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Effects of beta-blockers on archery performance, body sway and aiming behaviour

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ABSTRACT

Objectives This study aimed to determine the effect of selective (bisoprolol-5 mg) and non-selective (propranolol-40 mg) beta-blockers on archery performance, body sway and aiming behaviour.

Methods Fifteen male archers participated in a randomised, double-blind, placebo-controlled, cross-over study and competed four times (control, placebo, selective (bisoprolol) and non-selective (propranolol) beta-blocker trials). Mechanical data related to the changes in the centre of pressure during body sway and aim point fluctuation and when shooting was collected. During the shots, heart rate was recorded continuously.

Results Results indicated that, in beta-blocker trials, although shooting heart rates were lowered by 12.8% and 8.6%, respectively, for bisoprolol and propranolol, no positive effect of beta-blockers was observed on shooting scores. Also, the use of beta-blockers did not affect shooting behaviour and body sway.

Conclusion The use of either selective or non-selective single dose beta-blockers had no positive effect on shooting performance in archery during simulated match conditions.

Terminology in relation to archery

- Archery performance: Performance in archery is designated based on the sum of the scores of the arrows shot by an athlete hitting the target.
- Body (or postural) sway: Body sway is assessed in terms of anterior-posterior and sideway deviations using the centre of pressure changes data obtained through force plates.
- Aiming behaviour: Every shooter has unique aiming behaviour, and this is assessed by tracking the quantified aim point fluctuations.

What are the new findings

- Although selective and non-selective beta-blockers lowered shooting heart rates, this had no positive effect on shooting scores.
- There was no effect of selective and non-selective beta-blockers on aim point fluctuations during shooting.
- Selective and non-selective beta-blockers intake had no effect on the centre of pressure changes during shooting.

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INTRODUCTION

Beta-adrenergic receptor blockers (BBs) are chemical substances that decrease the heart rate (HR) by inhibiting the binding process of noradrenalin and used for medical conditions like high blood pressure, congestive heart failure and myocardial infarction.[1] The effects of selective and non-selective BBs on physical performance are conflicting.[2–4] Exercise performance is impaired to a greater extent following non-selective than selective blockade, irrespective of exercise intensity and duration.[5] No effects of BBs on power, strength and short-term muscle endurance were determined.[3 6 7] In contrast, possible negative effects were reported in sports that require aerobic capacity and endurance.[6 8–14] BBs are used (or misused) in art disciplines and sports branches like ballet dancing, shooting and archery that do not demand high physiological exertion but that require fine tuning or steadiness to decrease HR and tremor.[15 16] It has been demonstrated that by reducing postural sway during the release phase can increase shooting performance in skilled archery athletes.[17] The synchronisation between the centre of pressure (CoP) and bow sway influences the accuracy of the shot[18] irrespective of HR.[19]

The number of studies investigating the effects of BB on performance[16 20–22] is very limited. Only two studies conducted in pistol shooting reported a positive effect of BBs on performance.[15 23] Specifically, shooting performance of athletes who took selective BB (metaprolol) 50 mg in the morning and 100 mg 2 hours before the event was improved by 13.4%.[15] Similarly, pistol shooters who took 40 mg of oxprenolol only 60 min before indoor shooting competitions reported significant improvements in scoring

Figure 1 Testing set up.

compared with double-blind placebo matches.[23] These studies in shooters resulted in banning of BBs in archery since 1985.[24]

Although the use of doping substances is not common in sports requiring fine motor movements, some archers may use such drugs to reduce HR, diminish anxiety and reduce body sway during shooting based on the findings from previous studies.[15 23] However, the invention of so-called cardioselective BBs may allow a greater number of archers having medical conditions like high blood pressure to compete if the substance does not have a worthwhile performance benefit. This was one of the issues considered to test whether cardioselective BBs are effective, and differentiate between cardioselective BBs and traditional BBs. Hence, this study aimed to investigate the effects of BBs on shooting performance and their components in archers.

METHODS

Participants

Participants were 15 male volunteer archers with at least 4 years of training experience, who compete at the National Teams (age=20.5±1.9 years, height=177.9±6.5 cm, bodyweight=78.3± 10.6 kg). They were not taking any medication similar to BBs and were also not consuming any medication that might affect BBs' absorption or metabolism. Participants were asked not to consume alcohol, caffeine and caffeinated drinks during the testing period. Informed consent was obtained.

The study design comprised a randomised four-trial, double-blind, placebo-controlled, cross-over study. Each archer had to compete four times during the study (control, bisoprolol (β1), propranolol (β1, β2) and placebo). Control shots were performed 24 hours before the substance or placebo was given. There were 7 days in between testing days to allow washout of the substances.

The experiments were carried out in an indoor hall to provide standard ambient conditions. Archers were invited to the hall at 0900 hour on the testing days and requested to prepare as in a normal competition. On arrival, the archers resting HR (RHR) values was determined in lying and standing positions by telemetric HR monitors (Polar RS800 Finland). After determining RHR, on separate occasions, archers performed either control shots or were given an oral dose of either bisoprolol 5 mg (β1), propranolol 40 mg (β1, β2) or placebo in a randomised fashion. Two hours after the BBs or placebo administration, archers performed 30 shots (3 arrows and 10 sets in 2 min, which is the official competition time). After the shots, archers waited for another 2 hours and then their RHR was measured again and performed another 30 shots as in the previous trial. For all conditions, data was collected 2 and 4 hours after BBs and placebo intake to ensure peak blood levels following the specifications of each drug (for bisoprolol 2 hours, for propanolol 4 hours).[25 26] During the shots, the mechanical data related with the CoP and aim point fluctuation (APF) were recorded on a computer at 0.3 s before arrow release.

Substances

Archers were given an oral dose of 5 mg bisoprolol, 40 mg propranolol and placebo in a randomised design. BBs were obtained from a university hospital dispensing pharmacy, and placebo capsules (containing starch) were provided by the Pharmacology Department of the School of Medicine. The reason to choose bisoprolol was for a couple of reasons. First, as the trial was a placebo-controlled study and to save the double-blind design, the tablets' size and shape had to be similar. Additionally, the pharmacokinetic parameters, especially Tmax values should be similar to propranolol. Finally, to exclude any bioavailability, bisoprolol was the only available trademark in the country. BB doses were defined from the literature considering several criteria; (1) the volunteers should not feel any clinical sign or symptom which may affect their blindness, (2) Should be therapeutically equivalent, (3) cardio-specific beta-1 blocker (bisoprolol 5 mg) should not exceed the selectivity for beta-1 receptors and (4) 40 mg single dose propranolol (off-label use of for performance anxiety symptoms). The result on HR measurement on both treatments showed that the doses for both drugs had achieved the systemic effect, without any clinical symptom or adverse event observed or reported by the volunteers.[27]

HR measurements

HR was recorded before and during shooting with one-second intervals. RHR values were obtained from the average of last 1 min of a 20 min lying position. Afterwards, RHR values were continued to be recorded in a standing position for 4 min. Shooting HR (SHR) recording was initiated when archers stood on the force plate and continued until completing the shooting series. The average SHR after each three shots and the average of 10 sets of these three shots were used for analysis.

Shooting performance

Shootings were performed according to regular indoor competition standards. Official judging, 18 m distance shooting, and normal indoor competition rules were applied. Archers were asked to compete in pairs as in official matches. As two archers shot together to resemble a competition situation, shooting platforms were placed like in the field of competition (figure 1). Each competition lasted about 45 min.

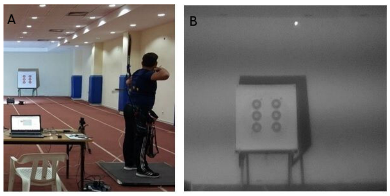

Figure 2 General setup with naked eye (note that, on the left, LASER marks are invisible to the camera with an IR filter which reflects what human eye sees) (A). Image through webcams with IR filters removed (B). IR, infrared radiation.

Measurement of aiming behaviour and CoP changes

Biomechanical data acquisition setup consisted of two parts; LASER light tracking system to analyse APF and force platform for measuring the CoP changes to track body sway.

LASER light tracking system (APF)

A device was developed at Hacettepe University Technopolis (EOS Engineering Ltd.) to measure aiming displacement in horizontal (x) and vertical (y) axes on target. An infrared radiation (IR) LASER beamer was used to track and evaluate aiming behaviour. A custom software was developed to detect the IR beam on the target, which was collected by using a custom IR camera. LASER-based acquisition setup was consist of two IR LASER pointers (which were secured onto bows), two cameras and a laptop computer for processing target images by using MATLAB (V.R2017b, The Mathworks, USA).

Two USB webcams streaming 640×480 pixel video had their IR filter removed and assembled in a custom enclosure with telephoto lenses. Removal of IR filters let the cameras detect IR LASER used in the experiment. The IR light spectrum for the experiment provided a 'hidden beam' from participants which did not affect their performance as the human eye is not sensitive to IR light spectrum and cannot be seen with the naked human eye (figure 2A,B). A camera calibration routine was done before every experiment day. After the image processing, camera data were normalised against target top and bottom points and then converted to centimetres using fixed target height.

CoP changes during body sway (CoP changes)

Two force platforms (120cmx120cm), each having four load cells with their signals amplified on a custom-designed circuit board, were used to track CoP. For each experiment, data obtained through the system was used to calculate the two-dimensional position of CoP. Postural sway of the total distance was calculated distances travelled from the CoP.

Data analysis

Kolmogorov-Smirnov test was used to check the normal distribution of data. For all variables, deviation from the normal distribution was not significant (p>0.05). Four (trial) x 2 (posture) two-way repeated-measures analysis of variance (ANOVA) and the Bonferroni post hoc test were used for lying and standing RHR before and after the drug administration. One-way repeated ANOVA measures with Bonferroni post hoc test were used to determine the effect of BBs on SHR, shooting scores, and mechanical variables. Mauchly's test for sphericity was used for repeated measures of ANOVA. In case of violations, if epsilon is (ε)<0.75 Greenhouse-Geisser and if (ε) >0.75 Huynh-Feldt corrections were applied. Partial eta squared was used to measure the effect size (Partial η^2 0.01=small effect, 0.06=medium effect, 0.14=large effect). Pearson's correlation coefficient assessed correlation between the variables. The level of significance was set at p=0.05. The data homogeneity was checked and was found good before proceeding with the analysis.

Patient and public involvement

Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

RESULTS

Resting HR

RHR is given in table 1. There were no differences among control, bisoprolol, propranolol, and placebo RHR values before drug administration (η_p^2=0.070). On the other hand, the effect of posture on the RHR was statistically significant (η_p^2=0.936). RHRs have substantially increased (average 20.2 bpm) in standing position. Both lying and standing RHRs were measured to check whether

Table 1 Lying and standing RHR values

	Before bisoprolol and propranolol		After bisoprolol and propranolol	
	$RHR_{(lying)}$ (bpm)	$RHR_{(standing)}$ (bpm)	$RHR_{(lying)}$ (bpm)	$RHR_{(standing)}$ (bpm)
Control	74.8±6.1	94.0±7.2	74.8±6.1	94.0±7.2
Bisoprolol	76.1±6.8	98.2±8.9	67.9±7.9	76.5±9.5
Propranolol	73.2±9.2	93.5±8.0	69.1±7.8	80.5±8.1
Placebo	75.1±8.4	94.1±13.4	75.5±10.9	89.7±10.1

*Since no beta-blocker or placebos were given; the controls were only measured once.
RHR, resting heart rate.

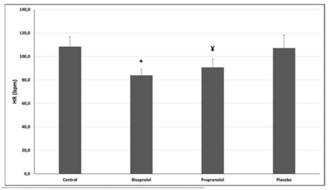

Figure 3 Shooting heart rates (HR) during control, bisoprolol, propranolol and placebo trials. *P=0.000 significantly lower than control, propranolol and placebo HR. ¥P=0.002 significantly lower than control and placebo HR.

the substances would affect vagal activity, resulting in a postural orthostatic change. For the RHR, the trial and posture interaction was not significant (η_p^2=0.023). Also, males tend to have lower HRs compared with females both during exercise and resting conditions. Therefore, to avoid the interpretation complexity due to the gender effect, this study was carried out on males only.

After the drug intake, BBs' effect on RHR was statistically significant (η_p^2=0.469). Bisoprolol and propranolol RHR were similar, and both were lower than control and placebo groups. Placebo and control RHR values were not different. Similarly, the effect of posture on RHR was statistically significant (η_p^2=0.914). RHR increased (average 13.3 bpm) during the standing position. In contrast to without drug usage, the trial x posture interaction for RHR was significant (η_p^2=0.272). These findings revealed that the archers who took bisoprolol and propranolol started shooting (in standing position) with significantly lower HR than control and placebo groups.

Shooting HR

SHR values during control, placebo, bisoprolol and propranolol trials are given in figure 3. The effect of BBs on SHR was significant (η_p^2=0.789). SHRs in bisoprolol and propranolol trials were significantly lower than control and placebo, and in bisoprolol trial, it was statistically lower than propranolol trial. On the other hand, the difference between control and placebo SHRs were not significant.

Shooting scores

Shooting scores during control, bisoprolol, propranolol and placebo trials are shown in figure 4. Repeated measures of ANOVA revealed a statistically significant difference (lower score) under the effect of propranolol (η_p^2=0.176). However, after the Bonferroni correction, no statistical significance was noted among trials. Therefore, it can be interpreted that the significant decrease in SHR during shooting did not affect the scores.

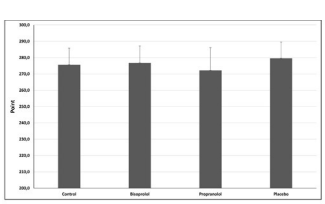

Figure 4 Shooting scores during control, bisoprolol, propranolol and placebo trials.

Aim point fluctuations

There were statistically significant differences between BB trials in terms of APFs (η_p^2=0.17). APF under bisoprolol (7.86±2.50 cm) was lower than propranolol trial (9.05±2.31 cm) 0.3 s before the arrow release. However, both APFs under bisoprolol and propranolol were not statistically different from control (8.29±1.91 cm) and placebo (8.41±2.02 cm). The correlations among APF and shooting scores in placebo (r=−0.776) and propranolol (r=−0.516) trials were negative and significant. On the other hand, these correlations were not significant in bisoprolol and control trials.

CoP changes

There were no significant differences between BB trials (10.29±4.17 cm for bisoprolol, 10.26±3.72 cm for propranolol), control (11.03±4.00 cm) and placebo (11.86±3.74 cm) in CoP at 0.3 s before arrow release (η_p^2=0.087). No significant correlations between control CoP changes and shooting scores (r=−0.057), propranolol CoP and shooting scores (r=−0.212) and placebo CoP changes and shooting scores (r=−0.338) were found. Scores with bisoprolol showed a significantly higher correlation with CoP changes (r=−0.675), meaning the less distance travelled during aiming in terms of body sway, the better scores were obtained.

DISCUSSION

Resting HR

During all trials, before and after drug intake, standing RHR was significantly higher than lying RHR (table 1). These findings are similar to the findings of the previous studies.[28] As known, the effects of gravity on human body changes per the changes in the posture and the distribution of body fluids are also rearranged.[29] This arrangement negatively influences the transport of oxygen to the tissues. The cardiopulmonary system function changes to supply optimal blood flow and oxygen transport.[28 30] Many studies have reported significant reductions in RHR after intake of single-dose oral selective and non-selective BBs.[12 31 32] Decreased standing RHR before shots indicated that archers performed their shots with lower standing RHR than control and placebo conditions.

SHR and shooting scores

Although all conditions were simulated, HR measured during shooting conditions was not high despite individual variations. In a previous study investigating the effect of benzodiazepine on indoor shooting performance in archers, all HR values obtained during shooting trials were similar to the HR values obtained in the present study.[33] Shooting performance in archery is characterised by a limited number of submaximal static-dynamic contractions in upper extremity muscles.[34 35]

Magnitude of the sympathetic cardiovascular adjustments evoked during isometric exercise in humans is determined in part by the size of the active muscle mass.[31] There are only a small number of studies investigating cardiovascular responses during competition in archers. In a study by Carrillo *et al*[36] in which data were collected during a simulated indoor competition, experienced archers demonstrated an increased parasympathetic nervous system activity when compared with precompetition values. In a case study describing women archers' performances during the European Archery Championship, HR was found to increase during bow draw and aim phases and decrease during the release phase.[37] In the same study, HR that was measured during shooting practice (below 120 bpm), official practice (more than 120 bpm) and elimination round (more than 150 bpm) were higher than the values obtained in the present study.[37] The reason for finding lower SHR in the present study might be related to the match simulated conditions.

Another finding of the present study was the significant decrease in average SHR after single-dose BB intake (figure 3). Moreover, the decrease in average SHR after the bisoprolol trial was more than that of the propranolol trial. These findings showed that selective and non-selective BBs lead to significant changes in cardiac vagal modulation. A recent study related to BB intake during muscular contractions support these findings. Significant reduction in exercise HR was observed (13%–24%) after selective (atenolol) and non-selective (propranolol) adrenergic blocker intake in 30% of maximal voluntary contraction that includes small (handgrip), medium (leg extension) and large (dead-lift) muscle mass.[31]

In BB trials, no positive effect of shooting scores was observed even though there was a significant decrease in average SHR. In other words, it can be said that tremors that are produced during the cardiac cycle (systole-diastole) do not impair fine motor performance and shooting performance. Despite significant decreases in average SHR, finding no change in shooting performance can be accepted as evidence that HR is not an important factor in shooting performance in archery. Studies related to the effect of BBs on shooting performance is limited to pistol shooters, and BBs usage has been found to have a positive influence on pistol shooting performance.[15] However, since the upper extremity's contribution, the amount of active muscles and aiming behaviour dynamics of archery and pistol shooting is different, the influence of cardiac modulation on shooting performance may be different. The control and placebo average SHR values of the present study are lower than that of Robazza *et al*'s study.[37] As a result, the lowering effect of BBs intake on SHR might not be reflected in shooting performance in the present study. In another study that determined the effect of HR on shooting performance in women and men archers, the increase in HR was found not to affect the shooting performance.[19] In that study, after 4×3 min of repeated exercise at running velocity of 4 mmol lactate threshold (Onset of blood lactate accumulation (OBLA)), no differences were found between shooting scores at RHR (95.9 bpm) and average HR (166–168 bpm).[19] These results indicated that postural tremor that occurs due to high HR is under control in the elite level of archers and has no effect on shooting performance. In that study average HR that was obtained during shooting was about 16–18 bpm higher than the average HR obtained in Robazza *et al*'s study.[37] Thus, it can be said that SHR results obtained in the present study is also acceptable for the real competition setting.

APF and CoP changes

No difference in CoP and APF variables during shots after BBs intake can be accepted as an indicator of no influence of BBs on shooting performance in the present study. In target-based sports like archery, pistol, and rifle shooting, there is a need for high precision, the relationship between aiming time during the aiming phase and body tremor is not clear. In some studies with archers, the relationship between body sway and shooting performance was observed.[38–40] In contrast, some other studies did not find such a relationship.[41 42] For instance, Keast and Elliot[39] reported that as the body sway increased, there was a decrease in shooting quality in elite men and women archers. In the present study, correlation coefficients between APF and shooting scores and CoP and shooting scores were negative. On the other hand, although all correlations were insignificant, this finding indicated that as the aiming time and body sway increased, shooting scores showed a decrease which is similar to the findings of previous studies.[38 41 42] Nevertheless, insignificant correlations among APF, CoP and shooting scores in some trials might reflect the fact that shooting quality in archers was not dependent on control of only aiming behaviour and body sway.

Limitations

This study's main limitation was to conduct the experiments during simulated competition conditions as the archers do not accept carrying any device on their bodies and bows during official matches. Another limitation can be counted on giving single doses of substances. However, even a single dose provided enough physiological effect for both substances (lowered HR). Therefore, the results could rely on current research conditions.

CONCLUSION

The present study indicated that although RHR and SHR were affected (lowered) by BBs, there was no difference in shooting scores and shooting behaviour, and body sway did not change by BBs. It can be concluded that the use of either selective or non-selective single dose BBs does not affect shooting performance in archery during simulated match conditions.

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Contributors EE: project administration, methodology, writing original draft preparation. TH: methodology, acquisition of the data and analysis, writing-original draft preparation. MC: project administration, acquisition of the data, AK-I: project administration, writing- reviewing and editing, SA and VDY: acquisition of the data and analysis, CA, RG and AC: writing- reviewing and editing.

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Data availability statement Data are available on reasonable request. Data may be obtained from a third party and are not publicly available. The data are available from corresponding author should there be a reasonable request from researcher on providing additional information.

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