DEVELOPMENT OF A CIRCUIT TRAINING MODEL TO INCREASE MUSCULAR ENDURANCE IN ARCHERY ATHLETES

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Abstract

Archery performance requires stable posture, consistent bow pulling, and sustained concentration during repeated shots. However, physical conditioning programs in archery are often less systematic and insufficiently specific to the muscular endurance demands of the sport. This study aimed to develop and examine the effectiveness of a circuit training model designed to improve muscular endurance in archery athletes. The study used a Research and Development approach adapted from Borg and Gall, combined with a pretest-posttest control group design. Forty junior and senior archery athletes were selected through purposive sampling and divided into an experimental group and a control group, with 20 athletes in each group. The experimental group followed an eight-week circuit training program, three sessions per week, consisting of eight exercise stations performed for 40 seconds with 20 seconds of rest between stations, while the control group continued conventional training. Data were collected using muscular endurance tests, including push-up, isometric bow hold, plank endurance, and archery accuracy tests. Data analysis included normality, homogeneity, paired sample t-test, independent sample t-test, and effect size. The results showed that the data were normally distributed and homogeneous. Descriptive statistics indicated an increase in the mean score from 62.90 to 82.45. The paired sample t-test showed a significant difference between pretest and posttest scores (p < 0.001). Findings indicate that the developed circuit training model is effective and can be applied by coaches to improve muscular endurance in archery athletes.

Keywords: *circuit training; muscular endurance; archery athletes; training model; sports performance*

1. INTRODUCTION

Archery is a competitive sport that demands a combination of physical, technical, mental, and concentration skills. In practice, an archer must maintain a stable body position, consistently draw the bow, and maintain focus for relatively long periods of time during training sessions and matches(Rankin et al., 2024). This makes physical fitness a crucial foundation for every archer to achieve optimal performance. Archery is not only a sport that relies on accuracy but also requires strong muscular endurance, particularly in the arms, shoulders, back, and core. Muscular endurance plays a crucial role in maintaining the quality of archery techniques repeatedly without experiencing a decline in performance due to fatigue(…, Bennett, et al., 2025). When an athlete's muscular endurance decreases, postural stability is compromised, leading to a decline in shooting accuracy.

In archery competitions, athletes are often faced with long matches with a high number of shots(Geng et al., 2023). This requires the muscles to work continuously to maintain posture, hold the bow, and consistently release the arrow. Therefore, developing the physical component of muscle endurance is a primary requirement in archery athlete development programs(…, Luqmani, et al., 2022). The reality on the ground shows that physical training programs in archery often focus more on technical training than on systematic physical conditioning development. Many coaches still use conventional training approaches that have not been specifically designed to meet the physiological needs of archers. This results in the development of muscle endurance being less than optimal.

This condition impacts athlete performance, particularly in the final stages of a match. Athletes often experience arm tremors, difficulty maintaining an anchor point, and decreased aiming stability(Archer-Nanda & Dwyer, 2024). These symptoms indicate muscle fatigue, which can impact shooting accuracy. This issue underscores the need for innovative, more effective and structured physical training models(…, Gilbody, et al., 2021). One approach to physical training that can be applied to improve muscle endurance is circuit training. Circuit training is a training method that combines several forms of exercise in a series of posts or stations performed sequentially with relatively short rest periods. This method is designed to train various physical components, including muscular endurance, simultaneously(Hung et al., 2021).

The advantage of circuit training lies in its flexibility in adapting the type of training to the needs of a particular sport. In the context of archery, circuit training can be specifically designed with an emphasis on static strength training, shoulder stability, arm muscle endurance, core strength, and postural balance(Grimmich et al., 2023). Therefore, this training model is highly relevant for supporting the performance of archers. Furthermore, circuit training is known to be effective in increasing training time efficiency(Kuch et al., 2023). Athletes can train various muscle groups in a single, integrated training session. This is crucial considering that archers' training schedules are generally already packed with technical and mental training. By using time efficiently, physical development can still be achieved without compromising the portion of technical training.

Previous research has shown that circuit training can improve muscle endurance in various sports. This method has proven effective in increasing functional strength, muscle work capacity, and physiological adaptation to repeated training loads. However, studies specifically developing circuit training models for archery are still very limited(Pike et al., 2022). These research limitations open up opportunities to develop more specific and applicable training models for archery athletes. The developed training model must consider the characteristics of archery movements, the needs of dominant muscles, match duration, and the principles of competitive sports training(Lu & Zhong, 2023). With this approach, the results are expected to make a significant contribution to improving athlete performance.

Developing a circuit training model for archery involves more than just designing exercise variations; it must also consider scientific principles such as overload, specificity, progression, individualization, and recovery(…, Carver, et al., 2025). Applying these principles is crucial to ensure optimal physical adaptation without the risk of injury or overtraining. In the context of modern sports development, developing a research-based physical training model is crucial. A training program based on scientific studies is more measurable, systematic, and effective than training based solely on practical experience(… et al., 2023). Therefore, research into developing a circuit training model for archery has both academic and practical urgency.

Academically, this research can enrich the body of sports science, particularly in the theory and methodology of physical training for precision sports(…, Stone, et al., 2022). Archery, as a unique sport, requires a different training approach than purely explosive or endurance sports(Jochimsen et al., 2024). This study is expected to provide new perspectives on the development of the physical condition of archery athletes. Practically, the results of this study can serve as a guide for coaches in designing more effective physical training programs. An empirically tested training model will facilitate coaches in implementing training programs tailored to the needs of athletes(Downing et al., 2022). Furthermore, athletes can also benefit from increased muscle endurance, which directly impacts the quality of their performance during competitions.

The development of a circuit training model is also relevant to the development needs of young athletes. In the long-term development phase, increasing muscle endurance must be done gradually and in a planned manner to support optimal technical development(…, Ridha, et al., 2021). The right training model will help young athletes build a strong physical foundation from an early age. In today's era of sports science, physical training approaches must be based on evidence-based practice. Each training model implemented needs to undergo a process of validation, testing, and effectiveness evaluation. This is crucial to ensure the resulting training model truly meets the needs of athletes and can be widely applied in archery development.

This research focuses on the development of a circuit training model specifically designed to improve the muscular endurance of archery athletes(…, Rao, et al., 2021). The developed model will be tailored to the biomechanical characteristics of archery movements and the physiological needs of athletes during training and competition. Thus, the training provided is contextual and applicable(Moriarty et al., 2024). Through the development of this model, it is hoped that athletes will improve their ability to maintain postural stability, pulling strength, and consistent shooting accuracy throughout the duration of the match. Good muscular endurance will help athletes minimize performance declines due to physical fatigue.

Furthermore, this research is expected to produce innovative, structured, and easily implemented training models for coaches at various levels. These products can take the form of training guides, modules, or circuit training protocols that are ready for implementation in the field. Based on this description, research on the Development of a Circuit Training Model to Improve Muscular Endurance in Archery Athletes is crucial. This research is expected to address the need for specific, effective, and scientifically based physical training models to support the continuous improvement of archery athlete performance.

2. METHODS

This study used the Research and Development (R&D) method by adapting the development model from Borg and Gall, which was simplified into several main stages, namely: needs analysis, product design, expert validation, small group trials, product revision, large group trials, and evaluation of model effectiveness(Gani & Purbangkara, 2023). The research design used was a mixed method with quantitative and qualitative approaches. The qualitative approach was used in the needs analysis and expert validation stages to obtain input related to the development of the circuit training model. In contrast, the quantitative approach was used in the model effectiveness testing stage with a pretest-posttest control group design. In this design, the research subjects were divided into two groups, namely the experimental group that was given treatment in the form of the developed circuit training model and the control group that was given a conventional training program. The research participants consisted of junior and senior-level archery athletes who actively participated in coaching at archery clubs in the research area. The research sample was determined using a purposive sampling technique, with inclusion criteria including: athletes aged 15–22 years, having at least one year of training experience, actively participating in regular training at least three times per week, and being in good physical condition without injuries to the shoulders, arms, or back. The study included 40 athletes, divided proportionally into two groups: 20 in the experimental group and 20 in the control group. In addition to the athletes, the study also involved three experts as product validators: a sports coaching expert, a sports physiologist, and a nationally certified archery coach.

The research instruments used included qualitative instruments. The quantitative instruments consisted of an arm muscle endurance test using a push-up test, a shoulder muscle endurance test using an isometric bow hold test, a core muscle endurance test using a plank endurance test, and an archery accuracy test with a competition-standard shooting score assessment. In addition, an observation sheet was used to assess archery technique performance during training. The qualitative instruments consisted of a semi-structured interview guide, an expert validation questionnaire using a 1–5 Likert scale, and a field note sheet to record athlete responses during the implementation of the training model. The instrument's content validity was tested through expert judgment, while the quantitative instrument's reliability was tested using the Cronbach's Alpha coefficient. The data collection procedure was carried out in several stages. The first stage was a needs analysis through field observations, interviews with coaches and athletes, and a study of documentation of the training program being implemented. The second stage was the preparation of a draft circuit training model based on the results of the needs analysis and theoretical review. The third stage was expert validation to obtain input on the feasibility of the content, training structure, intensity, duration, and suitability of the model to the characteristics of archery. The fourth stage was a small group trial on 10 athletes to determine the model's implementation. After revision, the model was tested on a large group for 8 weeks, with training sessions three times per week lasting 60 minutes each. Pretest measurements were taken before treatment, while posttests were administered after the program was completed. The following figure illustrates the research methods for this study.

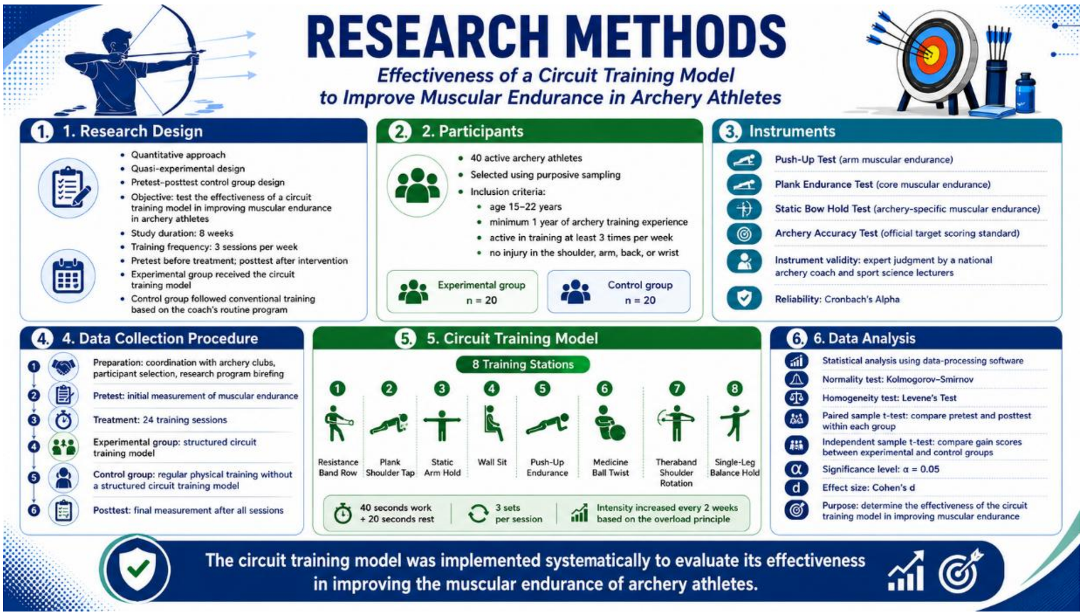

Figure 1. Research Methods

The circuit training model was implemented in the experimental group through eight training stations specifically designed to improve the endurance of dominant archery muscles, including resistance band rows, wall sits with bow simulation, plank shoulder taps, medicine ball twists, static arm holds, push-up endurance, single-leg balance holds, and theraband shoulder rotations. Each station was performed for 40 seconds with a 20-second rest period between stations, and each session consisted of three sets of exercises. The training intensity was increased progressively every two weeks according to the overload principle. Meanwhile, the control group underwent a regular physical training program implemented by the trainer without modifications to the circuit training model. During the implementation, the researcher and the trainer monitored the program's implementation and the athletes' physical responses. Data analysis techniques were descriptive and inferential. Data from expert validation were analyzed using a feasibility percentage to determine the model's validity category. Quantitative data from the pretest and posttest results were analyzed using normality and homogeneity tests as prerequisites for analysis.

Furthermore, the effectiveness of the model was tested using a paired sample t-test to determine differences in each group, and an independent sample t-test to compare improvements between the experimental and control groups. The effect of the training model was calculated using Cohen's d effect size. Meanwhile, qualitative data from interviews and observations were analyzed through data reduction, data presentation, and conclusion drawing. All analyses were conducted using statistical software to ensure the accuracy of the results, allowing for replication by other researchers in different contexts and populations. .

3. RESULTS AND DISCUSSION

RESULT

Before conducting a hypothesis test to determine the effectiveness of the circuit training model on increasing the muscular endurance of archery athletes, a prerequisite analysis test was first conducted on the research data. This prerequisite test aims to ensure that the data obtained meets the statistical assumptions required in parametric analysis, so that the test results can be interpreted accurately and validly. One of the prerequisite tests conducted is the Test of Normality, which is used to determine whether the distribution of pre-test and post-test data in the experimental and control groups is normally distributed. Normality testing was carried out using the Kolmogorov-Smirnov and Shapiro-Wilk tests with a significance level of $\alpha = 0.05$. The results of this test serve as the basis for determining the feasibility of using advanced statistical analysis techniques, such as the paired sample t-test and independent sample t-test, in testing the effect of the applied training model.

Table 1. Tests of Normality

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Hasil	Pretest A (Kelas Kontrol)	.143	20	.200*	.935	20	.192
	Posttest A (Kelas Kontrol)	.145	20	.200*	.951	20	.376
	Pretest B (Kelas Eksperimen)	.107	20	.200*	.972	20	.793
	Posttest B (kelas Eksperimen)	.123	20	.200*	.960	20	.538

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on Table 1. Tests of Normality, the normality test was conducted on four data groups, namely Pretest A/Control, Posttest A/Control, Pretest B/Experiment, and Posttest B/Experiment, with two testing methods, namely Kolmogorov–Smirnov and Shapiro–Wilk. Mathematically, the hypothesis used is H_0: data is normally distributed and H_1: data is not normally distributed, with the decision criteria that if the significance value $p > \alpha = 0.05$, then H_0 is accepted. In the Kolmogorov–Smirnov test, all groups obtained a Sig. value = 0.200, namely Pretest A = 0.200, Posttest A = 0.200, Pretest B = 0.200, and Posttest B = 0.200; because all of these values are greater than 0.05, the data is declared normal. These results are supported by the Shapiro–Wilk test, which shows a significance value of Pretest A = 0.192, Posttest A = 0.376, Pretest B = 0.793, and Posttest B = 0.538; all of which also meet the requirements of $p > 0.05$. The Shapiro–Wilk statistical values are 0.935, 0.951, 0.972, and 0.960, respectively, which are close to 1, indicating that the data distribution is relatively close to a normal distribution. Thus, it can be concluded that all pretest and posttest data, both in the control and experimental groups, meet the assumption of normality, so the data are suitable for analysis using parametric statistics, such as the paired sample t-test and the independent sample t-test.

Table 2. Test of Homogeneity of Variance

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Hasil	Based on Mean	6.476	1	38	.055
	Based on Median	6.357	1	38	.056
	Based on Median and with adjusted df	6.357	1	36.845	.056
	Based on trimmed mean	6.512	1	38	.055

Based on Table 2. Test of Homogeneity of Variance, the homogeneity test was conducted using Levene's Test to determine whether the variance between the control group and the experimental group is the same or homogeneous. Mathematically, the hypothesis used is H_0: $\sigma_1^2 = \sigma_2^2$, meaning that the variance of the two groups is the same or homogeneous, and H_1: $\sigma_1^2 \neq \sigma_2^2$, meaning that the variance of the two groups is different or not homogeneous. With a significance level of $\alpha = 0.05$, the decision-making criteria are if the Sig. value is > 0.05, then H_0 is accepted, whereas if Sig. < 0.05, then H_0 is rejected. In the table, the significance value based on the mean is 0.055, based on the median is 0.056, based on the median with adjusted df is 0.056, and based on the trimmed mean is 0.055. All of these values are greater than 0.05, so mathematically it can be written as $p = 0.055–0.056 > \alpha = 0.05$. This indicates that there is no significant difference in variance between the compared groups. The Levene Statistic values are 6.476, 6.357, 6.357, and 6.512, respectively, with degrees of freedom df1 = 1 and df2 = 38 or 36.845 in the adjusted df, still producing a significance value above the critical limit of 0.05. Thus, the research data meets the assumption of homogeneity of variance, so that the variance of the control and experimental groups can be considered equal, and the data is worthy of being continued to parametric analysis, such as the independent sample t-test, to compare the results between the two groups.

Table 3. Paired Samples Statistics

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	62.90	20	2.222	.497
	Postest	82.45	20	2.645	.591

Based on Table 3. Paired Samples Statistics, the data shows descriptive statistics of pretest and posttest results on the same measurement pair, with the number of subjects N = 20. The average pretest score is M_1 = 62.90 with a standard deviation of SD_1 = 2.222 and a standard error of the mean SE_1 = 0.497, while the average posttest score is M_2 = 82.45 with a standard deviation of SD_2 = 2.645 and a standard error of the mean SE_2 = 0.591. Mathematically, there is an average increase of $\Delta M = M_2 - M_1 = 82.45 - 62.90 = 19.55$, which means the score after treatment is higher than before treatment. Expressed as a percentage, the relative increase is $(19.55 / 62.90) \times 100\% \approx 31.08\%$, resulting in an average increase in muscle endurance of approximately 31.08% after the training program was administered. The standard deviation value for the posttest was slightly larger than for the pretest, at 2.645 > 2.222, indicating a slightly more varied distribution of scores after treatment. However, both standard error values were relatively small, at 0.497 and 0.591, respectively, so the sample mean estimate relative to the population mean can be considered quite stable. Therefore, descriptively, this table shows a significant increase in ability from pretest to posttest, at 19.55 points, and these results serve as the initial basis for testing the significance of this increase using a paired sample t-test.

Table 4. Paired Samples Test

Paired Samples Test										
		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	Pretest - Postest	-19.550	.759	.170	-19.905	-19.195	-115.168	19	<,001	<,001

Based on Table 4. Paired Samples Test, the results of the paired sample t-test show a very significant difference between the pretest and posttest scores on the same subject. Mathematically, the hypothesis used is H_0: $\mu d = 0$, meaning there is no difference in the average between the pretest and posttest, while H_1: $\mu d \neq 0$, meaning there is a difference in the average between the pretest and posttest. The mean difference value of -19.550 comes from the calculation of Pretest - Posttest, so the negative sign indicates that the posttest average is higher than the pretest by 19.550 points. The standard deviation value of the difference is SDd = 0.759, with a standard error of the mean = 0.170, which indicates that the variation in score differences between individuals is relatively small. The 95% confidence interval is in the range of -19.905 to -19.195, and because this interval does not cross 0, the difference between the pretest and posttest can be considered statistically significant. The t value = -115.168 with df = 19 indicates that the average difference is very far from zero when compared to its standard error. In addition, the significance value of one-sided $p < 0.001$ and two-sided $p < 0.001$, which means $p < \alpha = 0.05$, so that H_0 is rejected and H_1 is accepted. Thus, it can be concluded that there is a statistically significant increase after the treatment is given, so that the training model used is effective in increasing the muscular endurance of archery athletes.

DISCUSSION

Based on Table 1. Tests of Normality, all pretest and posttest data in the control and experimental groups meet the assumption of normality. This can be seen from the Kolmogorov–Smirnov significance value, which is all 0.200, as well as the Shapiro–Wilk significance value in Pretest A of 0.192, Posttest A of 0.376, Pretest B of 0.793, and Posttest B of 0.538. Mathematically, all of these values meet the criteria of $p > 0.05$, so the null hypothesis stating that the data is normally distributed can be accepted. Furthermore, Table 2. The test of Homogeneity of Variance shows that the data also meet the assumption of homogeneity of variance. The significance value of Levene's Test based on the mean is 0.055, based on the median is 0.056, based on the median with adjusted df is 0.056, and based on the trimmed mean is 0.055. Because all significance values are greater than $\alpha = 0.05$, the variance between groups can be considered homogeneous. Thus, the research data have fulfilled the two basic assumptions of parametric statistics, namely normality and homogeneity, so that the use of parametric tests such as the paired sample t-test and the independent sample t-test can be declared appropriate.

Based on Table 3. Paired Samples Statistics: There is an increase in the average value from pretest to posttest. The average pretest value is 62.90 with a standard deviation of 2.222, while the average posttest value increased to 82.45 with a standard deviation of 2.645. Mathematically, the average increase can be calculated with the formula $\Delta M = Mposttest - Mpretest = 82.45 - 62.90 = 19.55$. This increase indicates that after being given treatment in the form of a circuit training model, the athlete's muscular endurance ability increased by 19.55 points. When viewed from the standard deviation, the posttest value is slightly greater than the pretest, namely $2.645 > 2.222$, which indicates a slightly higher variation in results after treatment. However, the relatively small standard error mean value, namely 0.497 in the pretest and 0.591 in the posttest, indicates that the sample average is quite stable and can represent the data conditions well.

Based on Table 4. Paired Samples Test, the improvement seen descriptively in Table 3 is proven to be statistically significant. The mean difference value of -19.550 indicates that the calculation was carried out using the Pretest - Posttest formula, so the negative sign means the posttest score is higher than the pretest. The t value = -115.168 with df = 19 and a two-sided significance value of $p < 0.001$ indicates that the difference between the pretest and posttest is very significant because $p < 0.05$. In addition, the 95% confidence interval is in the range of -19.905 to -19.195, which does not cross the number zero, thus further strengthening that the average difference did not occur by chance. Thus, the null hypothesis H_0: $\mu pretest = \mu posttest$ is rejected, while the alternative hypothesis is accepted. This means that the circuit training model given during the study proved effective in improving the muscular endurance of archery athletes, because it resulted in a significant increase in scores after treatment.

4. CONCLUSION

This study concluded that the circuit training model developed for archery athletes was effective in improving muscle endurance. The results showed that the data met the assumptions of normality and homogeneity, making it suitable for analysis using parametric statistics. A comparison of pretest and posttest scores indicated an increase in muscle endurance after the training program. The results of the paired sample t-test also proved that the increase was statistically significant, indicating that the training model had a significant impact on improving the physical condition of archery athletes.

These findings address the research objective: that a structured circuit training model can be used as an appropriate training strategy to improve muscle endurance required in archery, particularly in maintaining postural stability, arm strength, core muscle endurance, and consistent archery technique. Practically, this model can serve as a reference for coaches in developing systematic, measurable physical training programs that are appropriate to the characteristics of archery. Further research is recommended to involve a larger sample size, a more diverse age group, and a longer intervention duration so that the effectiveness of the circuit training model can be tested more broadly and in-depth.

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