Sheffield Hallam University

Technical performance differences in elite Olympic recurve archers

SHAFIZADEH, Mohsen <http://orcid.org/0000-0002-7524-1058> and DAVIDS, Keith <http://orcid.org/0000-0003-1398-6123>

Available from Sheffield Hallam University Research Archive (SHURA) at:

https://shura.shu.ac.uk/34327/

This document is the Accepted Version [AM]

Citation:

SHAFIZADEH, Mohsen and DAVIDS, Keith (2024). Technical performance differences in elite Olympic recurve archers. International Journal of Performance Analysis in Sport. [Article]

Copyright and re-use policy

See http://shura.shu.ac.uk/information.html

Sheffield Hallam University Research Archive
http://shura.shu.ac.uk

Technical performance differences in elite Olympic recurve archers

Mohsen Shafizadeh and Keith Davids

College of Health, Wellbeing and Life Sciences, Sheffield Hallam University, Sheffield, UK

Corresponding author: Dr Mohsen Shafizadeh, School of Sport and Physical Activity, College of Health, Wellbeing and Life Sciences, Sheffield Hallam University, Sheffield, South Yorkshire, S10 2BP, United Kingdom Email: m.shafizadeh@shu.ac.uk

Technical performance differences in elite Olympic recurve archers

Abstract

The aim of this study was to identify technical differences in the shot cycle demonstrated by elite Olympic recurve archers in major tournaments. Participants were 30, world-ranked archers (15 men and 15 women) who competed in different World Cup series competitions in 2023. A video notational analysis system was designed, based on the shot cycle to assess technical differences between the elite archers. For each archer, 18 shots were selected from analysis of performance in individual or team competitions. Results showed that the execution of shot cycle phases varied among elite archers. Findings also revealed that these variations grouped into two styles of Olympic recurve archery: some displayed a common style and some a more complex style. The two styles were mainly different in movement complexity when raising the bow, loading and bow arm follow-through. In conclusion, the designed notational analysis system in recurve archery can be used by coaches and performance analysts for exploring skill adaptation of young archers in their development pathway. The observed technical differences in actions of the elite archers in this study could justify our re-definition of the ideal performance in this sport, re-directed towards skill adaptations, based on satisfying individual, environmental and task constraints.

Keywords: archery, notational analysis, performance adaptations, constraints, skill adaptation.

Introduction

Archers in Olympic recurve shoot arrows with a recurve bow at a target located 70 m away from the shooting line (Leroyer et al., 1993). Two key performance indicators associated with a successful performance in this sport are accuracy and consistency which are traditionally achieved by a tremendous amount of rehearsal and repetition of a highly invariant shot routine (Johnson, 2015). Accuracy which is the main objective in competitive performance and a key factor in winning and losing a contest is determined by total points scored from a series of arrows shot at the target. Consistency in the shot process is not specifically evaluated during competition, but it determines the amount of performance fluctuations and is the main reason for adherence to regular, repetitive practice programmes.

When shooting an arrow, archers must coordinate different body parts for holding the bow and pulling the bowstring, while aiming the arrow at a target. Coordinating different body segments for consistent performance of shooting actions for accurate aiming is the main challenge of archers in their performance development pathway from novice to advanced levels. This challenge is shaped by interacting constraints such as individual (e.g. muscular strength, flexibility, balance), environmental (e.g. coaching style, bow poundage) and task (e.g. practice organisation) demands (Newell, 1986). Harnessing the complexity of the system (formed by archer-bow-field) requires sufficient skill proficiency that is developed over time and is the main reason for observing intra-individual technical variability and inter-individual technical differences.

In terms of intra-individual variability, archers typically develop their unique shooting technique (Johnson, 2013) and might adapt their shooting procedure intentionally (due to weather conditions) or unintentionally (as a result of psychological pressure, and muscle fatigue) despite the stable task constraints, static nature of this sport and a lack of change in competition demands (Ertan, 2009). Vendrame et al. (2022) performed a systematic review of

41 studies between 1986-2021 on performance assessment in archery which underlined the significant roles of adopting personal strategies in postural orientation and stability and time management of expert archers.

The number of studies that have investigated inter-individual differences of elite recurve archers in completing a shot cycle is limited. Existing studies have mainly used biomechanical methods for analysing the recurve shooting performance and have used statistical analysis, involving the coefficient of variation (CV), standard deviation (SD) or root mean square error (RMSE) values for quantifying levels of inter-individual differences. For example, Kuch et al. (2023) showed that elite archers relative, to other skill levels, showed higher levels of variability (SD) in the velocity of postural adjustments in a mediolateral direction. Callaway et al. (2017) and Heller et al. (2012) also reported higher levels of performance variability (CV) in clicker-release times as a significant determinant of higher performance scores in elite recurve archers. Other studies demonstrated improved muscle coordination (Baifa et al., 2023), postural stability (Kuch et al., 2023; Spratford & Campbell, 2017; Simsek et al., 2019) and temporal sequencing (Callaway et al., 2017) in elite archers, in comparison to sub-elite and less experienced archers. This advantage is mainly due to their extensive training experience and knowledge, as well as their extensive experience of practising shooting in different environments (at short distance/long distance targets; in dry/rainy/windy weather conditions; during practice/competitive contexts). Technical differences of elite recurve archers in previous studies cannot be generalised to actual competitive performance because of the common use of biomechanical analysis methods in laboratory settings or in practice fields that are not representative of competitive contexts. According to practice designs in Nonlinear Pedagogy (e.g., Chow 2013; Chow et al., 2016), the similarity between performance assessment contexts and competition contexts (high representativeness) is important to gain a valid understanding of skill proficiency and adaptations, relative to task and environmental constraints.

Notational analysis provides information about the quality of sport performance that is usually acquired through designing a tagging panel and collecting data on relations between performers' actions, outcomes and contexts (Hughes et al., 2023, McGrray et al., 2013). Applications of notational analysis of performance in target sports generally, and archery specifically, are rare for different reasons. First, the number of tactical elements required for successful performance outcomes is low (Heller & Baca, 2013). Second, the performance context of archery typically remains stable and constant (Ertan, 2009). Last, it is believed that the shot cycle is acquired at the foundation level and quality of shot execution is less important than performance consistency and accuracy (Johnson, 2015). However, notational analysis methods can be usefully applied for developing pedagogical practice in coaching talented young archers, founded on evidence from studying high-level archers. First, notational analysis is a popular method for performance profiling that is used for identifying successful performance indicators in talent development systems and creating normative data from expert performers (O'Donoghue, 2013). Using a well-defined shot process, observed in successful archers, can help to develop a stable foundation of movement pattern to support consistent shooting performance under pressure and prevent the risk of overuse injuries (Krueger, 2013). Second, the main role of notational analysis in archery is for augmented feedback provision for performance enhancement during learning. The application of feedback for error detection and error correction in target sports, such as archery, is paramount (Heller & Baca, 2013). Last, measurement systems for performance improvements, based on biomechanical models are not practical for field target archery, whereas coaches can benefit from using augmented approaches, such as using video analysis systems, for comparing actual and desired movement forms. In this study, we aimed to analyse the shot cycle of elite Olympic recurve archers in major tournaments to identify technical differences between them (inter-individual technical variability). To our knowledge, this is the first study that has used notational analysis of a sport skill in the assessment of inter-individual variability in elite recurve Olympic archers during performance at international competitions.

Methods

Participants

Participants in this study were 30 (15 men and 15 women), top-ranked, Olympic recurve archers, selected non-randomly, based on the latest (May 2024) World recurve archery rankings (www.worldarchery.sport). The demographic measures of the participants are presented in Table 1. The World ranking and annual performance points are determined through attendance and performance ratings at a series of international tournaments. The participants were selected for this study, based on their overall performance levels in 2023. A local ethics committee at the university approved all stages of this study.

Materials

We selected different international tournaments in 2023 for the notational analysis of archers' performance at the following events: the Berlin World Cup (Germany), the Antalya World Cup series (Türkiye), the Hermosillo World Cup series (Mexico) and the Asian Games (Thailand). The video footage of performance at the competitions were accessed from YouTube (World Archery Channel), available publicly and without requiring permission. The video clips were analysed without any modifications in frame rate and resolution.

Procedure

A notational analysis tagging panel was created for data collection. The tagging panel was made in NacSport scout software (NacSport video analysis, Spain) through standard button layouts that were defined, based on phases of the recurve shot cycle (see Table 2 for operational definitions). The shot cycle was defined as a sequence of actions that an archer organises to shoot an arrow at the target. There are different methods of classification of the shot cycle, but for the purposes of this study, we selected a 7-phase model that is a modification of the KSL method (Krueger et al., 2013). The 7 phases of the shot cycle in this study are: stance, bow raise, loading, full draw, anchor, release and follow-through. The bow arm was only observed in the bow raise phase. The string arm was observed in the loading, full draw, anchor and release phases. Follow-through was observed in both arms. The stance phase was only observed in the positioning of the feet.

We tested intra-rater reliability of the tagging panel by analysing 6 archers who were randomly selected from a specific competition (Berlin World Cup 2023). We selected three shots from each archer and repeated the same procedure 24 hours later. The Kappa method was used to confirm the reliability of the tagging method and a value of 0.91 (excellent consistency) was achieved. Because the nature of this study was exploratory, the tagging panel was revised if more action groups emerged during data collection.

Two performances of each archer in different competitions were observed. In total, 18 shots by each archer were selected for notational analysis. Shots were selected from team or individual competitions in the final stages of competing (semi-final, final or third-place). Raw data were exported from NacSport to MS Excel for further analysis.

Data analysis

Descriptive and inferential statistics were used to analyse the raw data. First, we observed the types of action in each phase (technique variation) and reported frequency and percentages. We used one-way Chi-squared test to compare the frequency of different types of action in each phase. Second, we used a cluster analysis method to identify similarity and differences in the shot cycle among the archers, creating a performance profile. This exploratory method is usually used for grouping participants based on experimental analyses of common features (variables) of performance. For the purpose of this study it was used to classify the archers (output) based on observed styles of shot cycle (input). Last, to confirm accuracy in group allocation, we used 2-way Chi-squared tests as a follow-up for the cluster analysis. All statistical analyses were tested at a 95% confidence interval (two-tailed). We used SPSS (V.23) for all statistical analyses.

Results

1. Styles of the shot cycle

The elite Olympic recurve archers displayed different styles in executing different phases of the shot cycle (see Figure 1).

Stance. We identified 2 common stance positions, as many archers revealed a square stance (n=18, 60%), and an open stance (n=12, 40%). None of the participants selected a closed stance. The Chi-squared statistical analysis did not show any significant differences between frequency of stance positions ($p>0.05$).

Bow raise. The reference line was alignment with the target and any deviation from this line was the principle of classification. There were 2 styles of raising the bow arm. Some archers only used an upward movement to reach the target line (n=14, 46.7%), whereas others (n=16, 53.3%) used an upward movement, followed by a downward movement to align the bow with the target line. The Chi-squared analysis did not show any significant differences in frequency of bow raise styles ($p>0.05$).

Loading. There were 2 different methods to pull the string: many archers used a constant motion (n=23, 76.7%), whereas some archers implemented a variable motion (n=7, 23.3%), with a short pause in string pulling. The Chi-squared result showed a significant difference between frequency of loading styles ($p<0.05$).

Full draw. There were 2 trajectory lines from the start of pulling to the anchor point: linear motion (n=19,63.3%) and angular motion (n=11,36.7%). In angular motion, the string was moved in a curvilinear path and was slightly far from the face in the middle of the full draw. In the linear draw, the string was kept close to the jaw (face). The Chi-squared result did not show any significant differences in frequency of full draw styles ($p>0.05$).

Anchor. Many of the archers placed the string in the middle of the lips (n=21, 70%) and some (n=9,30%) placed it laterally (away from the middle and towards the corner of the mouth). The Chi-squared result showed a significant difference in frequency of anchoring styles ($p<0.05$).

Release. The common release style used relaxed fingers (n=28, 93.3%), but some archers (n=2,6.7%) opened their fingers during string release. The Chi-squared result showed a significant difference between the frequency of release styles observed ($p<0.05$).

Follow-through. The common style of string arm follow-through was sliding backwards to the middle of the neck (n=24,80%), or sliding upward/backwards to the earlobe (n=6,20%). The Chi-squared result showed a significant difference between the frequency of string follow-through styles ($p<0.05$). The bow in some archers was swung proximally, with the whole arm (n=13,43.3%), distally and only with the bow hand (n=8,26.7%) or variably: some attempts were proximal and some attempts distal (n=9,30%). The Chi-squared analysis did not show any significant differences between bow arm follow-up styles ($p>0.05$).

2. Performance profile of Olympic recurve archers

The results of the cluster analysis showed that the style of shooting in elite Olympic recurve archers can be classified into two groups. Many of the elite archers have a common style (n=23,76.7%) and a small number have a complex style (n=7,23.3%) in the shot cycle. Figure 2 shows the performance profile of each group. The complex style archers are distinguished from the common style archers in 3 main areas: a) employing an extra movement (upward then downward) in the bow raise phase, b) changing a movement pace with a short pause in the loading phase, and c), using a proximal swing in the follow-through phase. The other important phases that were different between the groups were full draw and anchor. Results of Chi-squared tests showed that the two archer groups displayed variations in bow raise ($\chi^2=8$, $p<0.05$), loading ($\chi^2=30$, $p<0.05$), full draw ($\chi^2=5.28$, $p<0.05$), anchor ($\chi^2=3.91$, $p<0.05$) and bow follow-through ($\chi^2=11.95$, $p<0.05$). These results confirmed the findings of the cluster analysis method in grouping the archers.

Discussion

The aim of this study was to investigate whether there were any technical differences observed in the execution of shot cycle phases in elite Olympic recurve archers. Although it has long been assumed that elite athletes evolve towards a unified expert model of performance (e.g., Hatze, 1976), the findings of this study showed that there were important inter-individual differences among elite archers in recurve shooting cycle, with at least, two style (forms) in each phase. We also observed that archers, based on their shooting style, can be divided into the common style and the complex style groups.

Olympic recurve archers usually practice similar forms of movements in the shot cycle under highly stable task constraints (Ertan, 2009), but they have their unique style of shooting (Johnson, 2013). It is challenging to make sense of the small differences displayed between archers without comprehensive biomechanical analyses using sophisticated measurement systems in a laboratory environment. However, using notational analysis methods was useful in the current study to explore the technical differences that exist between elite archers which may be observed in competition (Hughes et al., 2019). Previous studies that investigated technical variability between elite recurve archers have highlighted significant levels of inter-individual differences in some biomechanical parameters, such as postural stability (Vendrame et al., 2022; Kuch et al., 2023) and time management (Callaway et al., 2017;

Heller et al., 2012). Our study revealed some important movement form modifications in phases of the shooting cycle that might be a reason for reported postural adjustments in elite archers. For example, two types of loading identified in this study, constant and variable, can cause different postural adaptations because of the changes in string arm and trunk accelerations, but without any adverse effects on the overall postural stability of the performer. The loading phase mainly requires rotation of the trunk around a pivotal axis (bow shoulder to mid trunk) to generate appropriate torque and shoulder-bow alignment (Lee, 2013). However, this movement does not affect body equilibrium in elite archers, due to excellent consistency in this process. A previous study showed that postural sway area and velocity levels observed in elite archers were less than in non-elite archers (Simsek et al., 2019), suggesting the adoption of functional postural stability during the entire shooting cycle due to increased expertise.

None of the shot cycle phases revealed a single, dominant form of movement. More specifically, we identified at least 2 forms (styles) in each phase that make the Olympic recurve shooting technique a unique and person-dependent skill, despite general assumptions of technique commonality. Individual adaptability observed in elite archers could be explained by their tendency to re-organise movements to exploit the available degrees of freedom in their movement system (Bernstein, 1967). In other words, continuous practice of the same technical routine under individual (body shape and size, physical fitness, sex, age, maturity, muscular strength) and task constraints (bow poundage, coaching styles) could shape a unique and archery-specific re-organisation of the musculoskeletal system in the development pathway that advances the archers from a basic and prime technique. According to the theory of ecological dynamics (e.g., Davids et al., 2005), the process of skill adaptation in sport performance is a non-linear, dynamic, individualised and constraint-led process (Rothwell et al., 2022). Further, understanding the process of evolution in skill adaptation in highly skilled recurve archers requires a longitudinal study, especially considering the interactive role of individual, environmental and task constraints on their sports performance. We should also emphasise that, whilst movement forms of some phases might be constrained by coaching (e.g. selecting square stance versus open stance), the majority of the modifications in the process of movement execution are implicit and emerge under personal and organismic constraints. For example, in the bow raise phase, coaches might, or might not, explicitly instruct novice archers on the degrees of shoulder abduction. Instead a performer may adopt a preferred style during skill development in practice. Because accuracy and consistency of performance outcomes are two important key performance indicators in archery (Johnson, 2015), any modifications to movement execution are less important. Individualised techniques and variations in the shot cycle among elite recurve archers further criticise the old-fashioned philosophy of coaching that emphasises the optimisation of technique in the acquisition of sports skills (Davids et al., 2005).

Our findings also showed that despite the same routine of the recurve shot cycle, there are differences among the elite archers in the shot cycle complexity, with two groups of archers identified: the archers with a complex style and the archers with a common style. In the current study, increasing shot cycle complexity was seen at the bow raise and loading phases. The complex style archers demonstrated extra movements and modifications in the movement pace that differentiated them from the common style archers. It is difficult to understand the origin of such differences, but it may be explained through the concept of individual constraints. Individual constraints in sports performance have been used as a concept to explain individual differences or individuality of development and performance (Newell, 1986). But another view of an individual constraint may define it as a personal approach and strategy to adapt to performance requirements of the task/sport skill. Our results suggest that reproducing a common ‘optimal technique’ may not be a prerequisite for skilled behaviour (Brisson & Alain, 1996). Instead, the capacity to adapt and re-organise stable, individualised performance solutions is critical (Button et al., 2020). Skill adaption can be defined as enhancing an individual's functionality in a sport performance environment which can be continually improved (Renshaw & Chow, 2019). Skill adaptation is our strategy in responding to the requirements of sport performance and is continually across different timescales shaped by individual, environment and task constraints. Hence, facilitating a learning environment for athletes to search for movement solutions, matched to their personal constraints is a core principle of ecological dynamics in creating individualised performance strategies (Davids et al., 2005). Skill adaptation may explain why archers in their skill development process displayed different functional adaptations in the shot cycle. For example, one established individual constraint in adopting the complex style was sex and only women archers selected this style of shooting in our study (7 out of 15 women). Understanding the underlying reasons based on the current dataset is challenging, but the complex style might be related to body morphology of the athlete, movement mechanics and individual constraints in terms of strength, and body posture that may have influenced successful performance. For example, muscle synergies from active muscle groups, associated with skill and expertise (Baifa et al., 2023), might explain why some archers adapted their actions to improve performance or reduce the risk of overuse injuries in the upper body. This issue also needs further investigation.

The findings of this study have some practical implications in archery technical analysis. First, this is the first study that has used a notational analysis method to analyse the shot cycle in elite archers during formal competitions. The representative design (Button et al., 2020) of such skill performance analysis methods, relative to traditional laboratory biomechanical analysis, is higher. This ecological characteristic suggests that technical notational analysis may be useful as an additional measurement methodology for assessing technical proficiency in sports like Olympic recurve archery. Second, the notational system that was designed, based on the shot phases in archery, can provide an observational tool for the coaches and sports analysts to quantify the shot cycle in practice and competitions and provide kinematic feedback for skill performance adaptations accordingly. Last, we identified 2 styles of shooting in elite archers that can be observed and quantified in young archers on the talent pathway, for possible exploration and adaptations in their existing actions. Embedding adaptive strategies in coaching the recurve shot technique during the development pathway can provide opportunities for young archers to modify their movement patterns, according to their interactions with the environmental and task constraints.

This study had some limitations. We did not change the available video footage for better quality. This limitation overlooked the potential of shot timing as an important performance indicator in Olympic revurve archery. Video-recording the performance of archers in a competitive context, instead of using public media, with added flexible recording modes (high speed, high resolution, etc.) could help sports analysts set up a digital platform for high-quality analysis of skill performance. We restricted the elite archers to the top World ranked (1st-15th) for the purposes of technical analysis and identifying the shooting style. There might be more variations in the recurve archery style if we extended analysis of the archers to lower-ranked performers.

In conclusion, the findings of this study showed that, in the sample of elite Olympic recurve archers, the shot cycle displayed some technical differences, and there was inter-individual variability in archers in different phases of the shot cycle. The technical differences might be related to the interactions of factors around the person, environment and tasks. Some features that made the style of some elite archers more complex were using movement variability, especially in the bow raise, loading and bow hand follow-through phases.

References

Baifa, Z., Xinglong, Z., & Dongmei, L. (2021). Muscle coordination during archery shooting: A comparison of archers with different skill levels. *European Journal of Sport Science*, *23(1),* 54–61.

Bernstein, N. A. (1967). *The coordination and regulation of movements*. Oxford: Pergamon.

Brisson,T.A., & Alain,C. (1996) Should common optimal movement patterns be identified as the criterion to be achieved? *Journal of Motor Behavior.* 28, 211-223.

Button, C., Seifert, L., Chow, J. Y., Davids, K., and Araujo, D. (2020). *Dynamics of Skill Acquisition: An Ecological Dynamics Approach*. Champaign, IL: Human Kinetics Publishers.

Callaway, A. J., Wiedlack, J., & Heller, M. (2016). Identification of temporal factors related to shot performance for indoor recurve archery. *Journal of Sports Sciences, 35(12),* 1142–1147.

Chow, J. Y. (2013). Nonlinear learning underpinning pedagogy: evidence, challenges, and implications. *Quest*, *65*, 469–484.

Chow, J. Y., Davids, K., Button, C., and Renshaw, I. (2016). *Nonlinear Pedagogy in Skill Acquisition: An Introduction*. London, New York: Routledge.

Davids, K., Araújo, D., Seifert, L., & Orth, D. (2015). Expert performance in sport: An ecological dynamics perspective. In J. B. & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 273-303). Routledge.

Ertan, H. (2009). Muscular activation patterns of the bow arm in recurve archery. *Journal of Science and Medicine in Sport, 12*, 357–360.

Frankfort-Nachmias, C. & Leon-Guerrero, A. (2017). Social statistics for a diverse society. 8th edition, New York: Sage publication.

Gibson, J. J. (1979). Ecological approach to visual perception. Boston: Houghton Mifflin.

Hatze, H. (1976). The complete optimization of a human motion. *Mathematical Biosciences,* **28**, 99-135.

Heller, M. (2012). Evaluation of arrow release in highly skilled archers using an acoustic measurement system. *Procedia Engineering, 34*, 532–537.

Heller, M. & Baca, A. (2013). Target sports. In McGarry et al (eds.). *Routledge handbook of sports performance analysi*s. London: Routledge.

Hughes, M., Franks, I.M., & Dancs, H. (2019). *Essentials of performance analysis in sport*. 3rd edition, London: Routledge Taylor& Francis.
Johnson, B. (2013). Becoming a competitive archer, In: USA Archery (Ed.), *Archery*. IL: Human Kinetics Publisher.
Johnson, T. (2015). *Archery fundamentals.* 2nd Edition, IL: Human Kinetics Publisher.
Krueger, G. (2013). Developing your shot sequence, In: USA Archery (Ed.), *Archery*. IL: Human Kinetics Publisher.
Kuch, A., Tisserand, R., Durand, F., Monnet, T., & Debril, J. F. (2023). Postural adjustments preceding string release in trained archers. *Journal of Sports Sciences, 41(7)*, 677–685.
Lee, K. (2013). Recurve shooting: setting up, In: USA Archery (Ed.), *Archery*. IL: Human Kinetics Publisher.
Leroyer, P., Van Hoecke, J., & Helal, J. N. (1993). Biomechanical study of the final push-pull in archery. *Journal of Sports Science, 11(1)*, 63–69.
McGarry, T., O'Donoghue, P., & Sampaio, A. J. de E. (Eds.). (2013). *Routledge handbook of sports performance analysi*s. London: Routledge.
Newell, K.M. (1986). Constraints on the development of coordination. In: Motor development in children. In: Wade M, Whiting H, (Eds.), *Aspects of coordination and control*. Dordrecht The Netherlands: Martinus Nijhoff.
O'Donoghue, P. (2013). Sports performance profiling. In McGarry et al (eds.). *Routledge handbook of sports performance analysi*s. London: Routledge.
Renshaw, I., and Chow, J. Y. (2019). A constraint-led approach to sport and physical education pedagogy. *Physical Education and Sport Pedagogy, 24*,103–116.
Rothwell, M., Davids, K., Woods, C. T., Otte, F., Rudd, James., & Stone, J. A. (2022). Principles to guide talent development practices in sport: The exemplar case of British rugby league football. *Journal of Expertise, 5*, 28-37.
Simsek, D., A. O. Cerrah, H. Ertan, & A. R. Soylu. (2019). A comparison of the ground reaction forces of archers with different levels of expertise during the arrow shooting. *Science & Sports 34(2),*137-145.
Spratford, W. & Campbell, R. (2017). Postural stability, clicker reaction time and bow draw force predict performance in elite recurve archery. *European Journal of Sport Science, 17*: 539-545.

Vendrame, E., Belluscio, V., Truppa, L., Rum, L., Lazich, A., Bergamini, E., & Mannini, A. (2022). Performance assessment in archery: a systematic review. *Sports Biomechanics*, 1–23.

Table 1-The participants ranks, nationality and annual points.

No	Sex	Name	Handedness	Nationality	World Ranking	Annual Points
1	Male	MD	Right	Brazil	1	347
2	Male	LW	Right	Korea	2	272
3	Male	KW	Right	Korea	3	264
4	Male	MN	Right	Italy	4	243
5	Male	BE	Right	USA	5	242
6	Male	MG	Right	Turkiye	6	240
7	Male	EP	Left	Canada	7	221
8	Male	KJD	Right	Korea	8	218.5
9	Male	FU	Right	Germany	9	215
10	Male	SW	Right	Holland	10	214.5
11	Male	ND	Right	Virgin Islands	11	196
12	Male	DO	Right	Moldova	12	188
13	Male	TCC	Right	Taiwan	13	187
14	Male	MG	Right	Mexico	14	180
15	Male	JW	Right	USA	15	177.5
16	Female	CK	Left	USA	1	313
17	Female	LS	Right	Korea	2	300
18	Female	AV	Right	Mexico	3	275
19	Female	MH	Right	Czech	4	258
20	Female	EC	Left	Spain	5	247
21	Female	KC	Right	Korea	6	219
22	Female	PH	Right	GBR	7	216
23	Female	CM	Right	Korea	8	212
24	Female	CR	Right	Italy	9	209
25	Female	KB	Right	Germany	10	198
26	Female	LB	Left	France	11	193.5
27	Female	MK	Right	Germany	12	191
28	Female	AS	Right	Korea	13	180.5
29	Female	LJ	Right	China	14	178
30	Female	CS	Right	Germany	15	166.5

Table 2-Operational definitions of the shot cycle phases in Olympic recurve archery.

Phase	Definition
Stance	Standing on the shooting line, placing fingers on the bow and string and turning head towards the target
Bow raise	Maintaining a correct posture and lifting the bow with two hands
Loading	Pulling the string whilst pushing the bow in the opposite direction
Full draw	Bringing the string towards the face
Anchor	Placing the string hand on the lower jaw bone (mandible)
Release	Opening the string fingers and sliding the string arm backwards
Follow-through	Continuous sliding of backward motion in the string arm and pushing the bow arm forward

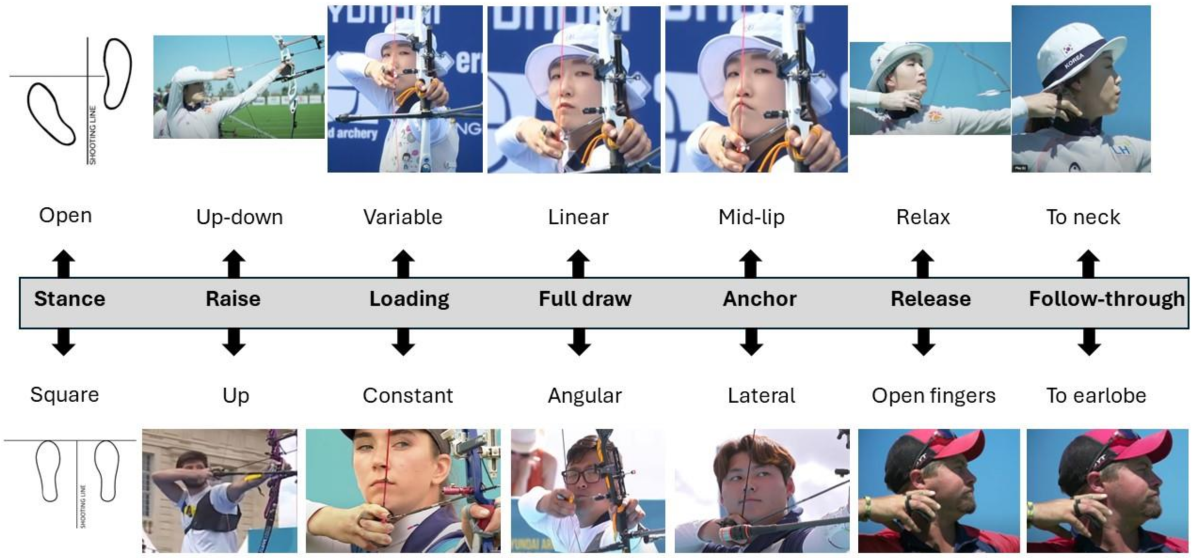

Figure 1. Different styles of shot cycle execution

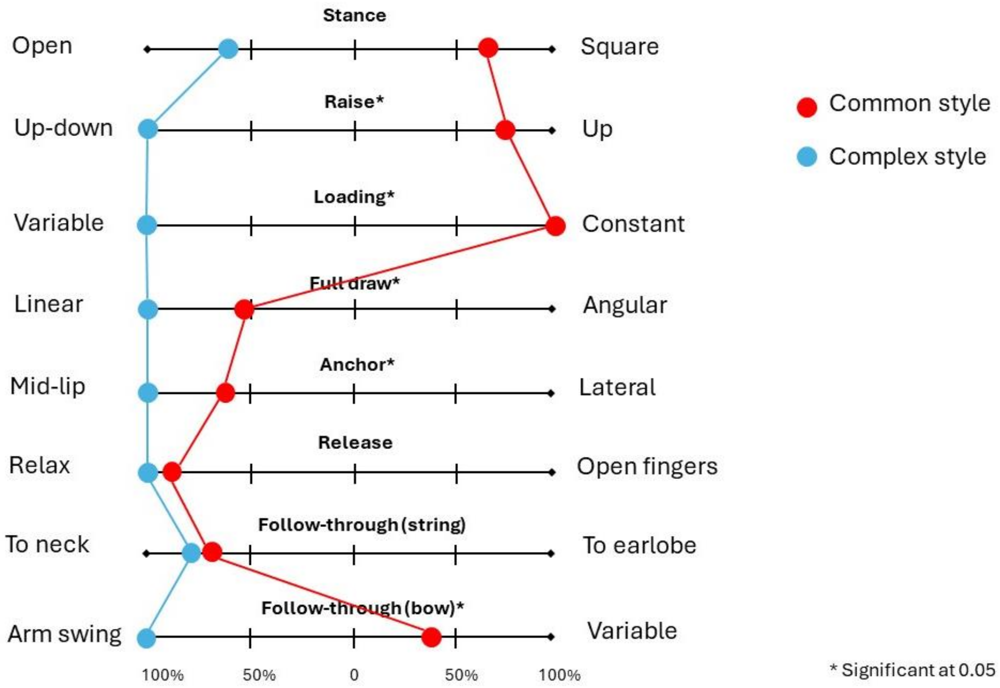

Figure 2. Performance profile of elite Olympic recurve archers