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Investigation of the Effect of Shooting Without Moving Elbow Support on Heart Rate and Shooting Performance in Air Rifle Shooting

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Abstract

Aim: The aim of this study is to examine the effects of two different shooting protocols on shooting scores and heart rate (HR) in air rifle shooting.

Method: Shooting scores and HR were measured during two protocols: the unsupported protocol, where the elbow support remained stationary throughout the 60 shots, and the supported protocol, where the elbow support was moved after each shot. HR was measured using a heart rate monitor, while shooting scores were measured using an electronic target system. The relationship between the mean HR and shooting scores across consecutive series was analyzed using Repeated Measures ANOVA. The relationship between the mean HR and shooting scores between the two protocols was assessed using the Paired Sample t-test.

Results: The mean HR during the unsupported shooting protocol was found to be higher than during the supported protocol across all series ($p<0.01$). The mean shooting scores for the 5th (102.3) and 6th (102.2) series in the supported protocol were significantly higher than those of the 1st series (100.7) ($p<0.05$). Additionally, the mean shooting scores for the 4th (101.5) and 6th (102.2) series in the supported protocol were significantly higher than those of the 4th (98.9) and 6th (99.5) series in the unsupported protocol ($p<0.01$).

Conclusion: The findings of our study indicate that unsupported shots increased HR in 10m air rifle shooters, consequently negatively affecting shooting performance.

Key words: *Shooter, Supported Shot, Unsupported Shot.*

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INTRODUCTION

Shooting is a highly precise and inclusive sport, open to individuals of all ages, genders, and performance levels (Krasilshchikov et al., 2007). It is featured in 15 different disciplines at the Olympic Games, with air rifle shooting, which has been part of the Olympic program since 1984, standing out for its demand for extreme accuracy (ISSF). In this discipline, shooters must hit a target from 10 meters away, where the center has a diameter of just 0.5 mm. Completing 60 shots within 75 minutes, shooters face minimal error tolerance, making air rifle shooting one of the most precise sports in the Olympic lineup (Ball et al., 2003). Research has shown that even the smallest movement can affect accuracy; for example, the angular movement of the rifle must be less than 0.016° to achieve a perfect ten-point shot (Zatsiorsky and Aktov, 1990). The physical and mental demands on the shooter are immense, as they must synchronize muscle coordination, balance, breath control, and visual-motor perception to achieve success. This level of precision is made possible by controlling micro-movements of the body, particularly during the shot, when even the shooter's heartbeat can affect stability. Thus, managing internal physiological rhythms is essential for consistent performance at this level.

Achieving elite scores in 10-meter air rifle shooting requires not only technical mastery but also high precision and stability (Magill & Anderson, 2010; Mon et al., 2014; Park et al., 2019). Success depends on a delicate interplay between mental skills, postural balance, and rifle control, and improving performance involves addressing various physical and physiological factors. Biomechanically, the shooter stands in a fixed position, supporting the rifle on their shoulder, while minimizing muscle use to achieve a steady aim. During this process, the body's balance systems particularly the spine, leg muscles, and feet are critical. Isometric muscle contractions keep movements controlled, while proper breath control helps the shooter remain stable and make precise shots. Synchronizing breathing with the shot reduces tremors and enhances accuracy. In recent sports research, heart rate has been recognized as a significant factor in precision sports like shooting (Liu & Zhang, 2019). A resting heart rate in healthy individuals means 75 beats per minute, but many factors—including environmental temperature,

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body position, altitude, age, diet, psychological state, and even smoking—can influence it (Aubert et al., 2003). The autonomic nervous system, composed of sympathetic and parasympathetic divisions, regulates heart rate (Freeman et al., 2006). The sympathetic system dominates in stressful situations, while the parasympathetic system prevails during relaxation. Balance between these systems is crucial for cardiovascular health and performance. In shooting, where accurate aim, steady posture, and body control are essential, heart rate can also significantly impact performance. However, research remains divided on its exact effects. Some studies suggest that a high heart rate negatively impacts shooting success (Kayihan, 2012; Hoffman et al., 1992; Ito et al., 2000; Kolayış, 2000; Landers et al., 1994), while others argue that the relationship is more complex and multifaceted (Karabağ et al., 2022; Bentley et al., 2007). This ongoing debate emphasizes the intricate nature of precision sports like shooting, where even physiological rhythms play a vital role in determining success.

The aim of this study was to evaluate the hearth rate and shooting performance of air rifle athletes during unsupported and supported shots. In this context, the objective was to examine athletes' heart rate and shot scores in both protocols and analyze the differences between unsupported and supported shots.

METHOD

Research model

This study was conducted using a controlled experimental design to evaluate the effects of supported and unsupported shooting techniques on heart rate and shooting performance in air rifle athletes. A sample of 13 licensed athletes with at least 3 years of active competition experience and having participated in national finals at least once was selected using simple random sampling. All participants were right-handed, and informed consent was obtained before participation. Two different shooting protocols were applied to the athletes on separate days: the first protocol involved unsupported shooting, while the second protocol involved supported shooting. Both protocols followed a 15-minute preparation and sighting time before starting the tests. Heart rate data were continuously monitored using a Polar H10 heart rate monitor, and shooting performance was recorded using the Sius HS10 Hybridscore electronic target system. In the unsupported shooting protocol, athletes performed 60 shots without lowering their rifles onto the tripod after loading the first shot, maintaining their position throughout the process. In contrast, during the supported shooting protocol, athletes lowered their rifles onto the tripod either after every shot or at certain intervals to load the pellets. Data collection involved continuous monitoring of heart rate and shooting scores for both protocols. Heart rate values were analyzed for 10-shot series, and shooting performance was assessed for both the 10-shot series and total competition scores (60 shots).

The research protocol

Two different protocols were applied to the athletes on two separate days. Before the protocols, a Polar H10 chest band was worn to monitor heart rate values; real-time shots made by athletes on the electronic shooting target were recorded to monitor shooting performance. After the devices were attached, athletes wore their underware and shooting clothes. Athletes wearing shooting clothes took positions on the shooting range. In both test protocols, athletes were given 15-minute preparation and sighting time. After 15 minutes, athletes lowered their rifles onto the table, and the devices were started. A 2-minute rest period with arms free was provided. After the rest period, athletes lifted their rifles onto the tripod, and in both protocols, they loaded the first pellets while on the tripod. In the protocol of the first day, athletes loaded their rifles on the tripod for 60 shots without lowering them and completed the competition without taking a break from shooting. In the second protocol, athletes lowered their rifles onto the tripod to load the pellets and completed the competition in this way. After completing 60 shots in both protocols, athletes lowered their rifles onto the table, and after a 2-minute recovery period with arms free, the device recording was terminated.

Unsupported shot: In this shooting pattern, athletes loaded the first shot pellets on the tripod. Then they took the shooting position. After completing the first shot, without altering the shooting position, with the lower extremities completely fixed and the upper extremity maintaining the position and location of the left hand holding the grip and the left elbow resting on the hip bone, and without lowering the rifle onto the tripod, the athlete only loaded the shot pellets using the right arm and completed 60 shots in this manner.

Supported shot: In this shooting pattern, athletes loaded the first shot pellets on the tripod and took the shooting position. After completing the first shot, each athlete lowered their rifle onto the shooting table at their own preference, either for every shot or at certain intervals. Those who lowered the rifle for each shot loaded the shot pellets on the tripod. Those who preferred to lower the rifle at intervals loaded their rifles with the help of their right arms during the shooting process without altering the position of the left arm, i.e., without lowering the rifle onto the tripod. All athletes completed 60 shots in this manner, intermittently lowering their rifles.

Population and sample

The study population consists of licensed air rifle shooters aged 18 and above. The sample of the study was selected through simple random sampling from athletes who have been actively licensed for at least 3 years, have competed in national finals at least once, and did not have any health problems. Necessary information was provided to, and consent was obtained from the research group. The sample group consisted of 13 athletes, all of whom were right-handed.

Data collection tools

Heart Rate (HR) Measurement: During both protocols, the athletes' heart rates were continuously recorded until 60 shots were done, using the Polar H10 heart rate monitor device. The duration between heartbeats (R-R interval) was recorded with a resolution of 1ms. The R-R interval is a parameter that measures the time between two consecutive R waves in a cardiac cycle. The R wave is one of the peak points of the heart's electrical activity on an electrocardiogram and represents the stimulus that initiates the heart's contraction. The heart rates during both protocols were evaluated in a series of 10 shots, and mean values were calculated.

Shooting Score Measurement: The athletes' shooting scores were measured using the 4.5 mm diameter shot pellets fired with their own 10-meter air rifles at the electronic target in the shooting range. The electronic targets (Sius HS10 Hybridscore system) are equipped with special software that connects the target and the shooting line, allowing for automatic determination of the shooting scores. Athletes made real-time shots with their air rifles at the electronic target on the shooting range, and these scores were evaluated. During the evaluation process, the scores of 10 shots per athlete were accumulated to calculate the series scores. The scores of six series were then accumulated to calculate the competition scores. Series and competition scores were considered during analysis.

Data analysis

Statistical analyses were performed using Jamovi 2.5.3 software. Descriptive statistics, including the mean and standard deviation values for all physical parameters, were initially calculated. The athletes' heart rates and shooting scores (both supported and unsupported) were analyzed in series of 10 shots each, as well as in terms of total competition scores (60 shots). For both the first and second protocols, mean values for the series of 10 shots were determined. Shooting scores for consecutive series within each protocol were compared using Repeated Measures ANOVA. Additionally, shooting scores between the first and second protocols were compared in series of 10 shots using the Paired Sample T-test. Mean heart rate values for the first and second protocols were also calculated for each series of 10 shots. The heart rate values for consecutive series of each protocol were compared using Repeated Measures ANOVA. The mean heart rate values for both the first and second protocols were further compared using the Paired Sample T-test. The difference in heart rate between supported and unsupported protocols was calculated by subtracting the mean heart rate of each series from the other. Similarly, the difference in scores between supported and unsupported protocols was determined by subtracting the mean scores of each series from one another.

RESULTS

Table 1. Demographic Data

Variables	Mean	S.D.	Minimum	Maximum
Age (years)	27,2	7,94	18	40
Sport Experience (years)	12,7	6,80	5	25
Height (m)	1,70	0,07	1,62	1,85
Weight (kg)	67,1	11,8	50	83
Body Mass Index (kg/m^2)	23,0	3,22	17,3	27,7

n= 13

The average age has been determined as 27.2 years. The minimum age is 18, while the maximum age is 40. The participants' average sports experience is 12.7 years, ranging from a minimum of 5 years to a maximum of 25 years. The average height of the participants is 1.70 m, with the shortest individual measuring 1.62 m and the tallest measuring 1.85 m. The average body weight is 67.1 kg, with a minimum of 50 kg and a maximum of 83 kg. Since the standard error is 11.8, weight distribution shows more variability compared to height distribution. The average BMI is 23.0 kg/m^2, ranging from 17.3 (underweight) to 27.7 (overweight).

Table 2. Supported - Unsupported heart rate descriptives

Series	Mean	S.D.
Supported 1st Series HR	91.7	7.66
Supported 2nd Series HR	92.8	7.20
Supported 3rd Series HR	92.2	7.25
Supported 4th Series HR	91.9	7.59
Supported 5th Series HR	92.4	7.73
Supported 6th Series HR	92.3	8.51
Unsupported 1st Series HR	97.4	6.37
Unsupported 2nd Series HR	99.5	6.16
Unsupported 3rd Series HR	100.8	6.73
Unsupported 4th Series HR	100.7	7.13
Unsupported 5th Series HR	100.3	7.47
Unsupported 6th Series HR	99.3	7.75

n=13

A Repeated Measures ANOVA was conducted to examine intra-group differences in heart rate between supported and unsupported shooting protocols. No statistically significant differences were found between the heart rates in the supported and unsupported series.

Tablo 3. Supported - Unsupported series scores descriptives

Scores	Mean	S.D.
Supported 1st Series score	100,7	2,24
Supported 2nd Series score	100,8	3,01
Supported 3rd Series score	101,4	1,76
Supported 4th Series score	101,5	2,24
Supported 5th Series score	102,3	1,64
Supported 6th Series score	102,2	2,80
Unsupported 1st Series score	101,3	2,23
Unsupported 2nd Series score	100,4	2,58
Unsupported 3rd Series score	100,1	3,12
Unsupported 4th Series score	98,9	3,67
Unsupported 5th Series score	100,8	2,96
Unsupported 6th Series score	99,5	3,54

n=13

A Repeated Measures ANOVA was performed to evaluate within-group differences in shooting scores between supported and unsupported series. Statistically significant differences were observed in the supported series scores ($p<0.05$), while no significant differences were found for the unsupported shots.

Table 4. Supported series scores results

Series Skor	Series	Mean Difference	S.D.	d.f.	t	p_{tukey}
1st Series score	2nd Series score	-0.154	0.639	12.0	-0.241	1.000
	3rd Series score	-0.685	0.248	12.0	-2.757	0.134
	4th Series score	-0.800	0.323	12.0	-2.476	0.206
	5th Series score	-1.654	0.484	12.0	-3.418	0.045*
	6th Series score	-1.508	0.443	12.0	-3.406	0.046*
2nd Series score	3rd Series score	-0.531	0.569	12.0	-0.934	0.930
	4th Series score	-0.646	0.621	12.0	-1.040	0.895
	5th Series score	-1.500	0.749	12.0	-2.004	0.394
	6th Series score	-1.354	0.638	12.0	-2.122	0.338
3rd Series score	4th Series score	-0.115	0.322	12.0	-0.359	0.999
	5th Series score	-0.969	0.402	12.0	-2.408	0.227
	6th Series score	-0.823	0.425	12.0	-1.936	0.427
4th Series score	5th Series score	-0.854	0.417	12.0	-2.049	0.372
	6th Series score	-0.708	0.523	12.0	-1.352	0.753
5th Series score	6th Series score	0.146	0.649	12.0	0.225	1.000

**p<0,05; Repeated Measures Anova*

Statistical comparisons of the consecutive series scores within the supported shooting protocol revealed significant differences only between the 1st and 5th series, as well as between the 1st and 6th series ($p<0.05$).

Table 5. Supported - Unsupported series heart rate analysis results

Supported HR	Unsupported HR	d.f.	t	p
1st Series	1st Series	12.0	-3.11	0.009**
2nd Series	2nd Series	12.0	-3.41	0.005**
3rd Series	3rd Series	12.0	-3.91	0.002**
4th Series	4th Series	12.0	-3.76	0.003**
5th Series	5th Series	12.0	-3.45	0.005**
6th Series	6th Series	12.0	-3.12	0.009**

***p<0,01; Paired Samples T-Test; HR: Heart Rate*

The inter-group comparison of heart rates for supported and unsupported shots was conducted using a Paired Samples T-Test. Statistically significant differences were found between the two conditions across all series ($p<0.01$), with unsupported shots eliciting significantly higher heart rates than supported shots. Across all series, heart rate was significantly higher during unsupported shooting compared to supported shooting ($p<0.01$), indicating a physiological stress response associated with unsupported conditions.

Tablo 6. Supported - Unsupported series scores analysis results

Supported Scores	Unsupported Scores	d.f.	Statistic	p
1st Series	1st Series	12.0	-1.451	0.172
2nd Series	2nd Series	12.0	0.700	0.497
3rd Series	3rd Series	12.0	1.946	0.075
4th Series	4th Series	12.0	3.560	0.004**
5th Series	5th Series	12.0	1.912	0.080
6th Series	6th Series	12.0	3.156	0.008**

***p<0,01; Paired Samples T-Test*

A Paired Samples T-Test was employed to compare the shooting scores between the supported and unsupported conditions. Statistically significant differences were observed in the 4th and 6th series, with the scores for supported shots being significantly higher than those for unsupported shots ($p<0.01$). The analysis revealed significant differences in shooting scores for the 4th and 6th series, where supported shots outperformed unsupported shots ($p<0.01$). No significant differences were observed in the first two series.

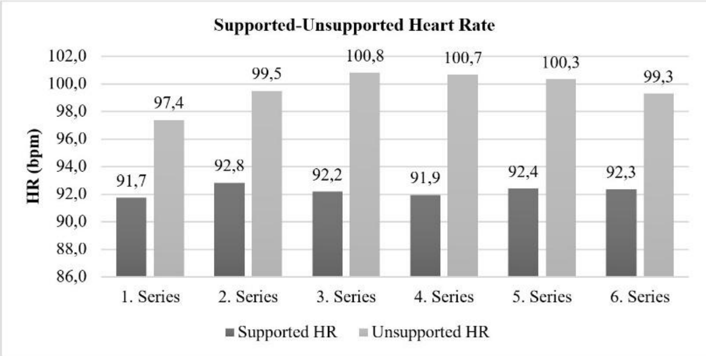

Figure 1. Supported - Unsupported series heart rate

The heart rate data for supported and unsupported series were plotted, revealing a consistent increase in heart rate for unsupported shots across all series (Graphic 1). In the first series, although the mean heart rate during unsupported shots was 5.7 bpm higher, the shooting performance in the unsupported series was 0.6 points higher. In the second series, the heart rate difference between supported and unsupported shots increased to 1 bpm, and while the score for supported shots improved slightly by 0.1 points, unsupported shots showed a decrease of 0.9 points. The performance for unsupported shots continued to decline from the second series onward. Although there was some recovery observed in the fifth series, there was another decline in the sixth series (see. Figure 2).

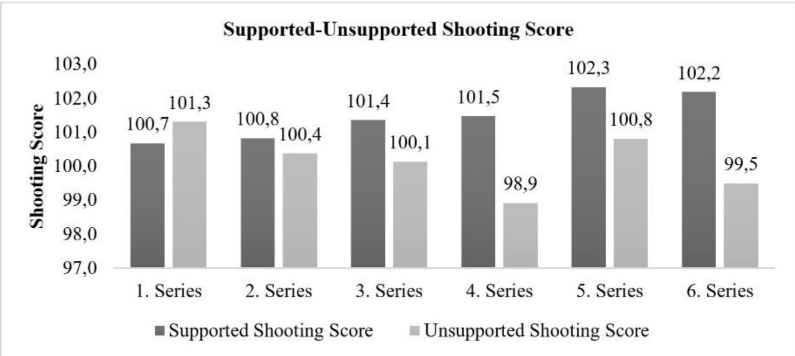

Figure 2. Supported - Unsupported series shooting score

The shooting performance scores for supported and unsupported series were visualized, showing a decline in scores for unsupported shots from the second series onward. There was no significant difference in shot scores between supported and unsupported protocols in the first 2 series. The decrease in scores in the 3rd and 5th series approached statistical significance. Significant decreases in shooting scores for unsupported shots were observed in the 4th and 6th series, which were statistically significant ($p<0.01$) (see. Table 6). Based on the available data, it has been observed that the increasing heart rate started to negatively impact on the scores of unsupported shots from the 2nd series onwards, but it became statistically significant in the 4th and 6th series.

DISCUSSION

In our study investigating the effects of shooting without moving elbow support on heart rate and shooting performance in air rifle shooting, it was found that participants had higher heart rates during unsupported shots, and consequently, lower shot scores were observed ($p<0.01$)

The mean age of the 13 participants in our study was 27.2±7.94 years, with a mean sports experience of 12.7±6.80 years, weight of 67.1±11.8 kg, height of 170±6.45 cm, and body mass index (BMI) of 23±3.22 kg/m². Comparable demographic characteristics have been observed in existing literature. Lang & Zhou (2022) conducted a study with 12 athletes from China's air rifle national team, reporting participants' mean age as 25.5±5.1 years, mean sports experience as 14.5±4.2 years, and mean weight as 67.2±6.6 kg. In a study by Gumussoy et al., (2024), the mean age was reported as 22.23±6.45 years, mean sports experience as 7.60±4.89 years, mean body weight as 69.77±14.27 kg, mean height as 168.43 ± 6.41 cm, and mean BMI as 24.94±4.99 kg/m². Kurt & Cengizel (2023) reported demographic data from a study involving 15 rifle athletes, indicating a mean age of 17.5±1.9 years, mean sports experience of 3.26±1.1 years, mean height of 173.9±4.9 cm, and mean body mass of 67.3±6.7 kg. Furthermore, Wedman (2023) conducted research with 5 male and 5 female participants from the Finnish national team, reporting mean ages of 36.5±8.0 years and 27.2±2.4 years, respectively. Tinaz (2019) conducted a study with 10 pistol shooters, reporting a mean age of 31.00 ± 10.54 years. Considering these findings, the demographic characteristics of our study align with those reported in existing literature. This correspondence enhances the generalizability of our study's results to a broader population.

The findings of this study are consistent with the conflicting results observed in previous literature regarding the relationship between heart rate and shooting performance. The analysis of both supported and unsupported shots revealed that heart rate is important variable influencing shooting performance, but its impact may vary depending on the type of shot being taken. The participants showed higher mean heart rates during unsupported shots compared to supported shots in all series, with the differences being statistically significant ($p<0.01$). This is consistent with previous studies that found increased heart rate during physical exertion negatively affects performance. For example, Vickers & Williams (2007) & Kayihan (2012) both reported that higher heart rates result in decreased shooting accuracy due to physiological factors such as tremors during the systolic phase of the cardiac cycle. In this study, the unsupported shots consistently showed higher heart rates, and although this could be expected to negatively impact performance, the effect seemed to depend on the series. The difference in heart rate between supported and unsupported shots was significant across all series, which may suggest that the unsupported shots require more physical effort, thus leading to higher heart rates.

The scores for supported shots showed a gradual increase over the six series, with significant differences observed between the first and fifth, as well as the first and sixth series ($p<0.05$). This suggests that there is a positive adaptation or improvement in technique or focus as the participants progressed through the series, possibly due to increased familiarity or comfort with the supported shooting protocol. Unsupported Shots: In contrast, scores for unsupported shots did not exhibit the same improvement. The significant decrease in performance observed in the fourth and sixth series ($p<0.01$) aligns with the expectation that a higher heart rate and the increased difficulty of unsupported shots negatively impacted performance. The steady decline in performance after the second series supports previous findings that increased heart rate, coupled with the physical demand of unsupported shots, results in decreased shooting accuracy. The increasing heart rate observed in the unsupported shooting series directly correlates with the decline in shooting scores from the second series onward. Although the first two series did not show significant differences in performance between supported and unsupported shots, the third and subsequent series demonstrated a significant drop in performance under the unsupported condition, which was statistically significant in the fourth and sixth series. The findings are consistent with Kolayiş (2000), who showed a significant negative correlation between heart rate and shooting score, especially when heart rates exceeded certain thresholds. The increase in heart rate during unsupported shots likely contributed to muscle fatigue and coordination challenges, as seen in the tremors that can affect precise hand-eye coordination in shooting sports (Kayihan, 2012).

The observation that supported shots produced more consistent and higher scores over time suggests that shooters may benefit from incorporating supported shots into their training to build technique, resilience, and stability in their performance. However, the performance decrement observed in unsupported shots highlights the need for additional training aimed at managing physical exertion and heart rate control during high-stress shooting situations. As the unsupported shot protocol showed a decline in performance as the heart rate increased, incorporating targeted training that involves shots under varied heart rates could help shooters adapt to physical and psychological pressure during competitions. Additionally, shooters could benefit from training under progressively higher heart rates to improve resilience to the tremors and mental fatigue associated with increased heart rate. The study's findings reinforce the notion that increased heart rate has a negative impact on shooting performance, especially in unsupported shots, aligning with previous research that emphasized the importance of managing heart rate during shooting sports. The results suggest that shooters may benefit from training designed to address the physical and psychological challenges associated with elevated heart rates. Future studies with larger sample sizes could help further elucidate the effects of heart rate on shooting accuracy and explore ways to mitigate its negative impact through training and technique refinement.

CONCLUSION

This study offers valuable insights into the effects of supported and unsupported shooting techniques on heart rate and performance in air rifle athletes. A key strength is the controlled experimental design, which enabled a detailed comparison of the two protocols under realistic conditions. The use of the Sius HS10 Hybridscore system ensured precise measurements, enhancing the validity of the results. The inclusion of experienced athletes further strengthened the study by minimizing variability. However, the small sample size (13 participants) limits the generalizability of the findings. Future research with larger groups and the inclusion of other factors like muscle fatigue, focus, and anxiety could provide a more comprehensive understanding. Despite these limitations, the study highlights the importance of heart rate management and technique adaptation in training, offering valuable insights for developing more effective training strategies for air rifle shooters.

In conclusion, this article investigated the impact of supported and unsupported shooting protocols on shooting performance and heart rate. Additionally, existing literature was reviewed to better understand the relationship between heart rate and shooting performance. Our study found that the heart rate during unsupported shots was higher than during supported shots across all series. Furthermore, the shooting scores in the 5th and 6th series of supported shots were higher than those in the 1st series, and the scores in the 4th and 6th series of supported shots were higher than those in the 4th and 6th series of unsupported shots. The research findings have revealed that the decline in unsupported shooting performance is not only attributed to the increase in heart rate but also to the unfamiliar shooting style for the athletes. The higher score in the first 10 unsupported shots compared to supported shots suggests that unsupported shooting technique can be improved with training. This encourages exploring strategies like keeping the elbow support still during each series, which could reduce movement distance and time, potentially lowering the athlete's physiological load and psychological stress. Training sessions with varying numbers of unsupported shots can be designed for air rifle shooters, and these can be incorporated into competitions. Additionally, including 60-shot unsupported training in endurance routines could help athletes build resilience to rhythm, focus, and competition pressures. This research is expected to guide future studies and offer practical insights for coaches.

Etical Approval and Permission Information

Ethics Committee:	Marmara University Faculty of Medicine Clinical Research Ethics Committee
Protocol/Number:	09.2022.1540

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