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Effect of heart rate on shooting performance in elite archers

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Abstract

Aim: The aim of the present study was to examine the effect of heart rate on shooting performance in elite archers.

Methods: Regularly trained 13 (7 female, 6 male) international level elite archers performed a (specific) protocol twice with 3 days interval in an indoor area. In order to raise the heart rate (HR) and related physiological stress the archers performed 4 sets of steady pace shuttle runs (males 10 km h^{-1}; females 8 km h^{-1}) for 3 minutes in a 20 m course following with 1 minute stop during which they performed 3 shots to 18 meter distance indoor target, and followed by 1 minute rest, where blood sample was collected from ear lobe for blood lactate (BL) analysis. Heart rate monitors were used for heart rate (HR) recordings with 5 seconds intervals for resting, running, shooting, and recovery periods. The score of the shots were recorded as in the normal archery indoor competition. Average (overall) results were taken into account for statistical analysis.

Results: Mean HR and BL during resting shoot in 1st and 2nd tests were 119.0 and 112.2 bpm (range 1st test: 101−142 bpm, 2nd test: 96−135 bpm) and 1.72 and 1.65 mmol.L^{-1} (range 1st test: 0.9−2.6 mmol.L^{-1}, 2nd test: 0.8−2.3 mmol.L^{-1}) respectively. Mean HR and BL during post exercise shooting in 1st and 2nd tests were 168 and 166 bpm (range 1st test: 152−191 bpm, 2nd test: 147−188 bpm) and 4.21 and 3.44 mmol.L^{-1} (range 1st test: 1.3−7.0 mmol.L^{-1}, 2nd test:

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1.3−5.7 mmol.L^{-1}) respectively. There was not any statistically difference between shooting scores (27.50−27.23 points) after running exercise and resting ($p > 0.05$). **Conclusion:** It was concluded that, under simulated indoor competition environment, high HR values do not influence short distance shooting scores.

Keyword: Physiology

1. Introduction

Archery comparatively demands very specific strength and endurance for successful intermittent repetitive shooting and performance, both during training and competition. When compared to other strength or endurance events, it does not show very high demanding efforts in strength and endurance fitness areas, yet, in its own sense, very fitness demanding for accurate shooting (Acikada et al., 2004). Several investigations on archers have demonstrated that there is a notable specific stress on cardiovascular system of archers during repetitive shooting (Carrillo et al., 2011), specifically during competition (Robazza et al., 1999). Despite the fact that there is a change in heart rate values prior to drawing, during drawing and shooting, influenced by psycho physiological factors, there is also some muscular stress imposed by posture, limited time of shooting, and repetitive shooting upon whole body musculature and chest and shoulder girdle muscles (Caterini, 1993; Robazza et al., 1999; Tinazci, 2001). Analysis of the event showed that there is a demand of cardiovascular fitness during long hours and high number of quality shooting for effective training capacity, and during competition which demands not less than 150 shots during the course of competition, spread over a day (Tinazci, 2001).

In shooting based sports where hand-eye coordination is important in shooting skills and performance, a problem is created by a whole body tremor caused by cardiac systolic cycle (Helin et al., 1987). Duration of the phases of systolic and diastolic phases of the cardiac cyle change according to HR, and increased HR shortens the diastolic and increases systolic phases (Guyton and Hall, 2006). It was observed that elite level shooters, just prior to shooting, lower their heart rates, and, also, perform the triggering during the diastolic instead of systolic phase (Helin et al., 1987). Similar to shooters, it was observed that top and average levels of archers, also, lower their HR during shooting (Wang and Landers, 1986). In archery, similar to pistol shooting, it is believed that higher HR values show low correlation with the scoring points (Landers et al., 1985; Bird, 1987; Konttinen and Lyytinen, 1992), implying that tremors due to HR have negative effect on the accuracy of aiming (Tinazci, 2001). However, during competition archers exhibit higher HR (Robazza et al., 1999).

Thus, there is a close relationship between accurate shooting and high level of performance and HR. The objective of this study, therefore, is to examine relatively

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high HR values during shooting on shooting performance in an indoor artificial competition environment in elite top level archers.

2. Material and method

2.1. Subjects

Regularly trained 13 (7 female, 6 male) international level elite archers from the national team voluntarily participated in the study. All the archers who volunteered took part in this study. Therefore, there was no inclusion or exclusion criterion. The subjects developed the necessary skills and as an international athlete they were capable of having the physical and psychological background for this study. Physical and physiological charactersics of subjects were shown in Table 1. All subjects were asked to sign a consent form which explained the procedure of the study and the testing. The study was approved by the ethical committee of Medical School of Hacettepe University, Ankara (HEK 07/151-47).

Heart rate and Shooting Performance: A specific testing protocol was set up in order to test the effect of HR on shooting performance. In order to minimize the influence of random factor in the test protocol the shooting scores as test performance, the test was repeated with three days between tests in order to have a full recovery (Laurent et al., 2011; Tufano et al., 2012). The testing procedure is summarized in Fig. 1. The test was conducted in an indoor area during the afternoon, where the runs were done on a synthetic surface. After the subjects reported to the testing area with their archery outfit, telemetric heart rate monitors (Polar Accurex, Kempele, Finland) were placed on them in order to record HR at 5 second intervals for running, shooting, and recovery intervals. Resting HR recordings and lactate measurements were taken after the subjects had 10 minutes of rest on a chair in a seated position. Then they started 5 minutes of warm-up exercises of their own choices which included several shots, stretching and runs in random order. Following the warming up period, subjects were asked to make 3 shots in 1 minute at the target at an 18 meters distance, on a regular 18 meter target sheet, at their own pace of shooting interval. The standing place for shooting was marked 3 meters away from the running finish line. At the end of 1 minute shooting they were asked to sit on a chair for 1 minute, during which a blood sample was taken from ear lobe for lactate analysis,

Table 1. Mean and standard deviation of body height, body weight, running velocities at 4 mmol.L^{-1} lactate level of male and female archers.

	n	Age (years)	Height (cm)	Body Weight (kg)	HR_{max} (bpm)	4 mmol.L^{-1} running velocity (km.h^{-1})
Males	6	26.0 ± 8.1	175.2 ± 7.4	75.8 ± 13.3	194.9 ± 5.5	10.69 ± 0.83
Females	7	22.3 ± 5.7	163.8 ± 4.5	55.8 ± 3.2	195.9 ± 7.5	8.27 ± 0.84

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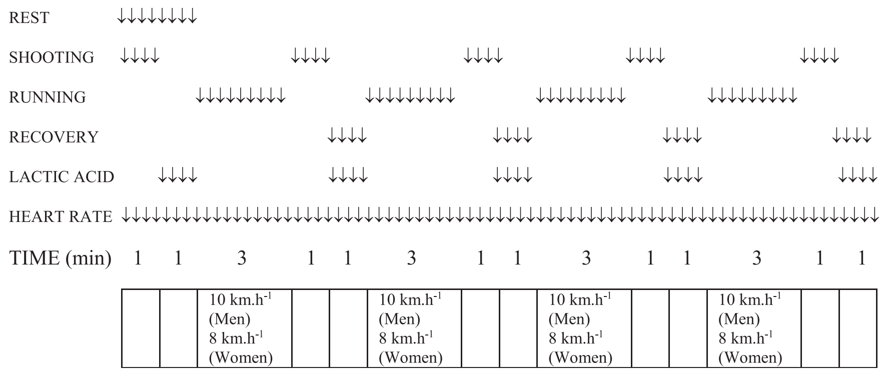

Fig. 1. Study design and specific test protocol.

using lactate analyser (Accusport, Boehringer Mannheim, Germany). In order to cause a physiological stress and raise the HR at the end of blood sampling, the subjects were asked to run a 3 minute steady pace of shuttle run on a 20 m long course, where the pace was given by a computerised pace keeper (Tümer Electronics, Turkey). Every time the pace keeper signalled, the subjects were asked to be at the end of the 20 m end line. Female archers were asked to run at 8 km h^{-1} and males at 10 km h^{-1} pace, which corresponded to approximately 4 mmol l^{-1} lactate threshold pace, determined on archers in a pilot study, and this was accepted as physiological standardized stress level as this workload was accepted a reliable and valid method (Bentley et al., 2007). Following a resting state, lactate analysis and shooting, the archers were asked to do 4 sets of running, which was followed by shooting and lactate analysis. All shots were to be completed within 1 minute and those who completed the shots earlier were asked to remain on the shooting line throughout the whole 1 minute. After the shots, subjects rested for 1 further minute during which the blood sample was collected from each subject. The score of the shots was recorded as in normal archery indoor competition. The archer himself or herself was asked to put the marker in order to determine the HR's for shooting, recovery, and running. Recorded HR values were then transferred to a computer to a software programme where they were analysed for mean HR for shooting and recovery. The average of the last 1 minute HR of three minutes of running was taken as the running HR (Lucía et al., 2006).

2.1.1. Running velocity test pilot study

The running velocity of archers during the test was determined in a preceding pilot study with 6 male and 7 female international archers. In this pilot study, the archers were asked to run on a circular 100 m course, marked at 20 m intervals for pace judgement, which was produced by pre-programmed pace simulator (Prosport, Tumer Electronic, Turkey). Male archers were asked to begin running at 8 km h^{-1} and females at a 7 km h^{-1} pace, and velocity was increased 1 km h^{-1} every 3 minutes after

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a 1 minute break until exhaustion. The test was ended if the archer failed to keep up with the pace in two following 20 m runs. Heart rate was recorded during the course of the test and during recovery by HR monitors (Polar Accurex, Kempele, Finland). A blood sample was taken from the ear lobe for lactate analysis at every 1 minute rest periods between the runs, using lactate analysers (Accusport, Boehringer Mannheim, Germany). For every running speed average of the last minute's HR of run were taken as the testing values (Lucía et al., 2006). Male archers have demonstrated 10.69 ± 0.83 km h^{-1} and females 8.27 ± 0.84 km h^{-1} for 4 mmol l^{-1} fixed lactate threshold (Table 1). It was observed that both in females and males the running velocities at 4 mmol l^{-1} were relatively homogenous (VC = 7.7 % and 10.1% respectively), and, therefore, 8.0 km h^{-1} and 10.0 km h^{-1} running velocities were accepted as specific endurance running velocities for females and males respectively. 4 mmol fixed lactate threshold running velocity was chosen as the testing velocity since it is accepted as the physiological variable which is one of the best indicator of aerobic fitness or training load with a high reliability at submaximal exercise intensity (Weltman et al., 1990; Grant et al., 2002; McMillan et al., 2005).

2.2. Statistics

The descriptive statistics (X ± SD) of the variables were calculated. The Friedmann Test was used to show the differences between resting and post-exercise shooting scores. The Wilcoxon test was used to show the differences between the each set in both tests for the shooting scores. Average (overall) results were taken into account for statistical analysis. Statistical significance was accepted at $\alpha = 0.05$ level.

3. Results

Male and female archers' physical and physiological variables are shown in Table1, resting HR, resting LA, and HR during resting shoot values are shown in Tables 2 and 3 is showing the scores of both test results of running, shooting, and recovery HR, and blood lactate values for each set. Shooting scores in both tests are presented in Table 4. In both tests there was no difference in scores of resting and after running (First test: $X^2 = 6.54$; $p > 0.05$, Second test: $X^2 = 5.05$; $p > 0.05$). Similarly, there was no difference between each set in both tests for the shooting scores.

Table 2. Resting HR, and LA, and HR during resting shoot.

	Test I	Test 2
Resting HR (bpm)	95.92 ± 16.0	95.62 ± 11.0
Resting La ($mmol.L^{-1}$)	1.72 ± 0.55	1.65 ± 0.64
HR during resting shoot (bpm)	119 ± 12.85	112 ± 10.46

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Table 3. HR at fixed running velocity and during shooting and recovery in test sessions I and II of the archery specific test.

	Set I	Set II	Set III	Set IV	Overall
Running HR-I (bpm)	176 ± 6.4	181 ± 7.1	184 ± 7.6	186 ± 7.8	182 ± 8.0
Shooting HR-I (bpm)	164 ± 8.6	167 ± 12.2	171 ± 10.3	173 ± 8.4	168 ± 10.3
Recovery HR-I (bpm)	131 ± 13	136 ± 9.3	135 ± 8.3	137 ± 9.3	135 ± 10.2
LA-I (mmol.l^{-1})	3.79 ± 1.40	4.40 ± 1.48	4.35 ± 1.43	4.31 ± 1.38	4.21 ± 1.41
Running HR-II (bpm)	169 ± 10.5	177 ± 9.9	180 ± 9.5	181 ± 9.3	177 ± 10.6
Shooting HR-II (bpm)	160 ± 12.2	167 ± 11.2	169 ± 10.7	168 ± 9.3	166 ± 11.1
Reovery HR-II (bpm)	122 ± 10.2	130 ± 10.2	129 ± 8.5	133 ± 7.0	129 ± 9.7
LA-I (mmol. L^{-1})	3.23 ± 1.18	3.55 ± 1.27	3.49 ± 1.20	3.46 ± 1.29	3.44 ± 1.21

Table 4. Pre (resting) and post running exercise shooting points values.

	Test I	Test II	z	p
Pre	28.23 ± 1.01	27.85 ± 1.34	-0.64	0.521
Set I	26.77 ± 2.05	27.31 ± 1.44	-0.94	0.344
Set II	27.69 ± 1.11	27.54 ± 1.20	-0.32	0.751
Set III	27.85 ± 1.34	26.69 ± 1.44	-1.95	0.051
Set IV	27.69 ± 0.85	27.38 ± 1.66	-0.68	0.496
Overall	27.50 ± 1.43	27.23 ± 1.44	-0.98	0.329

4. Discussion

Unintentional or involuntary muscle activity may negatively influence shooting performance. One of these activities may be the physiological tremor due to HR (Lakie, 2010). It was technologically impossible to measure the trace of HR movement and its influence on tremor by using electromyography. Therefore, it was sufficed to measure by HR monitors with 5 seconds intervals to record the HR. It was demonstrated that there was a negative relationship between the amplitude of tremor and shooting performance in shooters (Lakie et al., 1995; Tang et al., 2008). However, although, the tremor itself was not measured in this study, some studies showed that the amount of physiological tremor amplitude was significantly increased at the end of exercise (Furness et al., 1977; Viitasalo and Gajewski, 1994; Gajewski, 2006). For example, at the end of increasing intensity strength exercises on elbow joint flexion/extension on skiing ergometer showed dramatic increase in the amplitude of tremor in wrist joint (Gajewski, 2006). This increase is explained by the secretion of adrenaline and its influence on Na+/K+ pump, resulting in the reduction of K+ concentration (Lakie et al., 2004; Lakie, 2010). One other major source of tremor is HR and to a certain extend is the respiration system activity. Each and every heart beat results in a transient oscillation in an extremity. However, the partial amount

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of tremor caused by HR and respiratory activities in the total postural muscle activity tremor is relatively very small (Lakie, 2010).

A fixed HR at 4 mmo l^{-1} was used to create a measurable workload stress (Bentley et al., 2007). 4 sets of running and shooting were used to have similar stress in a competition situation. Measured mean HR range value of the elite archers at 4 mmol l^{-1} lactate threshold running velocity was 169−186 bpm. Shooting scores immediately after running at 4 mmol l^{-1} lactate threshold was not different than the scores performed at average resting HR values between 112-119 bpm (Table 2). These findings in this study show that in elite archers the postural tremors created by possible HR beats are kept under control and shooting performance has not been negatively influenced. Repeating the test 3 days after gave similar results which has also indicated that high HR values and running exercises did not negatively influence shooting performance. In a study on soldiers showed that pistol shooting performance was significantly deteriorated immediately after at 70, 80, and 90 % of VO_{2max} running exercise, but returned back to normal resting levels 1.5 minutes after the exercise (Ito et al., 2000). Similarly, in a study on biathlon athletes while shooting performance on the ground did not show any negative influence but standing shooting showed significant deterioration (Hoffman et al., 1992). In this study the measured resting HR shooting values were somewhat lower than the values during a competition. In a case study on a young female archer from European Archery Championship showed that the HR values during practice, official practice, and competition was 115.25 bpm, 122.9 bpm, and 150.22 bpm respectively (Robazza et al., 1999). In this study the HR values obtained after running exercise were approximately 16−18 bpm higher (Table 3) than the HR's of the young female archer in the European Championship. In this respect, it can be speculated that the HRs obtained immediately after running in this study is somewhat representative of competition HRs which are elicited as a combination of emotional and physiological stresses. In this study all the analysis were made in simulated competition environment, which may not show similar emotional stress with the official competition which may have both direct and indirect influence on HR and shooting performance. It is, therefore, important to study and analyze the influence of real competition environment both on emotional and physiological stresses that may have some bearing influence on HR and shooting performance.

A study on athletes showed that upper level of motor and cognitive skills modulated by very long term perceptual and motor training (Nakata et al., 2010). It was demonstrated that neural activation of brain during shooting was quite different on archers with a different levels of skill and non archers (Changa et al., 2011; Kim et al., 2014). Researchers claim and explain this state as having the elite archers being more efficiently focused and organized in neural networks, and as an outcome of this, they shoot with a less energy cost (Changa et al., 2011; Kim et al., 2014). It is, also, postulated that at high skill level archers, at central neural programming level, the motor

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planning and learning are relatively more economical, and, therefore, at high stress competition environment, they respond with a higher consistency in cognitive and motor processes for shooting (Changa et al., 2011). In conclusion, present study showed that in simulated competition environment high HR (short cardiac cycle) values in elite level archers have no negative influence on indoor shooting performance. The objective of this study is to examine the influence of high HR on shooting performance in elite archers. The main finding of this study is that there was no influence of high HR on shooting performance (27.50 versus 27.23 points) in elite archers.

Declarations

Author contribution statement

Caner Açıkada: Conceived and designed the experiments.

Tahir Hazır: Analyzed and interpreted the data.

Alper Asçı: Contributed reagents, materials, analysis tools or data.

Sinem Hazır Aytar: Performed the experiments.

Cevdet Tınazcı: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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