Hrvat. Športskomed. Vjesn. 2015; 30: 21-29

HEART RATE VALUES AND LEVELS OF ATTENTION AND RELAXATION IN EXPERT ARCHERS DURING SHOOTING

FREKVENCIJA SRCA I RAZINA PAŽNJE I OPUŠTENOSTI TIJEKOM GAĐANJA KOD VRHUNSKIH STRELIČARA

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SUMMARY

The main purpose of this paper was to present single channel EEG records and heart rate (HR) changes during shooting routine of 8 experienced archers. Possible differences between recurve and compound shooters in named values were investigated in accordance to arrow score. Additional contribution of this study was systematical review of psychophysiological studies done in archery. Descriptive statistics revealed that compound shooters achieved higher arrow score values, had higher heart rate values pre, during and post shooting, had higher attention values pre, during and post shooting and very similar meditation values pre, during and post shooting according to recurve shooters. ANOVA showed significant differences (p<0,01) between compound shooters and recurve shooters in variables of arrow score, all heart rate and attention level variables, except ones concerning meditation levels. Overall, the obtained results were interesting and can serve as a starting ground for future experiments in order to reach valid and concrete biofeedback data that will support archery excellence.

Keywords: archery, expert athletes, heart rate, EEG, psychophysiological measures.

SAŽETAK

Cilj ovog rada bila je prezentacija vrijednosti jednokanalnog mobilnog EEG-a i vrijednosti frekvencije srca tijekom gađanja 8 vrsnih streličara. Istraživane su potencijalne razlike u navedenim varijablama u odnosu na postignuti rezultat između dvije vrste streličara: sa zakrivljenim i složenim lukom. Dodatna vrijednost ovog rada je i pregled svih radova koji se tiču psihofizioloških mjera unutar streličarstva. Deskriptivna statistika pokazala je kako streličari sa složenim lukom postižu bolje pogotke, imaju više vrijednosti frekvencije srca prije, tijekom i nakon otpuštanja/okidanja, imaju više vrijednosti koncentracije/pažnje prije, tijekom i nakon otpuštanja/okidanja, i vrlo slične vrijednosti opuštenosti prije, tijekom i nakon otpuštanja/okidanja u odnosu na streličare sa zakrivljenim lukom. ANOVA je pokazala značajne razlike (p<0,01) između streličara sa složenim i zakrivljenim lukom u varijablama vrijednosti pogotka, frekvencije srca i nivoa koncentracije/pažnje. Zaključno, dobiveni rezultati su zanimjivi i mogu poslužiti kao osnova za buduća istraživanja kako bi se dobili konkretni i pouzdani biofeedback protokoli koji će poboljšati ukupnu streličarsku izvedbu.

Ključne riječi: streličarstvo, vrsni sportaši, frekvencija srca, EEG, psihofiziološke mjere.

INTRODUCTION

Historically, archery has been used for hunting and combat. Now days, archery is an Olympic sport and has a lot of disciplines depending on the types of archery and game rules (20,37). The most prevailing types of bows are recurve bow and compound bow. Archery can be described as a static sport that requires strength and endurance of the upper body, particularly of the shoulder girdle and forearm muscles (23). High performance shooting in archery is characterized as the capability of hitting the target repeatedly in a certain amount of time with high precision and accuracy (21,24). World Archery suggests 4 main phases with overlapping elements: preparatory movements (stance, nocking the arrow, arrow grip, bow arm, body pre-positioning, bow raise and predraw), period for the production of forces (predraw, full draw – anchoring, expanding), critical instant (anchoring, expanding, sighting and release) and final phase-continuity (follow through and relaxation) (38). However the action itself can also be divided into three: the stance, the arming, and the sighting (14,21,24), six: bow hold, drawing, full draw, aiming, release, and follow-through (27)., or eight stages: set up, drawing, anchoring, loading, aiming and expansion, release and follow through (19).

Key determinants of archery performance lie in general and specific motor skills and different psychological factors. General motor skills imply general strength, endurance, balance and flexibility (1). Among specific motor skills the most important are intermuscular coordination, rhythm, timing and precision (6). The most important psychological factors include concentration, relaxation and different types of attention accompanied by visual focusing (1,20). Besides mental attention, archery is associated with visual and selective attention. While shooting, mental attention may be involved first, but visual attention will play a major role at the later part of the shooting process. Selective attention is an important feature during states of higher tension and anxiety (e.g. during competition) when external or internal noise tend to be a distraction for an archer (19,28).

Unlike other sports, studies including anthropometric data and/or motor skills in archery are very scarce. This may be explained by some data recorded from the top male and female archers indicating that the somatotype, aerobic power and lactate levels during and between shots are not similar to some physically demanding events (1). At the same time, the coach's expertise reveals top level archery athletes with different types of morphological status and levels of motor proficiency. Although archery may not appear physically demanding, during a national or an international competition, an archer is forced to shoot minimum of 80 arrows in a day (or more depending on the competition). During that a recurve female archer is to apply approximately 18-20kg, a compound female archer 25-30kg (but with a different mechanical system), a recurve male archer 22-25kg and a compound male archer 28-30kg of force each time the bow is pulled. This sums up to at least 1440kg for female recurve shooters and stretches out to 2400kg of force applied for compound men archers in a single day of competition during very stressful condition. During practice and training, the workload is even two or three times higher (number of shots) in order to meet the essential requirements of archery sport: repetition of the arrow in the space and propelling force applied to the arrow (14,38).

Most of the authors of respected archery literature agree that archery is mainly mentally oriented (1,4,6,12,13,19), but concrete evidence and studies with results of specific mental training are lacking. On the other hand, there is a moderate number of studies investigating different psychophysiological measures during archery shooting, concentrating mainly on ECG, EMG and EEG data. Caterini (4) conducted a study involving 7 archers to search for HR changes during the archery shooting. She found that before the shooting or during the concentration phase HR was decreased and during the shooting phase the HR was increased compared to resting HR values. Landers et al.17 involved 11 right handed subjects, (5 male and 6 female students) enrolled in a 15 week beginning archery class. The pre and posttest findings revealed that HR deceleration was significant only during the posttest. The psychophysiological changes from pre to posttest were characteristic of what would theoretically be expected if archers were to develop their attentional skills over the course of training. Tinazci (1,32) divided subjects as male and female and reported increase in HR after the release in both subject groups. However, the increase in both subject groups was not statistically significant. Carillo et al. (3) assessed autonomic nervous system modulation through changes in heart rate variability during an archery competition, as well as archery performance by comparing novice and experienced adolescent archers. They found out that, compared with novices, experienced adolescent archers take more time per shot, have a higher low frequency band, square root of the mean of squared differences between successive R-R intervals and percentage of successive normal-to-normal intervals greater than 50 ms, and demonstrate an increase in parasympathetic nervous system activity compared with pre-competition values. Filhos et al. (12) conducted a probabilistic approach of individual affect-related performance zones (IAPZs), for studying the link between affective states and athletic performance, in order to determine idiographic profiles associated with optimal and non-optimal performance. The archers reported their perceptions of arousal and pleasure, and had their heart rate responses recorded. Results indicated that the archers possess unique IAPZs for the different archery shooting distances, they fluctuated among their optimal and non-optimal IAPZs throughout the season, and optimal performance was not prevalent following optimal performance. The archers' IAPZs differed in both the affective (arousal and pleasure) and the bodilysomatic (HR) variables. Thus, it was clear that even through different channels the athletes present idiosyncratic states, which are related to optimal performance, in line with the IZOF form dimension. Robazza et al. (29) conducted a case study of an elite female archer to gain insight into individual psychophysical reactions accompanying an athletic event, and to test predictions of pre-performance emotions effects upon performance. Good performance was expected when the actual pre-performance emotions resembled the recalled optimal emotion pattern. Conversely, poor performance was expected when the actual pre-performance emotions paralleled the recalled ineffective emotion pattern.

Nishizono et al. (27) was among the first researchers analyzing the activation levels of muscle groups involved in archery shooting. The study included 2 world class archers, one middle class and two beginner archers. The analysis showed strong activation of m.deltoideus in world class archers, contraction level of back muscles was higher than in the arm muscles in world class archers, and world class archers showed almost same level of activities in back muscles in both sides. The middle class archer and beginner archers showed an unbalanced activity in the same muscle groups. During release and follow-through phases, the disappearance of action potential (silent period) in the M.deltoideus was observed in world class archers. Hennessy and Parker (cited in Ergen and Hibner, 2004.)1 conducted a study using digital computer analysis of the electromyograms from thirty shots for two archers, which facilitated an examination of the relationship between the measured activity of the muscles and their function during release. The findings of the studies showed that activities of M.biceps brachii increased from beginning to the end of the shooting movement. The activity level of M.triceps brachii decreased 60ms before the clicker signal. By the sound of the clicker, the activation level of M.triceps brachii returned to almost same level with the preceding the 60ms before the clicker. The reduction of the activation level was considered as EMG silent period (transitory decrease if EMG activity in the sustained contraction elicited from passive muscle stretch, unloading of a muscle or provoked from peripheral nerve stimulation). It has also been described as an EMG phenomena that may precedea phasic burst of activity in muscle undergoing isometric contraction. Clarys et al.5 performed 4 experiments concerning archery shooting. Experiment 1 investigated muscular behaviour in target shooting, both indoors (18 and 25 m) and outdoors (50, 70 and 90 m). Experiment 2 investigated the muscular economy of four string grips: the three-finger grip, two-finger grip, thumb grip and reversed grip. Experiment 4 investigated the muscular activity of elite archers shooting at distances of 70 and 90 m with and without stabilizers. The most interesting findings were found in Experiment 3 which attempted to differentiate muscular activity and a number of performance variables in three different populations of archers (Olympic, National and beginners) in order to obtain feedback regarding improved performance. Apparently, overall muscle pattern, intensities and arrow speed were not discriminatory. The differences found between the groups (or levels of skill) were affected by the ability to reproduce identical patterns and arrow velocities in consecutive shots and by the constancy of neuromuscular control of the M. trapezius, M. biceps brachii and M. extensor digitorum.

Ertan et al. conducted several studies concerning archery7-11. In 2003., they7 conducted a study with 10 elite, 10 beginner and 10 non-archers. The purpose of this study was to analyze the release strategy in archers with different levels of expertise. In conclusion, it was established that archers develop a specific forearm flexor and extensor muscular strategy to accurately shoot an arrow to a given target after the fall of the clicker. Active contraction of the M. extensor digitorum and gradual relaxation of the M. flexor digitorum superficialis is an integral part of this strategy. Elite archers presented a faster reaction to the fall of the clicker than that of the beginners and non-archers. Ertan et al. (2005.)8 conducted a study to establish archery skill indexes based on EMG data with elite, beginner and non-archers. EMG activity of Muscle flexor digitorum superficialis and Muscle extensor digitorum were quantified. Two-second periods were used to obtain averaged and rectified EMG data. To estimate FITA scores from EMG data, skill indexes based on mean area under some parts of processed EMG waveforms were offered. All correlations between rank of FITA scores and natural logarithms of archery skill indexes were significant. It was concluded that EMG skill indexes may be useful for assessing shooting techniques, evaluation of archers' progress and selection of talented archers. Another study was made in 2005. by Ertan et al. (9): a specially designed device called an archery chronometer was developed to measure the reaction time of an archer to clicker's fall, arrow velocity, and external factors that may affect arrow velocity. The purposes of this study were to test the validity of Clicker Reaction Time measurer, and the reliability of Clicker Reaction Time in accordance with the Flying Time/Average Speed, temperature, wind speed and wind direction measurements. 20 elite archers participated in this study. The Reaction Time, which was derived from EMG values and CRT from the archery chronometer were correlated to test the validity of the CRT measurer. The test re-test method was applied to test the reliability of archery chronometer. CRT scores were related with RT scores ($r=.787$, $p<0.01$). The archery chronometer was valid in terms of predicting reaction time. The device was found to be reliable in measuring Clicker Reaction Time, Average Speed, Flying time, Wind speed, WInd direction and temperature. It was concluded that archery chronometer could be used for technical evaluation and enhancing shooting technique in archery.

Ertan10 conducted a study to compare the bow hand forearm muscular activation patterns of elite archers (n=10) with beginners (n=10), to define the muscular contraction-relaxation strategies in the bow hand forearm muscles during archery shooting and investigate the effects of performance level on these strategies. EMG activity of the M. flexor digitorum superficialis and the M. extensor digitorum were recorded together with a pulse synchronized with the clicker snap. The elite archers had a greater activation of the M. extensor digitorum, indicating avoidance of gripping the bow-handle not only by relaxing the flexor muscles, but also contracting the extensor muscle groups. In 2011., Ertan et al. (11) conducted a case study with a long term elite archer with an entirely different shooting strategy, which is thought to have positive effects on her performance. The muscle-contraction strategy between the predominant forearm and pull finger used in archery is defined as a response to the fall of the "clicker" by active contraction of the m. extensor digitorum (MED) and the gradual relaxation of the m. flexor digitorum superficialis (MFDS). After the snap of the clicker the subject's MFDS was clearly relaxed even ~ 100 ms was heard and a gradual relaxation of the MED was observed. The results found that this different type of contraction-relaxation strategy can be used in the drawing arm with success, as it may avoid causing a lateral deflection of the bowstring. Horsak and Heller (15) analyzed fifty-six shots of a competitive archer in terms of finger joint kinematics and maximum lateral bow string deflection in the horizontal plane. Multiple regression analysis revealed a weak but statistically significant positive relationship with maximum lateral bow string deflection and scores, which is in contrast to usual and correct archery technique. The authors argued that the study represented fundamental research in three-dimensional analysis of finger movement in archery with only one participant investigated, therefore results could not be generalized and the need to reproduce this research with a greater number of subjects was highlighted.

Salazar et al.30 used archery (an attentive state), to examine whether hemispheric asymmetry and HR deceleration would occur during the aiming period, and if they did, whether this would affect performance. HR and left and right temporal EEG were recorded from 28 right-handed elite archers for 16 shots. The results indicated that there was no HR deceleration, during the aiming period EEG alpha activity formed the dominant frequency and this was significantly greater in the left than in the right hemisphere, there were no significant right hemisphere EEG changes in spectral power from 3 s before the shot to arrow release, but there were significant left hemisphere increases at 10, 12, and 24 Hz and at 1 s prior to the shot, there were no significant right hemisphere spectral power differences between best and worst shots, but there were significant left hemisphere differences at 6, 12, and 28 Hz. Landers et al. (17) tried to determine whether EEG biofeedback training could improve archery performance as well as self-reported measures of concentration and self-confidence. Overall, the results provide some support for the use of known relationships between EEG and performance as an effective means of providing biofeedback to affect the performance of pre-elite archers. Kim et al. (16) tried to determine differences in neural networks between expert and novice archers during an archery pre-performance routine period (PPR). The resultant fMRI data showed that when the experts were aiming during the PPR period of a simulated archery task, the occipital gyrus and temporal gyrus were activated, but when the novices were aiming, the frontal area was mainly activated. Lee (20) tested archer's capability of attention and relaxation control during shooting process using single channel EEG technology. Attention and meditation algorithms were used to represent the levels of mental concentration and relaxation levels on elite, mid-level, and novice archers. Elite archers showed increases in both attention and relaxation and higher levels of attention at the release. Mid-level archers showed increased attention but decreased relaxation. Levels of attention and relaxation and their variation patterns were useful to categorize archers and to provide feedback in training.

In order to develop a mental training method and to provide individual training programs for each archer, it is essential to understand the mental state of the archer during training, and especially during competition. The psychophysiological measures are probably the best approach to evaluate mental concentration (20,26,31), and nowadays they can be measured relatively unobtrusively, are objective and do not make any additional task demands on the athlete during measurement (25,26).

The main purpose of this paper was to present single channel EEG records on the forehead (Fp1) and heart rate (HR) changes pre-, during and after (near) shooting routine of 8 experienced archers. We wanted to investigate possible differences between recurve and compound shooters in named values. Also, we wanted to find out the nature of relationship between heart rate, attention and meditation values with arrow scores. Additional contribution is systematical review of psychophysiological studies done in archery which include six ECG studies, nine EMG studies and four EEG studies.

SUBJECTS AND METHODS

Eight experienced archers (4 recurve, 4 compound bow type) participated in this study. The archers who were aged 26,34±12,85years (mean ± s), were all proficient in archery with mean archery experience of 7,76±6,67years (mean ± s). Also, WA Indoor 18m season best score was 553,5±13,26points (mean ± s). There were 3 female and 5 male archers, out of which 7 were right handed (right eye dominant) and one was left handed (left eye dominant). All archers provided informed consent before taking part in the study.

The study was carried out in a standard indoor archery field with target positioned at 18m. Each archer had a separate measuring procedure due to the technical constraints. Archers shot 9 arrows for warm up, after which a heart rate monitor and mobile EEG were put on and checked for connectivity with the main computer. The archers were told the purpose of the study which was to monitor their heart rate and brain wave changes during shooting. No other special instructions were given. Each archer shot 15 arrows (5 ends x 3 arrows) in the standard WA triple 40 target face. All arrow scores were noted chronologically for later comparison. Heart rate was measured using heart rate monitor (RS800CX, Polar Electro Oy, Kempele, Finland) validated for assessment of heart rate variability3,37. The data obtained from the heart rate monitor was managed with Polar Protrainer5 software. A single channel wearable EEG system Mindwave Mobile (MindWave®, NeuroSky, Inc. U.S.A.) and Mindplay Pro software were used to record and store the brain wave signals in a computer. The EEG system was in the form of a headset with one active electrode on the forehead (Fp1) and reference and ground electrodes placed on the ear clip. All electrodes were dry type. Detected EEG signals were filtered and converted to digital data at a 512 Hz sampling rate. Noise and abnormal EEG signals, whose amplitudes exceeded 100 microvolts, were eliminated. Embedded algorithms processed the signals to compute attention and meditation levels every second. The attention and meditation data were transmitted to the computer via Bluetooth connection. The attention meter indicates the intensity of a user's level of mental focus or attention, such as that which occurs during intense concentration and directed but stable mental activity. The meditation meter indicates the level of a user's mental calmness or relaxation and refers to a person's mental states, not physical levels. The levels of attention and meditation were presented as a relative score from 0 to 100. The computer displayed these signals and data with digital values and analog graphics so that they could be easily monitored. The data was also stored in the computer. (20,35,36) In order to precisely coordinate the measuring apparatus with shooting, time on a heart rate monitor was manually synchronized with the main computer (already connected with the Mind wave mobile handset). In addition, two cameras (Logitech HD Pro Webcam C920, U.S.A.) recorded the shooting process and were connected to the main computer. One camera recorded the archer in order to determine the exact time of the arrow release, and the other camera recorded the heart rate monitor which displayed the general time, record time and the current heart rate. At the same time a recording software, XSplit Broadcaster (SplitMediaLabs, Ltd.) was active on the main computer, which integrated video streams from cameras and screen region capture from MindPlay Pro application. All data was later exported and used for further statistical analysis made with StatSoft Statistica 7. From heart rate monitor 4 variables were taken, heart rate values 2 seconds prior to shot, one second prior to shot, at the exact time of the shot, and one second after the shot. Same pattern was used for obtaining data from the mobile EEG device, therefore 8 variables were taken: attention and meditation levels 2 seconds prior to shot, one second prior to shot, at the exact time of the shot, and one second after the shot. Descriptive analysis was made for all variables, and then separately according to the bow type (recurve bow and compound bow). Secondly, descriptive statistics was made according to the shot value (arrow score 8, 9 or 10, scores 6 and 7 were excluded because of the low number of shots) for each group. Thirdly, analysis of variance (ANOVA) was used to identify potential differences between different type of archers (recurve/compound) in arrow score, levels of heart rate, attention and meditation pre, during and post arrow shot. Also, ANOVA was used to identify differences in heart rate, attention and meditation values according to the arrow score within each bow type.

RESULTS

Descriptive statistics revealed that compound shooters (CS) achieved higher arrow score values, had higher heart rate values pre, during and post shooting, had higher attention values pre, during and post shooting and very similar meditation values pre, during and post shooting according to recurve shooters (RS) shown in Table 1.

Table1. Descriptive statistics for all variables for both bow types and separately for recurve bow and compound bow.
Tablica 1. Deskriptivni pokazatelji za sve varijable za obje vrste luka zajedno, te posebno za zakrivljeni luk i složeni luk.

	All bow type N=120		Recurve bow N=60		Compound bow N=60	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
ARR.SCORE	8,98	0,83	8,80	1,02	9,17	0,53
HR2SPRE	104,33	15,14	101,08	16,34	107,57	13,19
HR1SPRE	104,93	15,81	100,75	17,15	109,10	13,23
HR	107,33	15,71	103,18	16,35	111,48	13,98
HR1SPOST	108,82	15,01	104,73	14,91	112,90	14,08
ATT2SPRE	53,43	17,34	48,03	12,52	58,83	19,76
ATT1SPRE	54,10	17,05	46,08	12,36	62,12	17,39
ATT	53,91	16,03	45,37	11,83	62,45	15,17
ATT1SPOST	53,00	15,04	45,02	11,44	60,98	13,98
MED2SPRE	54,20	15,36	54,55	14,98	53,85	15,85
MED1SPRE	55,34	16,48	54,85	16,25	55,83	16,83
MED	55,84	16,39	55,30	15,68	56,38	17,19
MED1SPOST	55,53	15,16	54,48	14,61	56,58	15,73

ARR.SCORE-value of the arrow score, HR2SPRE-heart rate 2 seconds pre-shooting, HR1SPRE-heart rate 1 second pre-shooting, HR-heart rate during shot, HR1SPOST-heart rate 1 second post-shooting, ATT2SPRE-attention value 2 seconds pre-shooting, ATT1SPRE- attention value 1 second pre-shooting, ATT- attention value during shot, ATT1SPOST- attention value 1 second post-shooting, MED2SPRE-meditation value 2 seconds pre-shooting, MED1SPRE- meditation value 1 second pre-shooting, MED-meditation value during shot, MED1SPOST- meditation value 1 second post-shooting.

CS demonstrated ascending heart rate values during the near shot routine, while RS showed a slight descending trend before the shot. CS showed ascending pre shot attention values, maintaining of the value during the shot and a slight descending trend after the shot. RS showed descending attention values during the shot routine. Concerning meditation values, CS revealed ascending trend in values, in accordance to RS who demonstrated equal or very similar values during the near shot routine. Table 2. reveals descriptive statistics according to the arrow score for each group (bow type), showing mean heart rate, attention and meditation values in different time increments: 2 seconds before the shot (2SPRE), 1 second before the shot (1SPRE), at the shot (SHOT) and one second after the shot (1SPOST). As stated earlier, concerning HR values CS demonstrated higher figures, but also, higher values are associated with higher arrow score in both groups. When RS scored 8 and 10, they showed a small descending trend in mean HR values between 2SPRE and 1SPRE, and then a slight ascending trend. When they scored 9, a continuous ascending trend was present. In CS a continuous ascending trend in HR values was present at all scores. Concerning attention values, both groups achieved higher values when scoring lower scores. When scoring an 8, RS demonstrated a small descending trend between 2SPRE and 1SPRE, following with ascending values. When scoring 9 and 10, descending values were observed during the whole near shot routine. In CS, when scoring 8 and 9, ascending values were recorded between 2SPRE and 1SPRE, following with a descending drop of values at the time of the shot and 1SPOST. When scoring 10, CS demonstrated ascending mean values until after the shot, when a drop of values was noted. When RS scored 8 points, meditation values were ascending, starting to drop after the shot. Continuous ascending pattern was observed when RS shot 9 points. Continuous descending pattern was observed when RS shot 10 points. When CS scored 8 points, meditation values were ascending, but dropped at the shot and continued to drop after the shot. Meditation level slightly dropped between 2SPRE and 1SPRE, but plateaued during 1SPRE, SHOT and 1SPOST when CS scored 9 points. Continuous ascending pattern was observed when CS shot 10 points.

Table2. Descriptive statistics according to the arrow score for each group (bow type).
Tablica 2. Deskriptivni pokazatelji za postignute pogotke za svaku grupu (tip luka).

	BOWTYPE	ARR.SCORE	N	2SPRE Means	1SPRE Means	SHOT Means	1SPOST Means
HR	RS	8	14	95,71	94,14	97,86	100,14
ATT	RS	8	14	49	46,43	47	47,14
MED	RS	8	14	52,29	53,64	54,29	52,5
HR	RS	9	26	101,35	102,38	104,92	105,42
ATT	RS	9	26	48,31	47,54	46,12	45,5
MED	RS	9	26	52,73	54,73	56,73	58,69
HR	RS	10	15	108	106,13	107	109,27
ATT	RS	10	15	46,2	42,47	42,4	41,8
MED	RS	10	15	56,2	51,2	49,4	43
HR	CS	8	4	98,75	99,5	101,25	102,5
ATT	CS	8	4	84	88	83,5	75,25
MED	CS	8	4	63,75	67	60,75	59,5
HR	CS	9	42	106,19	107,62	110,12	111,45
ATT	CS	9	42	58,48	59,74	59,26	58,19
MED	CS	9	42	56,52	58,4	58,6	58,33
HR	CS	10	14	114,21	116,29	118,5	120,21
ATT	CS	10	14	52,71	61,86	66	65,29
MED	CS	10	14	43	44,93	48,5	50,5

BOW TYPE-RS (recurve shooter), CS (compound shooter), ARR.SCORE-value of the arrow score, N=number of arrows shot, 2SPRE-mean value 2 seconds pre-shooting, 1SPRE- mean value 1 second pre-shooting, SHOT- mean value during shot, 1SPOST-mean value 1 second after shooting, HR-heart rate, ATT-attention level, MED-meditation level

ANOVA showed significant differences ($p<0,01$) between CS and RS in variables of arrow score, all heart rate and attention level variables, except ones concerning meditation levels. In RS statistically significant differences were found in variables HR2SPRE ($p=0,048$) and MED1SPOST ($p=0,032$) between arrow score values of 8 and 10, and in variable MED1SPOST ($p=0,000$) between arrow score values of 9 and 10 shown in Table 3.

Table 3. Mean values and standard deviation for each arrow score in recurve shooters with noted significant differences between arrow scores.
Tablica 3. Aritmetička sredina i standardna devijacija za svaku vrijednost pogotka kod zakrivljenog luka sa izraženom značajnom razlikom između pojedinih pogodaka.

	8	9	10	Significant differences p<0,01
HR2SPRE	95,71±10,92	101,35±16,89	108,00±19,46	8 : 10
HR1SPRE	94,14±13,07	102,38±17,53	106,13±20,68	
HR	97,86±11,11	104,92±17,08	107,00±20,28	
HR1SPOST	100,14±12,67	105,42±15,08	109,27±17,66	
ATT2SPRE	49,00±16,94	48,31±12,06	46,20±10,83	
ATT1SPRE	46,43±16,63	47,54±11,74	42,47±9,98	
ATT	47,00±15,69	46,12±11,38	42,40±10,62	
ATT1SPOST	47,14±13,43	45,50±9,68	41,80±13,11	
MED2SPRE	52,29±13,63	52,73±15,91	56,20±14,47	
MED1SPRE	53,64±16,31	54,73±16,28	51,20±14,85	
MED	54,29±14,67	56,73±16,54	49,40±12,79	
MED1SPOST	52,50±13,10	58,69±13,46	43,00±9,35	8 : 10, 9 : 10

In CS statistically significant differences were found in variables ATT2SPRE (p=0,014), ATT1SPRE (p=0,002), ATT (p=0,002) and ATT1SPOST (p=0,019) between arrow score values of 8 and 9, in variables HR2SPRE (p=0,042), HR1SPRE (p=0,034), HR (p=0,040) and HR1SPOST (p=0,034), ATT2SPRE (p=0,004), ATT1SPRE (p=0,003), ATT (p=0,036), MED2SPRE (p=0,015) and MED1SPRE (p=0,017) between arrow score values of 8 and 10 and in variables HR2SPRE (p=0,047), HR1SPRE (p=0,030), HR (p=0,048) and HR1SPOST (p=0,042), MED2SPRE (p=0,005) and MED1SPRE (p=0,007) between arrow score values of 9 and 10 shown in Table 4.

Table 4. Mean values and standard deviation for each arrow score in compound shooters with noted significant differences between arrow scores.
Tablica 4. Aritmetička sredina i standardna devijacija za svaku vrijednost pogotka kod složenog luka sa izraženom značajnom razlikom između pojedinih pogodaka.

	8	9	10	Significant differences p<0,01
HR2SPRE	98,75±11,62	106,19±12,89	114,21±12,53	8 : 10, 9 : 10
HR1SPRE	99,50±13,89	107,62±12,60	116,29±12,55	8 : 10, 9 : 10
HR	101,25±14,01	110,12±13,41	118,50±13,52	8 : 10, 9 : 10
HR1SPOST	102,50±11,79	111,45±13,52	120,21±13,92	8 : 10, 9 : 10
ATT2SPRE	84,00±16,06	58,48±19,35	52,71±17,17	8 : 9, 8 : 10
ATT1SPRE	88,00±11,17	59,74±17,11	61,86±14,01	8 : 9, 8 : 10
ATT	83,50±12,77	59,26±14,22	66,00±13,66	8 : 9, 8 : 10
ATT1SPOST	75,25±16,09	58,19±13,28	65,29±12,81	8 : 9
MED2SPRE	63,75±14,38	56,52±15,29	43,00±13,25	8 : 10, 9 : 10
MED1SPRE	67,00±18,26	58,40±16,22	44,93±13,80	8 : 10, 9 : 10
MED	60,75±24,58	58,60±16,82	43,00±13,25	
MED1SPOST	59,50±28,31	58,33±14,11	44,93±13,80	

DISCUSSION

Given the static nature of archery and some similar sports (e.g. rifle or air pistol shooting, golf), a lot of studies (3,17,18,20,22,25,26,31) investigated different psychophysiological measures such as EEG and ECG, either to further investigate levels and nature of attention during a certain activity among different expertise levels of athletes, or to incorporate biofeedback in practice in order to improve athletic excellence. To our knowledge, this is the first study to simultaneously record changes in heart rate variability and levels of attention and meditation in archery via mobile and commercial psychophysiological devices. Also, until now no studies comparing compound shooters and recurve shooters were found. In this study we tested 8 expert level archers (4 recurve, 4 compound) in order to record their shooting score, heart rate and attention and meditation values during 15 shots for each archer. Concerning heart rate values, results implicate lower values being connected with lower arrow score values for both groups of archers, and also, recurve shooters having general lower mean heart rate values. The latter could be connected with different mechanical transfer of force with compound bow, having CS apply greater amount of force at the beginning of the draw and therefore manifesting increased heart rate values. On the other hand, differences in heart rate between arrow score are somewhat opposite from expected. In studies done with elite and novice golfers (25,26) and novice and experienced archers (3), the overall higher heart rate were found in novice in accordance to elite (i.d.experienced) golfers and archers. Since higher results are implied in expert athletes, lower HR values were expected to be achieved with higher arrow scores. Although both groups regardless of arrow scores demonstrated different HR values before the shot, it was indicative that all archers had higher values at the shot than before the shot, peaking one second after the shot (taking into consideration only the near shot routine time epoch 2SPRE-1SPOST). This could possibly be explained by (I) change of attentional focus from external to interna (l,34) (II) position of the visual focus at the moment of shot execution and it's possible change from bowsight to target face during followthrough period and (III) different breathing strategies during and after the shot (25,26). Considering first possible explanation, studies examining the role of the performer's focus of attention have consistently demonstrated that inducing an external focus (directed at the movement effect) is more effective than promoting an internal focus (directed at the performer's body movements). An external focus facilitates automaticity in motor control and promotes movement efficiency (34). Since the portrayed group of archers represents expert level, but not elite level of performance and result, at the critical point of shot execution, switch of focus of attention from „autopilot“ to intentional self-talk directed towards certain body movement was possible to occur therefore leading to the internal focus of attention which has been associated with HR increase (17,26). Concerning the second explanation (position of the visual focus at the moment of the shot), Loze at al. provided evidence 22 that suppression of pre-shot visual attention is a necessary component of expert pre-shot mental state and a prerequisite of automatic shot execution, as controlled by mechanism of intention. Since in present study no return information from archers was planned during testing, it would be interesting to find out position of visual focus for each shot. It is often common for the archers to try to "over-aim", leading away from autonomic behavior where little or no conscious thought is given to the performance. The visual focus during the follow through phase was also unknown in the present study, but plays a very important role in the final shot execution. This gaze during the final stage of archery technique in archery circles is often named only as the "follow through", but it actually corresponds to the term "the quiet eye period" (2,33). The "on field" experience confirms that over aiming connected with the change of focus of attention from external to internal promotes more cognitive processing, which is detrimental to a successful and fluid follow through. The reason regarding the different breathing techniques being responsible for higher values at the shot than before the shot, lies in the statement that the HR deceleration reflects respiratory influences. There is an established relationship between breathing and HR such that HR deceleration occurs during expiration (26). Since no special attention was given to the respiration pattern of the archers, it would be very interesting to find out for future studies the most effective breathing protocols in order to enhance performance and result. Concerning the attention and meditation values, ANOVA showed significant differences among CS and RS with CS having higher attention values during the shot. Possible explanation for this could be (I) an obvious and potential higher level of attention in CS, (II) higher mean arrow score value in CS (9,17) in contrast with RS (8,80) and (III) different aiming apparatus (bowsight) in different type of archers. Concerning meditation values, interesting results emerged in both groups. When scoring 9 points, RS demonstrated a slight decrease in ATT values, but an increase in MED values, in reference with CS who attained similar ATT and MED values during the whole near shot routine. When scoring 10 points, RS showed a decrease in ATT and MED values, contrary to CS who had an increase in both values. The latter was noticed in his experiment by Lee (20), and termed as a Type I variation characterized by a shooting process with a comfortable feeling without hesitation and anxiety, and also Kim16 et al. who observed that experts are able to increase their attention at the time point of trigger pull (release).

To our knowledge, this is the first study to incorporate simultaneously two psychophysiological measures in accordance to arrow score with different type of archers. With 4 recurve and 4 compound archers during altogether 120 shots, we wanted to observe psychophysiological changes during the period of the near shot routine. The obtained results were very interesting, and can serve as a starting ground for future experiments in order to reach valid and concrete biofeedback data that will support archery excellence. Namely after the study, we detected a few points which should be taken into consideration for future research. First of all, different types of performance level (novice/expert/elite) and a larger number of subjects and/or larger number of arrows should be involved in the experiment, thus providing more valid results. In order to try to detect attentional focus, a self-reported questionnaire could be introduced to archers after every shot. Also, a closer examination of breathing pattern, especially expiration in accordance to relaxation markers should be investigated.

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