoulder joint Drow hand in degree, Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line

in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.995), (.964), (.968), (.974), (.991), (.991), (.994), (.920),(.972), (.953), (.921), (.986) is found greater than the required tabulated value of (.878) at .05 level of significance.

All correlation coefficients are well above the tabulated value, indicating very strong positive relationships between these angular kinematical variables and performance in archery.

The high positive correlations imply that as these joint angles increase or decrease in a certain way, there is a corresponding increase or decrease in archery performance. Training programs can be designed to improve specific joint movements, ensuring a more effective and efficient execution of the archery technique.

It can be seen significant relationship was found between Angle of Shoulder joint Drow hand and Angle of Elbow joint Bow hand in degree, Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.981), (.942), (.962), (.989), (.980), (.994), (.926), (.951), (.934), (.881), (.967) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations between the angle of the shoulder joint for the draw hand and various angular kinematical variables indicate that changes in the shoulder joint angle are associated with corresponding changes in these other joint angles and projectile angles.

The extremely high correlation with Projectile Angle (r = 0.994) suggests that the angle of the shoulder joint for the draw hand is closely tied to the overall direction of force applied to the arrow during the release.

It can be seen significant relationship was found between Angle of Elbow joint Bow hand and Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.900), (.923), (.956) (.947), (.965), (.966), (.905), (.892), (.913) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles.

The strong correlation with Projectile Angle (r = 0.965) indicates that the angle of the elbow joint for the bow hand is closely related to the overall direction of force applied to the arrow during the release.

Similarly, the significant relationship was found between Angle of Elbow joint Bow hand and Angle of Elbow joint Drow hand in degree, Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.900), (.923), (.956) (.947), (.965), (.966), (.905), (.892), (.913) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles.

The strong correlation with Projectile Angle (r = 0.965) indicates that the angle of the elbow joint for the bow hand is closely related to the overall direction of force applied to the arrow during the release.

It can be seen significant relationship was found between Angle of Elbow joint Drow hand in degree and Angle of Wrist joint Bow hand in degree, Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.982), (.963), (.987), (.956), (.901), (.959), (.950), (.928), (.985), (.910), (.989) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations indicate that changes in the angle of the elbow joint for the draw hand are associated with corresponding changes in these other joint angles and projectile angles.

The high correlation with Projectile Angle (r = 0.956) suggests that the angle of the elbow joint for the draw hand is closely tied to the overall direction of force applied to the arrow during the release.

Similarly, the significant relationship was found between Angle of Wrist joint Bow hand in degree and Angle of Wrist joint Drow hand in degree, Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.989), (.994), (.982), (.886), (.955), (.941), (.893), (.884), (.939), (.987) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations indicate that changes in the angle of the wrist joint for the bow hand are associated with corresponding changes in these other joint angles and projectile angles.

The extremely high correlations with Angle of Trunk Inclination (r = 0.994), Angle of Wrist joint Drow hand (r = 0.989), Angle of Projectile angle (r = 0.982), Angle of Bow arm and the line of force (r = 0.955), Angle of Arrow line and the bow arm line (r = 0941) and Angle of Draw Upper Arm Line and the Shoulder Line (r = 0.939) suggest that the wrist joint angle is closely tied to the inclination of the trunk and the alignment of the upper arm with the shoulder.

It can be seen significant relationship was found between Angle of Wrist joint Drow hand in degree and Angle of Trunk inclination in degree, Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.993), (.999), (.898), (.963), (.891), (.879), (.906), (.905), (.983) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the wrist joint for the draw hand are associated with corresponding changes in these other joint angles and projectile angles.

The extremely high correlation with Projectile Angle (r = 0.999) and Trunk inclination (r = 0.993) indicates that the wrist joint angle for the draw hand is closely tied to the overall direction of force applied to the arrow during the release.

It can be seen significant relationship was found between Angle of Trunk inclination in degree and Projectile angle (Angle of Line of force and the arrow line) in degree, Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.990), (.917), (.966), (.927), (.883), (.924), (.946), (.993) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of trunk inclination are associated with corresponding changes in these other joint angles and projectile angles.

The extremely high correlation with Angle of Line of Force and the Bow Arm Line (r = 0.993) indicates that the angle of trunk inclination is closely tied to the alignment of the line of force with the bow arm during the archery motion.

It can be seen significant relationship was found between Projectile angle (Angle of Line of force and the arrow line) in degree and Angle of Draw forearm line and the line of force in degree, Angle of Bow arm and the line of force in degree, Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.904), (.962), (.914), (.895), (.979) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations indicate that changes in the projectile angle are associated with corresponding changes in these other joint angles during the archery motion.

The extremely high correlation with Angle of Line of Force and the Bow Arm Line (r = 0.979) suggests that the projectile angle is closely tied to the alignment of the line of force with the bow arm during the release.

It can be seen significant relationship was found between Angle of Angle of Draw forearm line and the line of force in degree and Angle of Arrow line and the bow arm line in degree, Angle of Bow arm line and the shoulder line in degree, Angle of draw forearm line and the force line in degree of the subject among independent variables as calculated "r" (.880), (.913), (.881) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the draw forearm line are associated with corresponding changes in the line of force, arrow line and bow arm line, bow arm line and shoulder line, and the force line.

The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in drawing and releasing the bowstring.

It can be seen significant relationship was found between Angle of Bow arm and the line of force in degree and Angle of draw forearm line and the force line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.949), (.931), (.987) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the bow arm are associated with corresponding changes in the line of force, draw forearm line and force line, draw upper arm line and shoulder line, and the line of force and the bow arm line.

The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in holding the bow and drawing the bowstring.

It can be seen significant relationship was found between Angle of Arrow line and the bow arm line in degree and Angle of Bow arm line and the shoulder line in degree, Angle of draw upper arm line and the shoulder line in degree, Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.919), (.939), (.934), (907) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the arrow line are associated with corresponding changes in the bow arm line, shoulder line, draw upper arm line, line of force, and the bow arm line.

The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in aiming and releasing the arrow.

It can be seen significant relationship was found between Angle of draw forearm line and the force line in degree and Angle of draw upper arm line and the shoulder line in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.918), (.941) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the draw forearm line are associated with corresponding changes in the force line, as well as changes in the angle of the draw upper arm line with the shoulder line, and the angle of the line of force with the bow arm line.

The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in drawing the bowstring and aligning the force.

Finally, the significant relationship was found between Angle of draw upper arm line and the shoulder line in degree and Angle of draw upper arm line and the line of force in degree, Angle of Line of force and the bow arm line in degree of the subject among independent variables as calculated "r" (.952), (.960) is found greater than the required tabulated value of (.878) at .05 level of significance.

The significant positive correlations suggest that changes in the angle of the draw upper arm line are associated with corresponding changes in the shoulder line, as well as changes in the line of force and the bow arm line.

The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in drawing the bowstring and aligning the upper arm with the shoulder and the line of force.

The present study agrees with **Tabitha Dorshorst (2019)** highly supported and conducted the study on "Archery's Lasting Mark: A Biomechanical Analysis of Archery". The only significant difference in range of motion between draw arm and bow arm was observed in elbow flexion/extension. The draw arm showed a greater range of motion in this aspect ($g = 2.16$, $p = 0.008$).

During the release phase, the draw arm exhibited significantly greater elbow flexion, shoulder flexion, and internal shoulder rotation, and less shoulder abduction compared to the bow arm.

Increased elbow flexion in the draw arm during release might be associated with the mechanics of releasing the arrow effectively.

Greater shoulder flexion and internal rotation could be related to the draw arm's role in providing power and precision during the release. At the start of the shot, the draw arm again displayed greater elbow flexion, shoulder flexion, and internal shoulder rotation compared to the bow arm.

## CONCLUSION

1. There is an insignificant relationship between the angle of bow vertical alignment and performance in archery. The study reveals that specific joint angles, especially those related to shoulder, elbow, and wrist joints, play a crucial role in archery performance. Extremely high correlations (e.g., projectile angle) indicate critical joint configurations that significantly impact the success of the archery motion.

2. The study concludes that there is a highly significant positive relationship between the angle of the shoulder joint for the draw hand and various angular kinematical variables in archery. These relationships suggest the importance of the shoulder joint position in determining the overall biomechanics of the archery motion.

3. The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles.

4. The significant positive correlations between the angle of the elbow joint for the bow hand and various angular kinematical variables suggest that changes in the elbow joint angle are associated with corresponding changes in these other joint angles and projectile angles.

5. The significant positive correlations indicate that changes in the angle of the elbow joint for the draw hand are associated with corresponding changes in these other joint angles and projectile angles.

6. The significant positive correlations indicate that changes in the angle of the wrist joint for the bow hand are associated with corresponding changes in these other joint angles and projectile angles.

7. The study concludes that there is a highly significant positive relationship between the angle of the draw forearm line and various related angles, emphasizing the coordination of these variables during archery.

8. The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in holding the bow and drawing the bowstring.

9. The high correlations indicate that these angles are interconnected during the archery motion, emphasizing the coordinated movement involved in aiming and releasing the arrow.

10. The study concludes that there is a highly significant positive relationship between the angle of the draw forearm line and the force line, as well as between the angle of the draw upper arm line and the shoulder line, and the angle of the line of force and the bow arm line.

11. The study concludes that there is a highly significant positive relationship between the angle of the draw upper arm line and the shoulder line, as well as between the angle of the draw upper arm line and the line of force, and the angle of the line of force and the bow arm line.

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