



Heart Rate Values During Shooting is a Field-Side Performance Analysis Tool in Archery-A study of Elite Indian Archers

Chandra Sekara Guru ^{1,*}, Anup Krishnan ², Uma Mahajan ² and Deep Sharma ¹

¹Department of Sports Medicine, Armed Forces Medical College, Pune, India

²Army Sports Institute, Sports Sciences Faculty, Pune, India

*Corresponding author: Department of Sports Medicine, Armed Forces Medical College, Wanowrie, Pune, India. Tel: +91-9790422777, Email: drscsguru@gmail.com

Received 2019 November 24; Accepted 2020 January 17.

Abstract

Background: Heart rate value during different phases of archery shooting has been correlated with performance scores.

Objectives: This study was done to ascertain this and with an aim of real-time objective field assessment of training and performance among Elite Indian archers.

Methods: The study was conducted in Indoor archery hall as per World Archery Association rules with Cross-sectional study design. Seven volunteered male elite archers (mean age: 23.9 ± 3.00 years, mean experience: 8.5 ± 2.35 years) shot 30 arrows each ($n = 210$) with simultaneous recording of heart rate, score and shooting action. Release frames were identified by slow motion analysis. Heart rate values during release (0 s), every second for 5 seconds before and after the release of arrow were noted and analyzed. One-way ANOVA test was employed. Level of significance was set at $P < 0.05$.

Results: One-way ANOVA of heart rate values at all 11 time-points between the three scores 8, 9 and 10 showed significant differences from -5 s to -1 s with heart rate values at score 8 being significantly higher ($P < 0.05$). Heart rate decreased significantly from -5 s to +1 s and increased further.

Conclusions: Heart rate deceleration was found in aiming and release phases of shooting. The elicited change in trend of the heart rate values can be used as a field-tool for training archers. Future studies on novice archers would help us understand the change in trend with training and experience in the sports.

Keywords: Athletic Performance, Attention, Heart Rate Control, Motor Skill

1. Background

Archery requires high level of mental concentration, precision and accuracy (1). Performance in archery is designated based on the skill of the archer to score maximum points repeatedly (2). Heart rate response during different phases namely drawing the bow, aiming and releasing the arrow has been studied in elite archers (3, 4). Archery requires the interaction of psychological factors, physiological measures and motor performance. Arousal is one of the most important among the psychological variables which influence the motor performance and, more importantly, precision (5). In sports that require both accuracy and precision, the high level of arousal due to anxiety and fear can negatively decrease the performance of the participants (3, 6).

Elite archers were found to be relaxed with highest level of attention during shooting similar to elite rifle shooters (7, 8). This performance within the sport is attained by maintaining a balance between parasympathetic

and sympathetic activity (4, 9). Heart rate measurement, one of the most commonly used physiological measures in both laboratory as well as field, to assess and correlate with performance, offers insights into the interaction of activity with attention processes (2, 3, 6) and has been reported that with an effectively focused attentional process, the athlete maintained a deceleration in heart rate just before execution of the motor response (1, 6).

Heart-rate deceleration could be considered a sign of good performance and have important implications for assessment of autonomic nervous system modulation, attention and concentration learning, monitoring of training adaptation and mental training including self-regulatory interventions such as biofeedback and relaxation-energizing techniques (10-12). Studies have found inverse relationship between heart rate deceleration and performance scores in experienced archers as well as lower arrow scores in non-elite experienced archers (1, 3, 6).

Limited studies have been conducted among elite Indian archers. It is also known that the heart rate response varies with race and ethnic differences (13). Moreover, most of the studies in archers have utilized either pre-shot heart rate (one value) alone for correlating with performance scoring with the help of simple equipment (3, 14) or have assessed at time points of pre-performance routine phase of shooting using sophisticated equipment either raising the training cost or hindering the shooting technique (1, 6). Assessment of training adaptation and performance of an athlete is a basic necessity for a coach to plan the training strategy.

2. Objectives

This study aimed to carry out indoor field measurement of the elite Indian archers' heart rate during shooting activity in a sports institute using commonly used heart rate monitor and was correlated with performance.

3. Methods

3.1. Ethics

Informed consent was obtained from each participant and the study protocol was designed following ethical standards of research abiding the Helsinki Declaration and Ethical Standards in Exercise and Sports Sciences Research by Harris and Atkinson (15). After obtaining approval of the Institutional Ethical Committee, the study was conducted in the indoor archery hall.

3.2. Study Design

To measure the heart rate during shooting and correlation of shooting performance in Indian archers, we used a cross sectional observational study design among volunteered elite archers who had participated in International Archery Tournaments as part of the National Team or selected by the Indian Archery Federation (16).

3.3. Materials

Seven male elite archers (04 compound archers and 03 recurve archers) of the Sports Institute volunteered for the study. Their mean age was 23.89 ± 3 years and mean sports experience was 8.45 ± 2.35 years. Basic anthropometric and sports profile of the participants is shown in Table 1. All participants were involved in active sports training and were free of any illnesses and not consuming medications during the study. All participants were in the preparatory phase of sports training and performed when no audiences or coaching staff were present with the outcome of the study having no consequence in their sports career.

All the participants were instructed not to consume foods or beverages such as tea, coffee or energy drinks before the study. They were also instructed not to involve in vigorous sports activity on the day prior to the conduct of the study and to sleep at least for 8 hours on the night prior. Participants used their standard personal archery equipment that were used for sports training.

Essential and easily available sport equipment in the field like a heart rate monitor, camcorder and a free slow motion analysis software were used to record the heart rate, score and time points during shooting. The shooting conditions, venue, timing, protocol, environment and the observer were maintained same for all the participants. All the participants were given practice sessions with heart rate chest belt worn for familiarization.

3.4. Analysis

To meet the aim of measuring the heart rate pattern during the entire key phases of shooting namely aiming, release and follow through rather than pre-shot routine, we had included 05 seconds before and 05 seconds after arrow release as usually shooting an arrow varies between 05-08 seconds with varying skill of the archer (2). All the archers shot 30 arrows each from a distance of 18 m on to the prescribed target face as per the World Archery Association Indoor Archery rules in a standard indoor archery hall under comfortable temperature and humidity (Figure 1). The study involved recording of the arrow shooting and simultaneously recording heart rate using validated Polar V800 heart rate monitor (Polar Electro Oy, Kempele, Finland) (17). A Sony HD camcorder (HDR-PJ670, Sony Electronics, San Diego, CA, USA) set at 50 frames per second was used to record the shooting activity. As shown in Figure 2, the video recorded frame included both the arrow shooting posture of the archer and the heart rate monitor (watch) displaying the heart rate that was being recorded real-time.

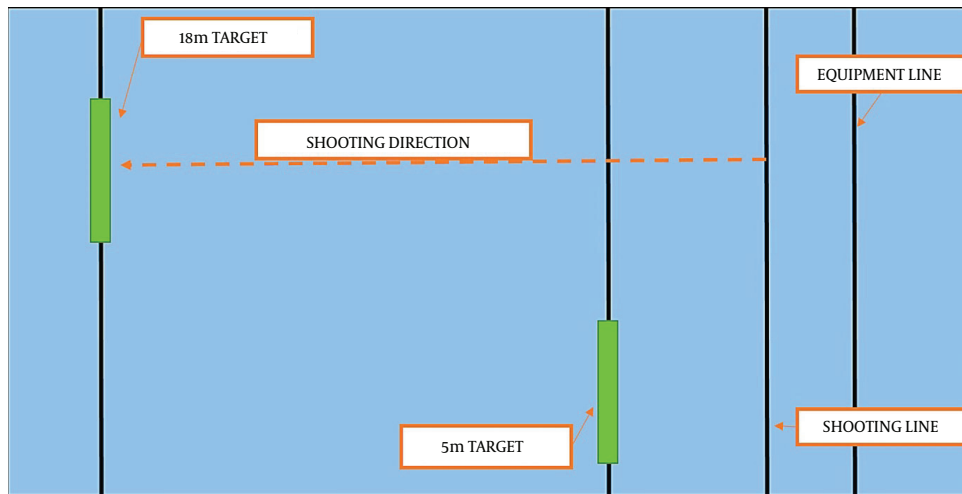
In a single day only one archer underwent the study and was conducted within the same time interval on all days. All archers underwent standardized fifteen minutes of warm up session including target practice with the chest belt affixed after the anthropometric and sports profile recording. Each archer shot 30 arrows in 10 ends containing three arrows each, thereby constituting a sample size of 210 arrows ($n = 210$). Each end was to be shot within a period of 2 minutes as per the World Archery rules which was timed and monitored by the observer (18). The score made by the arrow that was shot on to the target face was also recorded as numerical values from 1 to 10 as per standard archery rules by the observer.

Slow motion analysis was done using a free motion analysis software (version 0.8.15; Kinovea association, Paris, France) and time points frames were identified based

Table 1. Anthropometric Profile of Elite Archers^a

Profile	Archery Event		All Archers (N = 7)
	Compound (N = 4)	Recurve (N = 3)	
Age, y	24.7 ± 3.66	22.9 ± 2.07	23.9 ± 3.00
Experience, y	7.2 ± 1.51	10.2 ± 2.30	8.5 ± 2.35
Height, cm	166.0 ± 4.00	172.0 ± 7.00	168.0 ± 6.00
Body mass, kg	68.0 ± 4.00	70.0 ± 10.00	69.0 ± 6.00
Body mass index, kg/m ²	24.8 ± 1.21	23.7 ± 1.40	24.3 ± 1.33
Body fat, %	12.4 ± 1.40	11.0 ± 1.90	11.9 ± 1.7
Lean body mass, %	87.4 ± 1.40	89.0 ± 1.90	88.1 ± 1.7
Waist-to-hip ratio	0.89 ± .02	0.86 ± .05	0.88 ± 0.04

^aValues are expressed as mean ± SD.

**Figure 1.** Schematic design of the shooting activity in the indoor archery hall as per World Archery Association rules**Figure 2.** Video recording both shooting and heart rate value in the same frame

on the release of the arrow. The time points identified were

every second for 05 seconds before release, release of arrow and every second for 05 seconds after release, thus comprising a total of 11 time points and named -5 s, -4 s, -3 s, -2 s, -1 s, 0 s, +1 s, +2 s, +3 s, +4 s and +5 s respectively. Each identified frame had the recorded heart rate at that particular point of time displayed in the same frame (Figure 2). This heart rate value was noted from every frame for the corresponding time points for every arrow shot. The outcome measures were mean heart rate values at these time points i.e. before, during and after shooting of arrow and the corresponding mean performance scores.

3.5. Statistical Analysis

Kolmogorov Smirnov test and Levene's test were used to test normality of continuous variables and homogeneity of variances respectively. One-way ANOVA was used to

test the differences in mean values of heart rates at all 11 time points and archery scores 8, 9 and 10. Kruskal-Wallis test was used for comparing mean heart rates at time points +2 s and +3 s between three different scores as they were not normally distributed. Tukey's HSD test was used for post hoc analysis to test the difference in heart rates among the three scores. Repeated measures ANOVA was used to test the change in mean heart rates. Ninety five per cent confidence intervals (95% CI) were calculated. Statistical significance was set at $P < 0.05$. All statistical analyzes were done in SPSS version 20.0.

4. Results

This study involved elite archers of both compound and recurve events. There was no significant difference in the anthropometric and sports profile of archers based on the archery event ($P > 0.05$). As all were elite archers, out of the total of 210 arrows shot, the lowest score recorded was 8 and was recorded only 07 times. Score 9 was recorded 86 times and score 10 was recorded maximum, namely 117 out of 210 arrows shot. Among the archery scores of 8, 9, and 10, the mean heart rate of all the 11 time points was highest for score 8 when compared with the other scores namely 9 and 10. Between scores 9 and 10, the mean heart rate varied by 1 bpm at each of the 11 time points. The score-wise mean heart rate values during shooting is shown in [Figure 3](#).

The mean values of heart rates of at least two archery scores showed statistically significant difference from -5 s to -1 s between score 8 and 9 as well as score 8 and 10 but no significant difference between the heart rates for score 9 and 10 as shown in [Table 2](#). Repeated measures ANOVA used to test the change in the heart rate values at the 11 time points with respect to the arrow release showed significant time effect i.e. heart rate changes significantly at -5 s to +1 s time release of arrow [Wilks Lambda $\Lambda = 0.195$, $F(10, 200) = 82.64$, $P < 0.0001$, effect size $\eta^2 = 0.805$]. Further pair wise comparisons showed that there was significant decrease in the mean heart rates from -5 s to +1 s ($P < 0.0001$) and then it increased till +5 s which was not statistically significant (data not shown).

5. Discussion

The aim of this study was to observe this complex association of adaptive training response using a single variable. Hence heart rate values during the shooting process in the field was measured and correlated with performance score which is considered the final outcome of training.

5.1. Heart Rate Pattern

The pattern of heart rate deceleration alone during release without considering the corresponding score followed similar pattern demonstrated in archers by various researchers. The mean heart rate values significantly decelerated from -5 s to +1 s and started increasing further till +5 s ([Figure 3](#)). This pattern of deceleration signifies that the heart rate started decelerating during the aim phase i.e. -5 s and continued to decelerate till release (0 s) and +1 s i.e. the pre-shot routine phase and onset of follow through phase. This deceleration pattern was largely attributed to the attentional process as hypothesized by Lacey's intake rejection hypothesis (19). According to Lacey's hypothesis, as the attention focus shifts from internal narrow to external narrow focus, the individual moves into a well-practiced learned automatic motor performance routine during which arithmetic calculation is at its least resulting in deceleration in heart rate. This external narrow spectrum also involves the follow through or the quiet eye period (20-22). Hence the deceleration persists till +1 second after the release. Another probable hypothesis is also attributed to a specific breathing pattern wherein elite trained athlete hold the breath for the duration just prior to release, which might be the reason for decrease in venous return and hence a deceleration of the heart rate values during the process (1).

5.2. Score-Wise Analysis of the Heart Rate Values

Performance scores and heart rate correlation showed that there was significant variation in the deceleration pattern between score 8 and 9 and score 8 and 10 ([Figure 3](#)). This variation was significantly different between -5 s to -1 s i.e. during the aiming phase. This finding clearly exhibits the pattern of deceleration with respect to the performance demonstrated by various researches in archers (1, 3, 6). As the performance score increases, the deceleration pattern is more i.e. the heart rate decreases showing an inverse relation and vice versa.

However, in this study, there was no significant difference in the pattern of deceleration between score 9 and 10. Also, the heart rate deceleration of score 10 was higher compared to score 9. Similar findings have been recorded by Vrbik et al. (1) where-in the expert archers had higher heart rate when the score was maximum. The authors in that study have argued that the finding was seen in expert archers but not in elite archers. In this study, the archers who participated were elite, but still the reason for the higher heart rate values during maximum score requires further study comparing with novice as well as expert but non-elite archers.

Although not statistically significant, the deceleration pattern of heart rate values at score 8 ([Figure 3](#)) reached

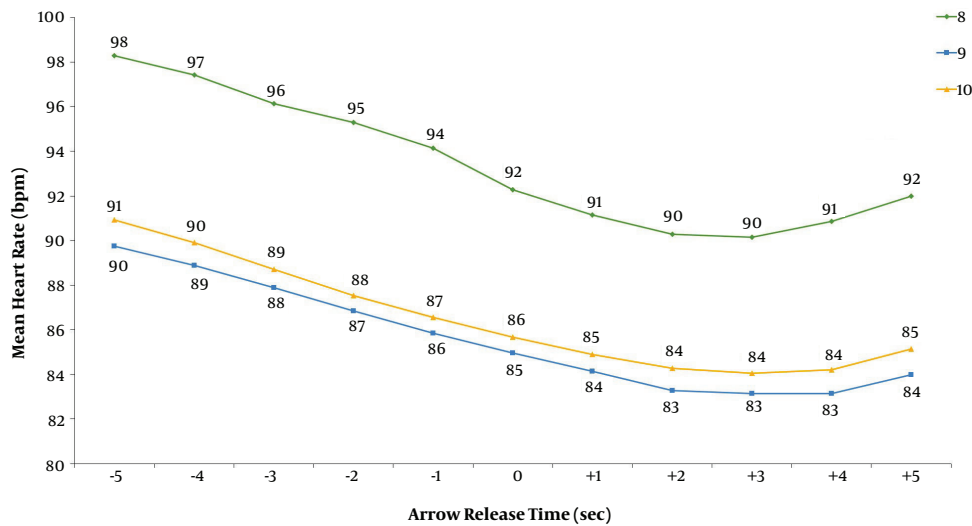


Figure 3. Archery score wise mean heart rate in elite archers

Table 2. Score-Wise Mean Heart Rate Values During Shooting- Post Hoc Analysis

Arrow Release Time, s	Archery Scores		Mean Difference in Heart Rates (95% CI)(I-J)	P Value
	(I)	(J)		
-5	8	9	8.5 (0.86, 16.22)	0.025
		10	7.4 (-0.24, 14.96)	0.060
	9	10	-1.2 (-3.95, 1.60)	0.576
-4	8	9	8.5 (0.98, 16.08)	0.022
		10	7.5 (0.05, 15.00)	0.048
	9	10	-1.0 (-3.74, 1.72)	0.657
-3	8	9	8.3 (0.79, 15.70)	0.026
		10	7.4 (0.06, 14.82)	0.048
	9	10	-0.8 (-3.50, 1.89)	0.760
-2	8	9	8.5 (1.03, 15.86)	0.021
		10	7.8 (0.41, 15.10)	0.036
	9	10	-0.7 (-3.37, 1.99)	0.815
-1	8	9	8.3 (0.81, 15.80)	0.026
		10	7.6 (0.17, 15.02)	0.044
	9	10	-0.7 (-3.42, 2.00)	0.810

the minimum at +2 s and lasted till +3 s following which there was a rise. In case of both scores 9 and 10, the deceleration pattern reached minimum at +2 s as in score 8 but lasted till +4 s compared to +3 s in score 8. A similar prolonged stage of maintenance of a quiet eye period in visual focus during follow through phase of these aiming sports has been noted and has been attributed to development of skill of aiming to maintain visual focus even after the release during the follow through phase. In these studies, it was observed that longer the quiet eye period better is the motor performance (20, 21). Similarly, it is hypoth-

esized that longer the maintenance of minimum decelerated heart rate values in the post release follow through period better the performance in addition to the deceleration per se. The reason might be a smooth and swift complex interaction of the attentional, visual, physical and psychological process in elite archers for a longer period of time during the peak performance.

5.3. Conclusions

Heart rate deceleration pattern assessment in field by the coach has practical applications in performance en-

hancement. The pattern of heart rate values during shooting process gives insight into the adaptive process developed by the athlete over the years of training not only physically but also psychologically. Such a field study helps in providing real time inputs to the athlete, coach and sports scientists. This study only involves elite Indian archers confirming the established pattern of heart rate values pattern in elite archers, thus giving a direction for carrying out performance enhancing research in this field. The limitation of not comparing with non-elite archers' paves way for future consideration in this field. Also, research involving measurement of variables of motor, respiratory, visual and psychological systems simultaneously may aid in understanding the phenomenon of deceleration of heart rate values during shooting process holistically.

Acknowledgments

We are thankful to all athletes, coaches and administrators of Army Sports Institute, Pune, India.

Footnotes

Authors' Contribution: Study concept and design: Chandra Sekara Guru and Deep Sharma. Analysis and interpretation of data: Chandra Sekara Guru, Uma Mahajan, and Anup Krishnan. Drafting of the manuscript: Chandra Sekara Guru, Anup Krishnan, and Uma Mahajan. Critical revision of the manuscript for important intellectual content: Chandra Sekara Guru, Anup Krishnan, and Deep Sharma. Statistical analysis: Uma Mahajan.

Conflict of Interests: None.

Ethical Approval: The study protocol was designed following ethical standards of research abiding the Helsinki Declaration and Ethical Standards in Exercise and Sports Sciences Research by Harriss and Atkinson. After obtaining approval of the Institutional Ethical committee, the study was conducted.

Funding/Support: None.

Informed Consent: Informed consent was obtained from each participant before conduct of the study. Purpose and procedure of the study was explained to the participants.

References

- Vrbik A, Bene R, Vrbik I. Heart rate values and levels of attention and relaxation in expert archers during shooting. *Hrvatski Sport-skomedicinski Vjesnik*. 2015;**30**(1):21-9.
- Kolayis IE, Mimaroglu E. The effects of heart rate and aiming time on performance in Turkish National Archery Team. *J Hum Sci*. 2008;**5**(1).
- Clemente F, Couceiro M, Rocha R, Mendes R. Study of the heart rate and accuracy performance of archers. *J Phys Educ Sport*. 2011;**11**(4):434.
- Keast D, Elliott B. Fine body movements and the cardiac cycle in archery. *J Sports Sci*. 1990;**8**(3):203-13. doi: [10.1080/02640419008732146](https://doi.org/10.1080/02640419008732146). [PubMed: 2084267].
- Ganesan S, Paul M, Sandhu JS, Simon JV. Effect of sensory motor rhythm neurofeedback on psycho-physiological, electroencephalographic measures and performance of archery players. *Ibnosina J Med Biomed Sci*. 2012;**4**(2):32. doi: [10.4103/1947-489x.210753](https://doi.org/10.4103/1947-489x.210753).
- Robazza C, Bortoli L, Nougier V. Physiological arousal and performance in elite archers: A field study. *Eur Psychol*. 1998;**3**(4):263-70. doi: [10.1027/1016-9040.3.4.263](https://doi.org/10.1027/1016-9040.3.4.263).
- Sade S, Bar-Eli M, Bresler S, Tenenbaum G. Anxiety, self-control and shooting performance. *Percept Mot Skills*. 1990;**71**(1):3-6. doi: [10.2466/pms.1990.71.1.3](https://doi.org/10.2466/pms.1990.71.1.3). [PubMed: 2235271].
- Salazar W, Landers DM, Petruzzello SJ, Han M, Crews DJ, Kubitz KA. Hemispheric asymmetry, cardiac response, and performance in elite archers. *Res Q Exerc Sport*. 1990;**61**(4):351-9. doi: [10.1080/02701367.1990.10607499](https://doi.org/10.1080/02701367.1990.10607499). [PubMed: 2132894].
- Lo CT, Huang SH, Hung TM. A study of the relationship between heart rate variability and archery performance. *Int J Psychophysiol*. 2008;**69**(3):276. doi: [10.1016/j.ijpsycho.2008.05.231](https://doi.org/10.1016/j.ijpsycho.2008.05.231).
- Hong ST. Effect of arousal control training conjugated heart rate biofeedback for national substitute archery players. *J the Korea Contents Assoc*. 2011;**11**(9):469-84. doi: [10.5392/jkca.2011.11.9.469](https://doi.org/10.5392/jkca.2011.11.9.469).
- Landers DM, Petruzzello SJ, Salazar W, Crews DJ, Kubitz KA, Gannon TL, et al. The influence of electrocortical biofeedback on performance in pre-elite archers. *Med Sci Sports Exerc*. 1991;**23**(1):123-9. [PubMed: 1997806].
- Robazza C, Bortoli L. Mental preparation strategies of olympic archers during competition: An exploratory investigation. *High Ability Stud*. 1998;**9**(2):219-35. doi: [10.1080/135981398090207](https://doi.org/10.1080/135981398090207).
- Zhang J. Effect of age and sex on heart rate variability in healthy subjects. *J Manipulative Physiol Ther*. 2007;**30**(5):374-9. doi: [10.1016/j.jmpt.2007.04.001](https://doi.org/10.1016/j.jmpt.2007.04.001). [PubMed: 17574955].
- Acikada C, Hazir T, Asci A, Aytar SH, Tinazci C. Effect of heart rate on shooting performance in elite archers. *Heliyon*. 2019;**5**(3). e01428. doi: [10.1016/j.heliyon.2019.e01428](https://doi.org/10.1016/j.heliyon.2019.e01428). [PubMed: 30976699]. [PubMed Central: PMC6441821].
- Harriss DJ, Atkinson G. Ethical standards in sport and exercise science research: 2016 Update. *Int J Sports Med*. 2015;**36**(14):1121-4. doi: [10.1055/s-0035-1565186](https://doi.org/10.1055/s-0035-1565186). [PubMed: 26671845].
- Bo K, Artal R, Barakat R, Brown W, Davies GA, Dooley M, et al. Exercise and pregnancy in recreational and elite athletes: 2016 evidence summary from the IOC expert group meeting, Lausanne. Part 1-exercise in women planning pregnancy and those who are pregnant. *Br J Sports Med*. 2016;**50**(10):571-89. doi: [10.1136/bjsports-2016-096218](https://doi.org/10.1136/bjsports-2016-096218). [PubMed: 27127296].
- Giles D, Draper N, Neil W. Validity of the Polar V800 heart rate monitor to measure RR intervals at rest. *Eur J Appl Physiol*. 2016;**116**(3):563-71. doi: [10.1007/s00421-015-3303-9](https://doi.org/10.1007/s00421-015-3303-9). [PubMed: 26708360]. [PubMed Central: PMC4751190].
- Rulebook, world archery. [cited 2019 Nov 27]. Available from: <https://worldarchery.org/rulebook/article/13>.
- Carroll D, Anastasiades P. The behavioural significance of heart rate: The Lacey's hypothesis. *Biol Psychol*. 1978;**7**(4):249-75. doi: [10.1016/0301-0511\(78\)90059-5](https://doi.org/10.1016/0301-0511(78)90059-5). [PubMed: 373810].
- Behan M, Wilson M. State anxiety and visual attention: The role of the quiet eye period in aiming to a far target. *J Sports Sci*. 2008;**26**(2):207-15. doi: [10.1080/02640410701446919](https://doi.org/10.1080/02640410701446919). [PubMed: 17926174].
- Williams AM, Singer RN, Frehlich SG. Quiet eye duration, expertise, and task complexity in near and far aiming tasks. *J Mot Behav*. 2002;**34**(2):197-207. doi: [10.1080/00222890209601941](https://doi.org/10.1080/00222890209601941). [PubMed: 12057892].
- Gonzalez CC, Causer J, Grey MJ, Humphreys GW, Miall RC, Williams AM. Exploring the quiet eye in archery using field- and laboratory-based tasks. *Exp Brain Res*. 2017;**235**(9):2843-55. doi: [10.1007/s00221-017-4988-2](https://doi.org/10.1007/s00221-017-4988-2). [PubMed: 28660285]. [PubMed Central: PMC5550539].