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Pengaruh Latihan Keseimbangan dan Daya Tahan Aerobik terhadap Akurasi Tembakan Atlet Pistol Angin 10 Meter

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Abstrak

Penelitian ini bertujuan menganalisis pengaruh latihan keseimbangan berbasis *core stability* dan latihan daya tahan aerobik berbasis *fartlek* terhadap akurasi tembakan atlet pistol angin 10 meter. Penelitian menggunakan pendekatan kuantitatif dengan desain kuasi-eksperimen *two-group pretest-posttest*. Sepuluh atlet dari populasi 21 atlet dipilih melalui *purposive sampling* dan dialokasikan menggunakan *ordinal pairing* ke dalam kelompok latihan keseimbangan (n = 5) dan kelompok daya tahan aerobik (n = 5). Intervensi dilaksanakan selama lima minggu dengan frekuensi empat sesi per minggu, sedangkan akurasi diukur melalui tes 60 tembakan pistol angin 10 meter. Kelompok keseimbangan meningkat dari 530,40 ± 9,10 menjadi 537,40 ± 7,00 (p = 0,003; d = 0,896), sedangkan kelompok daya tahan aerobik meningkat dari 528,80 ± 13,60 menjadi 538,60 ± 11,70 (p = 0,005; d = 0,938). Perbedaan peningkatan antarkelompok tidak signifikan (p = 0,254). Temuan menunjukkan bahwa kedua model latihan dapat meningkatkan akurasi tembakan dan dapat digunakan sebagai komponen latihan fisik.

Kata kunci: akurasi tembakan; keseimbangan; *core stability*; daya tahan aerobik; pistol angin 10 meter.

Balance and Aerobic Endurance Training Effects on Shooting Accuracy 10 Meter Air Pistol Athletes

Abstract

Shooting accuracy in the 10-meter air pistol event requires postural stability, fine motor control, concentration, and the ability to sustain performance throughout repeated shooting sequences, highlighting the need for physical conditioning that supports consistent athletic performance. This study aimed to analyze the effects of core-stability-based balance training and fartlek-based aerobic endurance training on shooting accuracy among 10-meter air pistol athletes. A quantitative quasi-experimental approach with a two-group pretest-posttest design was employed. Ten athletes from a population of 21 were selected through purposive sampling and allocated by ordinal pairing to a balance training group (n = 5) and an aerobic endurance training group (n = 5). The interventions were conducted for five weeks at a frequency of four sessions per week, while shooting accuracy was assessed using a 60-shot 10-meter air pistol test. The balance group improved from 530.40 ± 9.10 to 537.40 ± 7.00 (p = 0.003; d = 0.896), whereas the aerobic endurance group improved from 528.80 ± 13.60 to 538.60 ± 11.70 (p = 0.005; d = 0.938). The difference in improvement between groups was not statistically significant (p = 0.254). These findings indicate that both training models can improve shooting accuracy and may serve as complementary physical-conditioning.

Keywords: *Shooting accuracy; core stability; aerobic endurance; fartlek; 10 meter air pistol.*

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INTRODUCTION

Shooting accuracy is a central performance outcome in precision shooting because the competitive result depends on the athlete's capacity to reproduce highly stable, controlled, and repeatable motor actions under strict target, distance, and scoring conditions. In the 10-meter air pistol event, the athlete must hold the pistol with one hand, align the sight with a small target, regulate breathing, maintain attention, and execute the trigger while minimizing unnecessary body and hand movement. This makes shooting accuracy a complex response variable rather than a simple indicator of technical skill. Precision-shooting literature shows that performance is related to perceptual, cognitive, and neuromotor processes, including visual function, attentional control, cortical efficiency, and preparation-stage regulation. Studies on rifle shooting among athletes with vision impairment demonstrate that visual function and contrast sensitivity can predict performance quality, indicating that accuracy is partly shaped by the athlete's capacity to process target-related visual information (Allen et al., 2016, 2018). Neurophysiological studies also show that superior shooting performance is associated with specific EEG patterns, beta rhythm network activity, and resting-state brain characteristics during aiming or preparation (Cheng et al., 2023; Gong et al., 2017, 2018). Other evidence indicates that skilled shooters show distinctive brain-network organization when preparing to shoot under restricted sensory conditions, while high-precision shooting tasks involve neural mechanisms linked to preparation, control, and marksmanship regulation (Gu et al., 2022; Shi et al., 2026). Therefore, research on shooting accuracy should be positioned within sport performance science as an inquiry into how technical execution, bodily stability, attentional regulation, and physiological readiness converge in a measurable competitive outcome.

Despite the importance of shooting accuracy, a practical problem remains in identifying which supporting physical-conditioning components can be integrated into routine training for 10-meter air pistol athletes. Technical shooting practice is essential, but repeated 60-shot performance also requires postural steadiness, concentration, self-control, and resistance to fatigue across time. Empirical work on Olympic shooting indicates that shooters themselves perceive psychological and performance-related factors as important components of successful shooting, while studies on self-control and mental exertion show that the effect of cognitive demand on shooting performance can vary according to athlete level and task characteristics (Englert, Dziuba, Giboin, & Wolff, 2021; Englert, Dziuba, Wolff, & Giboin, 2021; Moreira da Silva et al., 2021). In addition, research on light exposure, acute mental recovery strategies, and caffeine intake demonstrates that shooting performance can be influenced by pre-performance physiological or recovery conditions, although the direction and magnitude of effects are not always uniform across contexts (Červenka et al., 2025; Leichtfried et al., 2016; Loch et al., 2023; Nygaard et al., 2019). These findings indicate that the problem is not simply whether athletes can shoot accurately, but how coaches can design conditioning programs that support the physical and psychophysiological requirements of accurate shooting. The problem may occur because precision-shooting training often prioritizes technical repetition, whereas the physical foundations of sustained postural control and endurance may receive less systematic attention. It can be partially addressed by testing structured conditioning interventions that target mechanisms relevant to accuracy, such as balance control through core stability and fatigue resistance through aerobic endurance training.

Previous studies have examined a wide range of strategies to improve shooting or target-oriented performance, but the available literature remains fragmented across different interventions, sports, and measurement contexts. Mental-skill approaches such as neuro-linguistic programming have been tested in shooters, indicating that shooting performance is open to intervention beyond technical practice alone (Ahmadzadeh et al., 2019). Physical and sensorimotor interventions have also been explored, including hand and finger exercises for shooting accuracy, taping in target shooting, and transcranial direct-current stimulation in elite Deaflympic athletes (Balamut & Ocak, 2022; Kisa & Kaya, 2023; Pantovic et al., 2022). Other studies have investigated performance-related interventions in adjacent precision contexts, including balance and shooting accuracy in goalball athletes and hypnosis in air rifle competition (Makaracı et al., 2022; Mattle et al., 2020). These studies show that shooting-related performance can be approached from physical, psychological, and neurophysiological directions. However, they do not directly resolve the specific question addressed in the present study: whether core-stability-based balance training and fartlek-based aerobic endurance training produce comparable or different effects on 10-meter air pistol shooting accuracy within the same field-based quasi-experimental framework. The novelty of this study therefore lies in its simultaneous comparison of two active physical-conditioning models that target different performance pathways. Balance training is positioned as an intervention directed toward postural control and body stabilization, whereas aerobic endurance training is positioned as an intervention directed toward fatigue resistance and sustained performance across repeated shots. The research gap is methodological and contextual: prior work has examined selected interventions or related precision tasks, but limited evidence is available on a direct comparison of these two conditioning models among Perbakin Rinjani NTB 10-meter air pistol athletes using actual 60-shot scoring outcomes.

Accordingly, this study aimed to determine the effect of balance training on shooting accuracy, determine the effect of aerobic endurance training on shooting accuracy, and compare the effects of both intervention models among 10-meter air pistol athletes of Perbakin Rinjani NTB. The study focused on two independent intervention conditions: balance training based on core-stability exercises and aerobic endurance training based on fartlek running. The response variable was shooting accuracy, operationalized as the total score obtained from a standard 60-shot 10-meter air pistol scoring test. The empirical scope was limited to 10 active athletes drawn from the available Perbakin Rinjani NTB shooting context and divided into two groups of equal size. The intervention was implemented over five weeks with four training sessions per week, and the analysis was directed toward pretest-posttest changes within each group and the difference in improvement between groups. The study did not attempt to measure all possible determinants of shooting accuracy, such as EEG activity, heart-rate variability, anxiety, hand tremor, center-of-pressure movement, or direct aerobic capacity; therefore, its contribution is intentionally focused on field-based evidence regarding two practical conditioning programs. Within this scope, the study is expected to contribute to sport-training science by clarifying whether balance-oriented and endurance-oriented conditioning can support shooting accuracy and whether one model shows stronger empirical support than the other. Practically, the findings can inform coaches in designing complementary physical-conditioning programs for precision shooting athletes while maintaining the need for future studies with broader samples and more direct physiological or biomechanical measurements.

METHOD

Research Design

This study used a quantitative quasi-experimental approach with a two-group pretest-posttest design. The design was selected because the objective of the study was to examine whether two structured physical-conditioning interventions produced measurable changes in shooting accuracy among 10-meter air pistol athletes. The independent variable was the intervention model, consisting of balance training based on core-stability exercises and aerobic endurance training based on fartlek running. The dependent variable was shooting accuracy, operationalized as the total score obtained from a standard 60-shot 10-meter air pistol scoring test. The design was quasi-experimental because the athletes were assigned to two active intervention groups through ordinal pairing rather than full randomization. This approach was appropriate for the club-based field setting, where the number of eligible athletes was limited and the intervention had to be implemented within the athletes' existing training environment. Similar precision-shooting studies have treated shooting score and technical execution variables as measurable performance outcomes in air pistol and rifle contexts (Olsson & Laaksonen, 2021; Mon-Lopez et al., 2022).

Table 1. Research design and intervention structure

Group	Pretest	Intervention	Posttest	Primary comparison
Group 1	60-shot 10-meter air pistol score	Balance training based on core stability	60-shot 10-meter air pistol score	Pretest-posttest change within the balance training group
Group 2	60-shot 10-meter air pistol score	Aerobic endurance training based on fartlek running	60-shot 10-meter air pistol score	Pretest-posttest change within the aerobic endurance group
Between groups	Baseline scores considered through ordinal pairing	Different active intervention models	Post-intervention and gain-score comparison	Difference in improvement between the two intervention models

Participants

The population consisted of 21 10-meter air pistol athletes affiliated with Perbakin NTB. Of this population, 10 athletes were included as research participants because they were active, willing to participate, and able to complete the entire research procedure. The sampling technique used was purposive sampling, followed by ordinal pairing for group allocation. The intended inclusion criteria included active training during the previous year, achievement as a shooting athlete, and a maximum age criterion of 18 years. However, the reported participant characteristics indicated that the analyzed sample ranged in age from 15 to 20 years. The final sample was divided into two groups of equal size: 5 athletes in the balance training group and 5 athletes in the aerobic endurance training group. The participants had a mean age of 17.6 ± 1.7 years and a mean training experience of 4.9 ± 1.6 years. In terms of educational level, 8 athletes were senior high school students and 2 were junior high school students.

Table 2. Participant characteristics and sampling information

Characteristic	Available information
Target population	21 10-meter air pistol athletes affiliated with Perbakin NTB
Final sample	10 athletes who were active, willing, and able to complete the research procedure
Sampling technique	Purposive sampling; group allocation using ordinal pairing
Group size	5 athletes in the balance training group and 5 athletes in the aerobic endurance group
Age	15-20 years; mean = 17.6 +/- 1.7 years
Training experience	2-6 years; mean = 4.9 +/- 1.6 years
Education	8 senior high school students and 2 junior high school students

Instruments and Research Procedures

The main measurement instrument was a 10-meter air pistol shooting accuracy test. Each athlete fired 60 shots at a standard 10-meter air pistol target, and the total score was used as the shooting accuracy score. The source document describes the target paper as a 170 mm x 170 mm standard target placed at the required 10-meter distance, with scoring zones from 1 to 10. The available source material reports that the scoring format followed official 10-meter air pistol scoring procedures, but formal evidence of instrument validity, inter-rater reliability, scoring reliability, or calibration reliability was not provided. Therefore, the instrument is described as the scoring instrument used in the field procedure, while formal validity and reliability evidence should be completed if the manuscript is submitted to a journal. The use of shooting score as a performance outcome is consistent with air pistol and sport-shooting research in which shot score, aiming quality, and shooting performance are used as primary performance indicators (Mon-Lopez & Tejero-Gonzalez, 2019; Olsson & Laaksonen, 2021; Wang et al., 2023).

The intervention instruments consisted of two structured training programs. The balance training program was based on core-stability exercises, including plank, high plank, side plank on the right and left sides, high plank with raised hand, high plank with raised leg, and an additional high plank to elbow exercise introduced in week 3. The progression involved increased hold durations and sets across five weeks, ranging from 20-second holds in the first week to 45-second and 40-second holds in later weeks. The aerobic endurance program used fartlek running, combining walking, jogging, and 50-60 meter sprint segments. The program progressed from shorter walking and jogging segments in the first two weeks to longer walking and jogging periods in weeks 3 to 5, with session durations ranging from approximately 20 to 70 minutes. These intervention choices were aligned with the physical demands of precision shooting, where postural control, upper-limb stability, and fatigue resistance are relevant to shooting performance; related DOI-indexed studies have examined scapular endurance, upper-limb activation, muscular strength, and inspiratory training in air pistol athletes (Aydin et al., 2026; Loh et al., 2024; Mon-Lopez et al., 2019; Sezik et al., 2023).

The research procedure was conducted in sequential stages. First, the researcher prepared administrative requirements, training equipment, stopwatch, target papers, scoring sheets, photo and video documentation tools, and daily log books. Second, all eligible athletes completed the pretest to determine initial shooting accuracy. Third, the athletes were allocated into two groups using ordinal pairing based on initial ranking or performance order. Fourth, the balance training and aerobic endurance training interventions were implemented for 5 weeks with 4 sessions per week on Monday, Wednesday, Friday, and Saturday. All sessions were conducted in the afternoon between 16.00 and 18.00 WITA under the supervision of the researcher and Perbakin coach. Fifth, each athlete completed the posttest using the same 60-shot scoring format after the intervention period. Sixth, all pretest and posttest scores were organized for descriptive analysis, assumption testing, inferential testing, and effect-size estimation. Documentation through photographs, videos, and daily log books was used to monitor training participation.

Table 3. Intervention program summary

Component	Balance training group	Aerobic endurance group
Intervention focus	Core-stability-based balance training	Fartlek-based aerobic endurance training
Duration	5 weeks	5 weeks
Frequency	4 sessions per week	4 sessions per week
Training days	Monday, Wednesday, Friday, and Saturday	Monday, Wednesday, Friday, and Saturday
Session time	16.00-18.00 WITA	16.00-18.00 WITA
Main activities	Plank, high plank, side plank, high plank with raised hand, high plank with raised leg, and high plank to elbow in week 3	Walking, jogging, and 50-60 m sprint segments in a fartlek format
Progression	Hold duration and set volume increased across weeks; approximately 20-45 second holds were reported	Walking and jogging segments increased across weeks; session duration approximately 20-70 minutes
Supervision and monitoring	Supervised by the researcher and Perbakin coach; documented using photo/video and daily log book	Supervised by the researcher and Perbakin coach; documented using photo/video and daily log book
Outcome measurement	60-shot 10-meter air pistol score	60-shot 10-meter air pistol score

Table 4. Measurement and procedural overview

Stage	Procedure	Output
Preparation	Preparation of administrative documents, target paper, stopwatch, scoring sheets, documentation tools, and log books	Research readiness and standardized field equipment
Pretest	All included athletes completed the 60-shot 10-meter air pistol scoring test before the intervention	Initial shooting accuracy score
Group allocation	Athletes were allocated into two groups using ordinal pairing based on initial ranking or performance order	Two active intervention groups with five athletes each
Intervention	Each group completed its assigned training program for 5 weeks, 4 sessions per week	Balance training exposure or aerobic endurance training exposure
Posttest	All athletes completed the same 60-shot scoring test after the intervention period	Final shooting accuracy score
Data organization	Pretest, posttest, gain score, assumption-test, t-test, and effect-size data were prepared for analysis	Dataset for statistical analysis

Data Analysis

The data were analyzed quantitatively using descriptive and inferential statistics. The source document reports the use of SPSS version 26 for statistical analysis, so the software version should be standardized in the final manuscript. Descriptive statistics were used to summarize age, training experience, pretest score, posttest score, gain score, percentage change, mean, standard deviation, total score, minimum, maximum, and distributional patterns where available. Assumption testing was conducted before inferential analysis. The Shapiro-Wilk test was used to assess normality because the sample size was small, while Levene's test was used to examine homogeneity of variance between the two intervention groups. A significance level of alpha = 0.05 was used for statistical decision-making. If $p > 0.05$ in the Shapiro-Wilk test, the data were interpreted as normally distributed; if $p > 0.05$ in Levene's test, the group variances were interpreted as homogeneous.

Inferential analysis was conducted in two stages. First, paired-sample t-tests were used to examine whether shooting accuracy changed significantly from pretest to posttest within each intervention group. This analysis was applied separately to the balance training group and the aerobic endurance training group. Second, an independent-sample t-test was used to compare the improvement scores between the two intervention groups. Cohen's effect size was calculated to estimate the practical magnitude of the pretest-posttest change in each group. The source document classified effect-size values of 0-0.20 as weak, 0.21-0.50 as moderate, 0.51-1.00 as large, and greater than 1.00 as strong. Pearson correlation, simple regression, and multiple regression were not used because the operational design compared two categorical intervention conditions rather than estimating prediction from continuous independent variables. In addition, direct numerical measures of balance capacity and aerobic endurance capacity were not reported, so regression coefficients, R Square values, or standardized Beta values could not be estimated without creating unsupported statistics.

Table 5. Data analysis plan

Analysis stage	Technique	Purpose / decision criterion
Descriptive analysis	Mean, standard deviation, total score, minimum, maximum, percentage change, and gain score	To summarize participant characteristics and shooting accuracy trends
Normality test	Shapiro-Wilk test	p > 0.05 indicates normal distribution
Homogeneity test	Levene test	p > 0.05 indicates homogeneous variance
Within-group comparison	Paired-sample t-test	p < 0.05 indicates a significant pretest-posttest change within each group
Between-group comparison	Independent-sample t-test	p < 0.05 indicates a significant difference in improvement between groups
Practical magnitude	Cohen's effect size	Used to estimate the magnitude of intervention effect according to the source classification
Unavailable analyses	Pearson correlation and regression analyses	Not conducted because continuous predictor variables for balance and aerobic endurance were not reported

RESULTS AND DISCUSSION

The first finding concerns the composition of the sample, the completeness of the data, and the structure of the research variables. The study analyzed 10 valid athlete records from the initial population of 21 10-meter air pistol athletes affiliated with Perbakin Rinjani NTB. The final sample was divided equally into two intervention groups: the balance training group based on core stability (n = 5) and the aerobic endurance training group based on fartlek running (n = 5). The available demographic data show that the participants were 15 to 20 years old, with a mean age of 17.60 +/- 1.70 years. Training experience ranged from 2 to 6 years, with a mean of 4.90 +/- 1.60 years. Most participants were senior high school students (8 athletes; 80.0%), while 2 athletes (20.0%) were junior high school students. The independent variable was the training intervention model, consisting of balance training and aerobic endurance training. The dependent variable was shooting accuracy, measured as the total score from a standard 60-shot 10-meter air pistol scoring test. All participants had complete pretest and posttest scores; therefore, no missing value was reported in the analyzed outcome data. The sample and variable profile is summarized in Table 6.

Table 6. Sample description, research variables, and data completeness

Component	Observed data
Initial population	21 10-meter air pistol athletes
Valid sample analyzed	10 athletes
Group allocation	Balance training n = 5; aerobic endurance training n = 5
Age	15-20 years; mean = 17.60 +/- 1.70
Education	Senior high school = 8 athletes (80.0%); junior high school = 2 athletes (20.0%)
Training experience	2-6 years; mean = 4.90 +/- 1.60
Independent variable	Training intervention model: balance training and aerobic endurance training
Dependent variable	Shooting accuracy score from a 60-shot 10-meter air pistol scoring test
Missing values	No missing pretest or posttest outcome data were reported

The second finding concerns the descriptive pattern of shooting accuracy before and after the intervention. At the overall level, the mean shooting score increased from 529.60 at pretest to 538.00 at posttest, producing an overall mean gain of 8.40 points across all 10 athletes. The overall pretest score ranged from 509 to 540, whereas the posttest score ranged from 520 to 550. This pattern indicates that all observed scores remained within a relatively high scoring band, but the posttest scores shifted upward after the 5-week intervention period. At the group level, the balance training group increased from a mean pretest score of 530.40 +/- 9.18 to a mean posttest score of 537.40 +/- 7.09, with a gain mean of 7.00 +/- 2.35 points. The aerobic endurance group increased from a mean pretest score of 528.80 +/- 13.66 to a mean posttest score of 538.60 +/- 11.78, with a gain mean of 9.80 +/- 3.96 points. The aerobic endurance group had a larger numerical mean gain and a wider gain range than the balance training group. However, the descriptive data alone only show the direction and size of the observed change; statistical testing was required to determine whether these changes were significant. The descriptive statistics are presented in Table 7.

Table 7. Descriptive statistics of shooting accuracy by intervention group

Variable	N	Mean	Median	SD	Variance	Range	Min	Max
Overall pretest score	10	529.60	536.00	11.01	121.16	31	509	540
Overall posttest score	10	538.00	541.00	9.19	84.44	30	520	550
Overall gain score	10	8.40	9.00	3.41	11.60	11	4	15
Balance pretest	5	530.40	536.00	9.18	84.30	20	519	539
Balance posttest	5	537.40	541.00	7.09	50.30	17	528	545
Balance gain	5	7.00	6.00	2.35	5.50	5	5	10
Aerobic pretest	5	528.80	537.00	13.66	186.70	31	509	540
Aerobic posttest	5	538.60	542.00	11.78	138.80	30	520	550
Aerobic gain	5	9.80	10.00	3.96	15.70	11	4	15

The third finding concerns the distribution of individual score changes within each intervention group. In the balance training group, all five athletes improved after the intervention, with gain scores of 5, 6, 5, 9, and 10 points. The most frequent gain score in this group was 5 points, which appeared in 2 athletes or 40.0% of the group. The remaining gain scores of 6, 9, and 10 points each appeared once, representing 20.0% of the group for each score. The range of improvement in the balance training group was 5 points, from a minimum gain of 5 points to a maximum gain of 10 points. In the aerobic endurance group, all five athletes also improved, with gain scores of 10, 15, 11, 9, and 4 points. Unlike the balance training group, no gain score was repeated in the aerobic endurance group; each gain value appeared once and represented 20.0% of the group. The aerobic endurance group showed a wider spread of improvement, with an 11-point range from a minimum gain of 4 points to a maximum gain of 15 points. This distribution shows that the direction of change was consistently positive in both groups, but the magnitude of individual improvement was more variable in the aerobic endurance group. The frequency distribution is shown in Table 8. No histogram or graphical figure was provided in the available research data.

Table 8. Frequency distribution of shooting accuracy gain scores

Group	Gain score	Frequency	Percent
Balance training	5	2	40.0
Balance training	6	1	20.0
Balance training	9	1	20.0
Balance training	10	1	20.0
Aerobic endurance	4	1	20.0
Aerobic endurance	9	1	20.0
Aerobic endurance	10	1	20.0
Aerobic endurance	11	1	20.0
Aerobic endurance	15	1	20.0

The fourth finding concerns the assumption tests and the magnitude of the intervention effects. The Shapiro-Wilk normality test indicated that the data for the balance training condition were normally distributed, $W = 0.824$, $p = 0.126$. The aerobic endurance condition also met the normality assumption, $W = 0.919$, $p = 0.527$. Since both significance values were greater than 0.05, the use of parametric procedures for the pretest-posttest comparison was supported by the reported assumption tests. The Levene homogeneity test produced a statistic of 0.100 with $p = 0.760$, indicating homogeneous variance for the between-group comparison. The effect-size results showed that both interventions had large observed practical effects. The balance training group produced Cohen's $d = 0.896$, while the aerobic endurance group produced Cohen's $d = 0.938$. The effect size for the aerobic endurance group was numerically higher than that of the balance training group, following the same pattern as the mean gain scores. However, these values describe the magnitude of change within each group and do not independently establish a statistically significant difference between the two interventions. Overall, the assumption-test results supported the use of the selected inferential tests, and the effect-size estimates showed that both intervention groups had large pretest-posttest changes in shooting accuracy. The assumption tests and effect-size results are presented in Table 9.

Table 9. Assumption tests and effect sizes

Test/variable	Statistic	Sig.	Decision
Shapiro-Wilk: balance training data	0.824	0.126	Normal distribution
Shapiro-Wilk: aerobic endurance data	0.919	0.527	Normal distribution
Levene homogeneity test	0.100	0.760	Homogeneous variance
Cohen's d: balance training	0.896	-	Large effect
Cohen's d: aerobic endurance	0.938	-	Large effect

The fifth finding concerns the within-group changes in shooting accuracy after five weeks of training. The paired-sample t-test showed that the balance training group had a statistically significant increase in shooting accuracy from pretest to posttest, t = -6.60, p = 0.003. The mean score increased from 530.40 +/- 9.10 to 537.40 +/- 7.00, producing a mean gain of 7.00 +/- 2.30 points, or approximately 1.30%. This result supports the first hypothesis that balance training improved shooting accuracy in the observed athletes. The aerobic endurance group also showed a statistically significant pretest-posttest increase, t = -5.50, p = 0.005. The mean score increased from 528.80 +/- 13.60 to 538.60 +/- 11.70, producing a mean gain of 9.80 +/- 3.90 points, or approximately 1.80%. This result supports the second hypothesis that aerobic endurance training improved shooting accuracy. The pattern across both groups was consistent: each group showed higher posttest means than pretest means, and both p-values were below the 0.05 significance level. These data indicate that both intervention models were followed by statistically significant improvements in the 60-shot 10-meter air pistol score. The paired-sample t-test results are presented in Table 10.

Table 10. Paired-sample t-test results for pretest-posttest shooting accuracy

Intervention group	Pretest Mean +/- SD	Posttest Mean +/- SD	Gain Mean +/- SD	% change	t	Sig.	Cohen d	Decision
Balance training (core stability)	530.40 +/- 9.10	537.40 +/- 7.00	7.00 +/- 2.30	1.30	-6.60	0.003	0.896	Significant
Aerobic endurance training (fartlek)	528.80 +/- 13.60	538.60 +/- 11.70	9.80 +/- 3.90	1.80	-5.50	0.005	0.938	Significant

The sixth finding concerns the direct comparison between the two intervention effects and the final hypothesis decision. The gain score in the balance training group was 7.00 +/- 2.30 points, whereas the gain score in the aerobic endurance group was 9.80 +/- 3.90 points. Numerically, the aerobic endurance group had a 2.80-point larger mean improvement than the balance training group. However, the reported independent-sample t-test indicated that this difference was not statistically significant, t(8) = -1.228, p = 0.254. Because the significance value was greater than 0.05, the third hypothesis was not supported. Therefore, the data did not show a statistically significant difference between the effect of balance training and the effect of aerobic endurance training on shooting accuracy. The pattern of the results shows two simultaneous findings: first, both groups improved significantly from pretest to posttest; second, the improvement difference between the two groups was not large enough to reach statistical significance in this sample.

Based on the hypothesis decisions, H1 and H2 were supported, while H3 was not supported. Thus, the main empirical result is that both training programs improved shooting accuracy among the observed 10-meter air pistol athletes, but neither intervention was statistically superior to the other. The between-group comparison and hypothesis decisions are presented in Table 11.

Table 11. Between-group comparison and hypothesis decisions

Hypothesis/Comparison	Statistical result	Sig.	Decision
H1: Balance training improves shooting accuracy	t = -6.60; Cohen d = 0.896	0.003	Supported
H2: Aerobic endurance training improves shooting accuracy	t = -5.50; Cohen d = 0.938	0.005	Supported
H3: Balance vs aerobic endurance gain difference	t(8) = -1.228; balance gain = 7.00 +/- 2.30; aerobic gain = 9.80 +/- 3.90	0.254	Not supported

In summary, the Results show a consistent positive change in shooting accuracy after the 5-week intervention period. The overall mean score increased from 529.60 at pretest to 538.00 at posttest, with a total observed gain of 84 points across all 10 participants. At the group level, the balance training group improved by 7.00 points and the aerobic endurance group improved by 9.80 points. The distribution of gain scores indicated that every athlete improved, although the aerobic endurance group displayed a wider spread of individual improvement. The assumption tests supported the use of parametric analysis, with normality values above 0.05 and homogeneous variance based on the reported Levene test. The paired-sample t-tests showed significant within-group improvements for both balance training ($p = 0.003$) and aerobic endurance training ($p = 0.005$), and both groups had large reported effect sizes. The between-group comparison showed that the aerobic endurance group had a higher numerical gain, but the independent-sample t-test did not show a statistically significant difference between the two intervention effects ($p = 0.254$). Therefore, the main pattern of the data is that both intervention models were associated with improved shooting accuracy, while the evidence did not support the statistical superiority of one model over the other in the analyzed sample.

DISCUSSION

The first issue raised by the findings is the meaning of the sample composition and the field-based intervention context. The study involved only 10 valid records from 21 eligible club athletes, divided equally into balance training and aerobic endurance training groups. This small and context-specific sample does not weaken the descriptive value of the findings, but it does frame the results as applied evidence from a club training environment rather than as population-level evidence for all 10-meter air pistol athletes. In precision shooting research, small samples are common because trained shooters are difficult to recruit and because testing often requires controlled shooting facilities, repeated scoring procedures, and supervised intervention conditions. This pattern is visible in several shooting studies that also relied on limited or specialized samples, such as air pistol work on upper-limb muscle activation, scapular endurance, hand tremor, and elite-level technical factors (Liu et al., 2024; Loh et al., 2024; Mon-Lopez et al., 2022; Sezik et al., 2023).

However, the present sample differs from larger observational studies in air rifle, adolescent shooters, and biathlon, which included broader athlete groups and therefore produced stronger statistical precision (Ihalainen et al., 2016; Jones et al., 2023; Zhao et al., 2024). The key difference lies in design and sampling: this study tested two short field interventions with five athletes per group, whereas many previous studies used cross-sectional, competition, or monitoring data. Consequently, the theoretical implication is that the study adds local experimental evidence to the conditioning literature, while the methodological implication is that future research should replicate the design with larger samples, clearly reported sex distribution, and stricter inclusion criteria.

The overall increase in shooting accuracy indicates that the athletes' 60-shot performance improved after the 5-week conditioning period, but the meaning of this improvement should be understood as a performance trend within a pretest-posttest design rather than as proof of one isolated causal pathway. Across all athletes, the mean score increased from 529.60 to 538.00, and every athlete showed a positive gain. This pattern suggests that both intervention conditions were followed by improved scoring consistency in the observed sample. The finding is coherent with the concept that shooting performance is multidimensional: technical execution, holding stability, aiming quality, and trigger control interact with postural and physiological stability. Air pistol research has shown that performance is associated with technical components such as aiming accuracy, stability of hold, and triggering quality (Mon-Lopez et al., 2022; Olsson & Laaksonen, 2021), while air rifle studies similarly identify holding ability, aiming accuracy, triggering, and competition-specific changes as important determinants of score (Ihalainen et al., 2016, 2018; Lang & Zhou, 2024). The present finding is similar in showing that score change reflects more than a single motor action; however, it differs because it did not measure aiming trajectory, trigger dynamics, or rifle/pistol movement directly. Studies using optoelectronic or biomechanical measurement provide more detailed process-level explanations than the present 60-shot total score can provide (Mon-Lopez et al., 2022; Spancken et al., 2021). Thus, the improvement is meaningful as an outcome-level change, but its underlying mechanism remains partly inferential. Practically, the finding supports the value of integrating conditioning work into shooting training, while methodologically it indicates the need for future studies to combine score outcomes with direct technical indicators.

The significant improvement in the balance training group suggests that core-stability-based training may contribute to shooting accuracy by strengthening the athlete's ability to maintain postural control during repeated aiming and firing sequences. In 10-meter air pistol shooting, athletes must hold the pistol with one arm while stabilizing the trunk and lower body; therefore, small changes in body sway, shoulder position, or arm alignment can influence shot consistency. This interpretation is consistent with research showing that postural balance and aiming technique are related to shooting performance in rifle athletes, particularly when the task requires stable standing control (Lang & Zhou, 2022, 2024). It also aligns with biathlon research indicating that body sway, rifle stability, and vertical or lateral movement can discriminate higher from lower shooting performance under specific shooting positions and workloads (Sattlecker et al., 2014, 2017; Zoppirolli et al., 2026). Evidence from pistol-related contexts further supports this mechanism: lower-extremity fatigue and footwear conditions can influence postural variables during 10-meter air pistol firing, and plantar pressure distribution has been associated with differences between state and national-level pistol shooters (Bhardwaj et al., 2025; Zhang et al., 2023). Nevertheless, the present finding should not be read as proof that postural balance alone determines accuracy. Some air rifle evidence indicates that direct postural-balance contribution can be small when technical holding and triggering variables are considered together (Ihalainen et al., 2016). The difference may arise because the present study tested a balance intervention without measuring center of pressure, sway velocity, or pistol trajectory. The practical implication is that core-stability training appears useful, but future work should include direct balance and aiming-stability measures to verify the pathway.

The significant improvement in the aerobic endurance group indicates that fartlek-based conditioning may support shooting accuracy by helping athletes sustain performance over a 60-shot sequence. Although 10-meter air pistol is not an endurance race, the scoring task requires repeated cycles of preparation, aiming, breath control, trigger execution, and psychological steadiness. Aerobic endurance may therefore matter not because it directly determines the shot, but because it supports fatigue resistance and physiological regulation across time. This interpretation is consistent with biathlon research showing that shooting accuracy and penalty outcomes are important contributors to race performance, particularly when athletes must shoot after repeated physical loads (Jones et al., 2023; Luchsinger et al., 2020). It also corresponds with evidence linking heart-rate variability and physiological state to shooting performance in sport shooters and adolescent shooters (Ortega & Wang, 2018; Zhao et al., 2024). However, the present finding differs from studies in which fatigue did not clearly reduce shooting accuracy. Heinrich et al. (2020) found that physiological fatigue affected shooting time more than accuracy in expert biathletes, while Akyuz et al. (2019) reported that skeletal muscle fatigue did not affect handball shooting accuracy. These differences may be explained by sport-specific demands, participant skill level, fatigue protocol, and the performance indicator used. The present study used a 5-week endurance intervention and 60-shot air pistol scores, whereas other studies used acute fatigue protocols or dynamic ball-sport tasks. A key limitation is that aerobic capacity, heart rate, and perceived fatigue were not directly measured. Thus, the implication is promising but conditional: fartlek training may be useful for maintaining performance consistency, but future studies should verify this pathway with physiological monitoring.

The positive gain distribution in both groups is important because it shows that improvement was not limited to one or two athletes. All five athletes in the balance group and all five athletes in the aerobic endurance group improved after training, although the pattern of improvement differed between groups. The balance group showed a narrower gain range, whereas the aerobic endurance group showed a wider gain range, including both the smallest and largest observed individual improvements. This pattern suggests that the two interventions may have produced more homogeneous adaptation in the balance group and more variable adaptation in the aerobic endurance group. Such variability is plausible in precision sports because athletes differ in baseline technical skill, neuromuscular control, autonomic regulation, and response to training. Studies on air pistol and pistol shooting show that upper-limb muscle endurance, handgrip and shoulder strength, muscle activation, and hand tremor can differ across athletes and relate differently to performance (Liu et al., 2024; Loh et al., 2024; Mon-Lopez et al., 2019; Sezik et al., 2023). Similar individual-response patterns appear in neurofeedback and psychophysiological studies, where attentional regulation and brain activity markers vary according to skill level and training response (Bakhtafrooz et al., 2025; Cheng et al., 2017; Wang et al., 2023). The present study differs from these works because it did not include direct EMG, tremor, EEG, or strength measures, making it impossible to identify which athletes improved because of neuromuscular, technical, or psychological mechanisms. This is a limitation of interpretation. Practically, the distribution of gains suggests that coaches should not only compare group means but also monitor individual response patterns when prescribing balance or endurance training.

The large within-group effect sizes add practical meaning to the statistically significant pretest-posttest changes, but they must be interpreted cautiously because effect sizes can be unstable in very small samples. The balance training group produced Cohen's d = 0.896 and the aerobic endurance group produced Cohen's d = 0.938, indicating large observed changes within the source classification. In precision-shooting research, practically meaningful changes can be valuable even when numerical score changes appear small, because competition outcomes may be influenced by narrow score margins. This is consistent with research showing that technical elements such as triggering, holding, and aiming accuracy can explain substantial variance in shooting score when measured precisely (Ihalainen et al., 2016; Mon-Lopez et al., 2022; Olsson & Laaksonen, 2021). However, the present study differs from these analytic models because it did not estimate variance explained by predictors and did not use regression, optoelectronic trajectory analysis, or process-level measurement. Other intervention studies using balance, respiration, or respiratory-muscle training have also reported performance benefits in shooting or precision athletes, but they often included different samples, training combinations, or outcome measures (Aydin et al., 2026; Park et al., 2019; Selcuk et al., 2025). These design differences make direct effect-size comparison inappropriate. The assumption tests supported parametric analysis in the present data, yet normality testing with n = 5 per group has limited diagnostic power. Therefore, the methodological implication is that effect sizes should accompany p values, but future studies should report confidence intervals, individual-response plots, and preferably control groups to strengthen practical interpretation.

The non-significant difference between the two intervention effects is one of the most important findings because it prevents a simplistic conclusion that one training model is superior. Although the aerobic endurance group had a larger numerical gain than the balance group, the independent-sample t-test did not show a significant between-group difference. This means that, within the available sample and intervention duration, the evidence supports improvement in both groups but not superiority of one intervention. This result fits the broader concept that precision-shooting performance depends on multiple interacting components rather than a single dominant physical factor. Studies in air pistol, air rifle, and biathlon consistently show that shooting performance may involve technical stability, triggering, aiming accuracy, postural balance, physiological regulation, and psychological control (Lang & Zhou, 2024; Mon-Lopez et al., 2022; Olsson & Laaksonen, 2021; Sattlecker et al., 2017; Spancken et al., 2021). At the same time, some intervention studies suggest that specific strategies can improve selected aspects of performance, including mindfulness, neurofeedback, balance-respiration training, and inspiratory muscle training (Aydin et al., 2026; Li et al., 2026; Park et al., 2019; Purmirza et al., 2024). The apparent difference between these literatures is not contradictory: specific interventions may be effective, but different interventions may converge on the same final score through different mechanisms. In the present study, balance training may have supported postural control, while aerobic endurance may have supported fatigue resistance. The small sample, short intervention period, and absence of a passive control group reduce the ability to detect between-group superiority. Practically, the safest implication is to integrate both training models rather than choose one exclusively.

The findings also have theoretical, practical, and methodological implications for future work on 10-meter air pistol performance. Theoretically, the study supports a multidimensional view of shooting accuracy in which physical conditioning contributes to performance alongside technical and psychophysiological factors. This view is consistent with studies linking shooting performance to sensorimotor rhythm, EEG activity, heart-rate variability, stress response, mindfulness, and ritualized self-control (Cheng et al., 2017; Li et al., 2026; Ortega & Wang, 2018; Wang et al., 2023; Yun et al., 2024; Zhang et al., 2021; Zhao & Zhang, 2025). Practically, the findings suggest that coaches may include both core-stability and aerobic-endurance work as complementary conditioning components, while monitoring whether each athlete responds more strongly to postural or endurance-oriented training. Methodologically, however, several limitations restrict the strength of inference. The study used only 10 athletes, did not report sex distribution, had an inconsistency between the stated age criterion and two reported athlete ages, and did not include a non-treatment control group. In addition, the study measured shooting score but did not directly measure balance capacity, aerobic capacity, heart rate, perceived fatigue, psychological state, EMG, tremor, or aiming trajectory. Future research should address these gaps by using larger samples, randomized or controlled designs, longer intervention periods, validated scoring systems, and direct process measures such as electronic targets, optoelectronic systems, wearable sensors, EMG, HRV, or EEG (Gao et al., 2024; Mon-Lopez & Tejero-Gonzalez, 2019; Saputra et al., 2024). These additions would clarify whether performance gains are driven primarily by postural stability, fatigue resistance, neuromuscular control, or psychophysiological regulation.

CONCLUSION

This study concludes that both core-stability-based balance training and fartlek-based aerobic endurance training improved shooting accuracy among 10-meter air pistol athletes of Perbakin Rinjani NTB. The findings directly answer the research objectives by showing that each intervention produced a meaningful pretest-posttest improvement in shooting performance, while the comparison between the two intervention models did not demonstrate a statistically significant difference. Thus, the evidence supports the effectiveness of both conditioning approaches but does not support the superiority of one model over the other.

Scientifically, this study reinforces the view that shooting accuracy in the 10-meter air pistol event is not only a technical outcome, but also a performance response influenced by physical-conditioning components related to postural control and fatigue resistance. Theoretically, the findings contribute to sport-training knowledge by positioning balance-oriented and endurance-oriented conditioning as relevant components in precision shooting preparation. Practically, the results suggest that coaches may integrate core-stability exercises and fartlek-based aerobic training as complementary elements within routine training programs for air pistol athletes, rather than treating them as competing alternatives.

However, the interpretation of the findings should consider several limitations. The study involved a small sample from one club context, used a short intervention period, did not include a non-treatment control group, and did not directly measure balance capacity, aerobic capacity, heart rate, fatigue, psychological state, or technical shooting variables. Future studies should involve larger and more diverse samples, longer intervention periods, controlled or randomized designs, and direct biomechanical, physiological, and psychophysiological measurements. Such improvements would help clarify the mechanisms through which physical conditioning contributes to shooting accuracy in precision shooting athletes.

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