

Muscle Endurance, Muscle Strength, Coordination, and Balance as Predictors of Archery Accuracy

Rico Choirul Azhar¹, Endang Rini Sukamti², Okka Bagus Subekti³, Afeb Chesa Arianto⁴

^{1,2,3,4}Department of Sport Science, Yogyakarta State University, Yogyakarta Indonesia

Email address: choirulrico99@gmail.com, endang_fik@uny.ac.id, okkabagus.2021@student.uny.ac.id,

a fs ariant. ches a @gmail.com

Abstract—This study aims to determine the effect of muscle endurance, muscle strength, coordination, and balance as predictors of archery accuracy. This type of research is correlational. The population in this study were archery athletes, which amounted to 47 athletes aged ≤ 12 years. The instrument used to measure muscle endurance and muscle strength is the Holding Bow Digitec Test, coordination using the tennis ball catch throw test, static balance is the Stork Stand Test, and a 30 meter archery accuracy test. Data analysis used is normality test, multicollinearity test, hypothesis testing using Anova test (F) and t test (partial). The conclusion of this study is that muscle endurance, muscle strength, coordination, and balance can be used as predictors of archery accuracy, with a pvalue of 0.000 < 0.05. Coefficient of determination muscle endurance, muscle strength, coordination, and balance can be used as predictors of archery accuracy of 91.10%. Future researchers are expected to add other independent variables, so that the variables that affect archery accuracy can be identified more and the results can be generalized.

Keywords— *Muscular endurance, muscular strength, coordination, balance, archery accuracy.*

I. INTRODUCTION

Archery is an activity that requires adequate power to be transferred from the bow to the arrow in order to move the arrow to the intended target. If the bow is drawn, it will produce potential energy (1). Archery is a target accuracy sport, because the goal is to shoot arrows at the target as precisely as possible (2); (3). Archery is classified as a static sport that also requires good physical condition including upper limb muscle strength and endurance. When pulling the bowstring, it causes isotonic muscle contractions, especially in the primary draw. In the full pull the position of the arm pulling the bowstring and for the fingers of the hand the position must touch the chin, besides that the fingers must also stick under the chin (anchoring) and the arm that holds the bow must be ensured in a locked condition as well as the pulling arm so that an isometric contraction occurs (4).

Archery in practice is a sport that requires coordination, endurance, flexibility, length of pull, and balance to form good archery techniques (5). Archery sports in terms of components that affect the performance of archery athletes are physical, tactical, technical, and mental. The physical components required in archery include: physical condition, muscle strength, muscle endurance, and technique (6); (7). In practice, archery is a sport that requires coordination, endurance, flexibility, length of pull, and balance to form good archery techniques (8). Archery is a statistical sport that requires good physical condition strength and endurance, especially in the upper body muscles. When doing archery techniques, especially when pulling the bowstring, the muscles will experience isotonic contractions, especially in the premary draw. On the full pull of the arm pulling the bowstring the fingers of the hand must touch the chin and the fingers of the hand must stick under the chin (anchoring) and the arm that holds the bow must be completely locked as well as the pulling arm, so that an isometric contraction occurs. One indication of the athlete's physical condition that greatly affects archery performance is arm muscle endurance (9), (10), (11).

Muscular endurance can be defined by the ability to repeatedly produce voluntary strength or to maintain voluntary strength production by certain muscles or muscle groups at submaximal levels for a long time (12). The use of arm muscle endurance in archers is when pulling a bow, aiming (holding), and releasing arrows (13). The importance of arm muscle endurance and archery accuracy, especially in archery, is because archery is done for a long time. Athletes with good arm muscle endurance, will help stabilize when archery which causes higher archery accuracy and get perfect points.

Strength is one of the important basic physical components because it is related to the quality of an athlete's movement. Athletes can move quickly, overcome certain loads and, maintain body position in moving situations if the athlete is equipped with good quality muscles. Athletes with good muscular strength and muscular endurance, it will provide a great advantage for archers to perform at their peak (14); (15). In addition, archery requires upper body and core muscle strength that mobilizes major muscle groups (16).

Athletes during archery, one arm is used to hold (push) the bow in a stable position while the other arm pulls the bowstring, with increased muscle tremors to hold the arrow target alignment until arrow release (17). Therefore body coordination is an important aspect that improves performance in this type of sport (18). The level of good or bad coordination of a person's movements is reflected in his ability to perform a movement smoothly, precisely, quickly, and efficiently (19). Shooting in archery requires not only physical training, but also high mental concentration, focus, and coordination (20); (21).

In addition to the factors of arm muscle strength, endurance, and coordination, balance is very decisive in producing good and correct basic archery techniques. In the sport of archery balance is needed because it must be able to



hold the body while on the other hand aiming to release the shot (22). Balance is the ability to maintain the neuromuscular system (nerve-muscle system) in a static condition, or control the nerve-muscle system so as not to fall or collapse; or the ability to maintain the neuromuscular system in a static condition, or control the neuromuscular system in an efficient position or attitude while moving. Balance is the ability to maintain the body's equilibrium when placed in various positions. Balance is defined as the relative ability to control the center of mass or center of gravity against the base of support (23). Based on this explanation, this research intends to prove more deeply about "Muscle Endurance, Muscle Strength, Coordination, and Balance; Predictors of Archery Accuracy".

II. METHOD

Study Participants

This type of research is correlational. Correlational research is research conducted to determine whether there is a relationship and the magnitude of the contribution between the two or more variables. The population in this study were archery athletes at Archery in Bantul Regency, which amounted to 47 athletes aged \leq 12 years.

Study Organization

Instruments used to measure endurance and arm muscle strength using the Holding Bow Digitec Test (24). The hand eve coordination instrument uses a tennis ball throwing catch to the target wall (25). Balance tests are measured using the Stork Stand Test. The Stork Stand Test is done by standing on one leg, on the dominant leg forever. Time starts when the testee lifts one leg until the testee loses balance (26). The archery accuracy test is to stick the arrows on target at a distance of 30 meters, how to calculate by the archer doing 36 arrow shots and adding up the results of the number of each arrow.

Statistical Analysis

The data analysis used is normality test, multicollinearity test, hypothesis testing using Anova (F) test and t (partial) test. The analysis was assisted by SPSS (Statistical Product and Service Solutions) Version 23.

III. RESULT

The results of the muscle endurance, muscle strength, coordination, balance, and archery accuracy are presented in Table 1.

Model	Ν	Mean ± Standard Deviation
Muscle Endurance (X1)	47	13.94 ± 2.60
Arm Muscle Strength (X2)	47	13.38 ± 2.98
Coordination (X3)	47	7.06 ± 3.53
Balance (X4)	47	20.47 ± 4.61
Archery Accuracy (Y)	47	276.72 ± 10.66

Based on Table 1, it shows that muscle endurance data obtained a mean of 13.94 and Standard Deviation of 2.60, muscle strength data obtained a mean of 13.38 and Standard

Deviation of 2.98, coordination data obtained a mean of 7.06 and Standard Deviation of 3.53, balance data obtained a mean of 20.47 and Standard Deviation of 4.61, archery accuracy data obtained a mean of 276.72 and Standard Deviation of 10.66.

Normality Test

The normality test uses the Kolmogorov-Smirnov Test, namely by looking at the significance value of the residual variable if the value is above 0.05, it can be said that the data is normally distributed. The results are presented in Table 2.

		Unstandardized Residual
Ν	47	
Normal Parameters ^a	Mean	0.0000000
	Std. Deviation	3.19968451
Most Extreme	Absolute	0.094
Differences	Positive	0.047
	Negative	-0.094
Kolmogorov	0.646	
Asymp. Sig. (2-tailed)		0.799

The results of the multicollinearity test, obtained the variance inflation factor (VIF) value has a VIF value <10 and a tolerance value > 0.10, so it can be concluded that there is no multicollinearity between the independent variables. Hypothesis Test Result

The t test (partial) was conducted to determine the effect of each independent variable, namely arm muscle endurance, arm muscle strength, coordination, and balance on the dependent variable, namely archery accuracy of Archery athletes in Bantul Regency. The results of the t test analysis (partial) are presented in Table 3.

TABLE 3. Partial Test Result (t test)						
Madal		Unstandardized		Standardized		Sia
		Coefficients		Coefficients		
Wodel	В	Std.	Beta	ι	Sig.	
		Error				
	(Constant)	234.124	4.892		47.863	0.000
1	Muscle Endurance (X1)	0.955	0.463	0.233	2.063	0.045
	Arm Muscle Strength (X2)	0.984	0.478	0.275	2.061	0.046
	Coordination (X3)	0.904	0.438	0.300	2.063	0.045
	Balance (X4)	0.476	0.208	0.206	2.281	0.028

The arm muscle endurance variable (X1) obtained a t value of 2.063 and a p-value of 0.045. Because the p-value of 0.045 <0.05, it means that H1 which reads "There is a significant relationship between arm muscle endurance and archery accuracy of Archery athletes in Bantul Regency" is accepted. Positive value, meaning that if the arm muscle endurance is getting better, the athlete's archery accuracy will also be better.

The arm muscle strength variable (X2) obtained a t value of 2.061 and a p-value of 0.046. Because the p-value of 0.046 <0.05, it means that H2 which reads "There is a significant relationship between arm muscle strength and archery accuracy of Archery athletes in Bantul Regency" is accepted.



Positive value, meaning that if the arm muscle strength is getting better, the athlete's archery accuracy will also be better.

The coordination variable (X3) obtained a t value of 2.063 and a p-value of 0.045. Because the p-value of 0.045 <0.05, it means that H3 which reads "There is a significant relationship between coordination and archery accuracy of Archery athletes in Bantul Regency" is accepted. Positive value, meaning that if coordination is getting better, the athlete's archery accuracy will also be better.

The balance variable (X4) obtained a t value of 2.281 and a p-value of 0.028. Because the p-value of 0.028 <0.05, it means that H4 which reads "There is a significant relationship between balance and archery accuracy of Archery athletes in Bantul Regency" is accepted. Positive value, meaning that if the balance is getting better, the athlete's archery accuracy will also be better.

The F (Simultaneous) test is needed to determine the effect of the independent variable on the dependent variable simultaneously and to determine the accuracy of the regression model used. The model accuracy test aims to determine whether the model formulation is correct or fit. H4 reads "There is a significant relationship between arm muscle endurance, arm muscle strength, coordination, and balance on the archery accuracy of Archery athletes in Bantul Regency". The analysis results are in Table 4.

TABLE 4. F Test Analysis Result (Simultan)

ANOVA [®]						
Model		Sum of	df	Mean	F	Sig.
		Squares		Square		
	Regression	4758.457	4	1189.614	106.002	0.000a
1	Residual	470.947	42	11.213	100.092	0.000
	Total	5229.404	46			

Based on Table 4, the calculated F value is 106.092 while the p-value is 0.000 <0.05, meaning that H4 which reads "There is a significant relationship between arm muscle endurance, arm muscle strength, coordination, and balance on the archery accuracy of Archery athletes in Bantul Regency", is accepted. It can be concluded that the regression model chosen is suitable for testing data and the regression model can be used to predict that arm muscle endurance, arm muscle strength, coordination, and balance together relate to the archery accuracy of Archery athletes in Bantul Regency.

The coefficient of determination is essentially used to measure how far the ability of the regression model to explain variations in the dependent variable. The results of the analysis in Table 5.

TABLE 5. The results of the coefficient of determination analysis

Model Summary				
Model R	D	D Squara	Adjusted R	Std. Error of the
	k Square	Square	Estimate	
1	0.954 ^a	0.910	0.901	3.34859

The coefficient of determination from the output in Table 5 shows the value of R Square of 0.910. This means that 91.10% of the variation in archery accuracy of Archery athletes in Bantul Regency can be explained by variations in the independent variables, namely arm muscle endurance, arm

muscle strength, coordination, and balance. The remaining 8.90% is explained by other causes outside the model.

IV. DISCUSSION

Arm muscle endurance can be used as a predictor of archery accuracy for Archery athletes in Bantul Regency. One indication of the athlete's physical condition that greatly affects archery performance is arm muscle endurance (27); (28). The importance of arm muscle endurance and archery accuracy especially in archery is because archery is done for a long time. Athletes with good arm muscle endurance, will help stabilize when archery which causes higher archery accuracy and get perfect points.

Muscle endurance and joint flexibility absolutely must be in good condition so that the results obtained are more optimal (29). Archery is a statistical sport that requires good physical condition strength and endurance, especially in the upper body muscles. When doing archery techniques, especially when pulling the bowstring, the muscles will experience isotonic contractions, especially in the initial pull (premary draw). On the full pull of the arm pulling the bowstring the fingers of the hand must touch the chin and the fingers of the hand must stick under the chin (anchoring) and the arm that holds the bow must be completely locked as well as the pulling arm, so that an isometric contraction occurs.

Arm muscle strength can be used as a predictor of archery accuracy for Archery athletes in Bantul Regency. Athletes who have good muscle strength and muscle endurance, it will provide a great advantage for archers to perform at their peak (30). Archery is a fitness activity that utilizes the muscle area of mental health development. Archery requires precision, control, focus, physical ability and determination. In addition, archery requires upper body and core muscle strength that mobilizes major muscle groups (31). Arm muscle strength is needed in archery.

Muscle strength is a condition where a muscle or group of muscles is able to withstand and lift a weight. Arm muscle strength really has a major role in archery because it leads to drawing movements (pulling the bowstring) when archery to release arrows. According to research, by having good arm muscle strength an archer will certainly be proficient in aiming so that it hits the target face as precisely as possible to score the highest score.

The dominant basic technique of holding the bow (holding) is done using the arm muscles not assisted by the body, the archer must remain concentrated so that the archery attitude does not change is a straight line of archery. The most underlying muscles to hold and pull the bow are the physical components of arm muscle strength and endurance of the arm and shoulder muscles. The most important and specific muscles needed to pull and hold the weight of the bow pull are the muscles of the trapezius finger, biceps, rhomboid, deltoid, and triceps (32).

Strength in archery has an important role in performing the movement of pulling the bowstring to the maximum to be able to release the arrow to the target face. Pulling is a way in the anchoring position to move the bowstring, then stretch the bow so as to obtain potential energy from the bow. In the



pulling phase, the archer's best position is to pull the bowstring until it touches the lips, chin and nose, when pulling the bowstring a type of isotonic contraction is needed, namely coscentric isotonic contraction, therefore the arm holding the bow must be maintained in order to regulate the strength of each pull performed. When making a full pull, the arm that holds the bow requires an isometric type of contraction to lock the bow's pull. To obtain an efficient and safe level of stretch when pulling the bowstring, the athlete must be able to use only the necessary muscles. Because if the tendency to use more muscles can cause athletes to fatigue quickly, it can cause a large possibility of error and make it difficult to maintain the optimal bowstring stretch.

In the standing position from pulling the bowstring to releasing the arrow, the athlete's position must be in a state of standing upright and balanced, the muscles that work when standing include the Erector Spinae Muscle, where this muscle can maintain the trunk to remain in an upright position while doing the pulling movement and maintaining the bow pull. Rectus Abdominis Muscle, this muscle acts together with the Erector Spine Muscle so that the body remains in an upright or vertical state. Gluteus Maximus Muscle, this muscle is used to maintain stabilization of the pelvis in a standing position during archery. Quadricep Femoris Muscle, a muscle group to maintain knee stability. Tricep Surae Muscle, is a muscle group consisting of the Gastrocnemius Muscle and Soleus Muscle to maintain ankle stability (33).

Coordination can be used as a predictor of archery accuracy for Archery athletes in Bantul Regency. Coordination is a harmonious relationship between various factors that occur in a movement (34). The results of the study supported that there was a significant positive influence between hand eye coordination on archery achievement (35). In archery, an archer must be able to apply good and correct techniques. Good and correct techniques will help increase the effectiveness and efficiency of energy use. In addition, by applying good and correct techniques it will be easier to get the consistency of archery movements. Consistency is important in archery. By doing good and correct techniques consistently will produce good shots and prevent archers from the possibility of injury.

Coordination ability allows sportsmen to perform a group of movements with better movement quality. Coordination is the ability to control body movements, someone is said to have good coordination when able to move easily, and smoothly in a series of movements, the rhythm is well controlled, and able to perform efficient movements. Coordination is a complex motor skill required for high performance. It is explained that coordination is the ability to perform certain pattern movements well. Coordination is closely related to speed, strength, endurance flexibility. Basically coordination is a person's talent to assemble how many movements into one effective and efficient pattern (36).

Balance can be used as a predictor of archery accuracy for Archery athletes in Bantul Regency. Some studies show that balance affects archery results carried out(37); (38); (39). In archery, balance is needed because it must be able to hold the body while on the other hand aiming to release the shot (22). Balance can be defined as the relative ability to control the center of mass or center of gravity against the base of support. The components of balance play an important role in the quality of a person's balance which is beneficial for everyday life (40).

Archery is done by shooting arrows at the target using a bow, so good accuracy is needed. Accuracy is the main thing in archery that athletes must master. If an archer does not have good shot accuracy, the athlete will find it difficult to win the competition. In archery, athletes are not required to have perfect technique. However, an archer is highly required to have good shot accuracy supported by archery techniques. In archery, the technique is not limited by the rules. Athletes are free to use any technique as long as it does not interfere with other archers during the match. If the technique is good and steady, it will produce good shots.

V. CONCLUSION

The conclusion of this study is that muscle endurance, muscle strength, coordination, and balance can be used as predictors of archery accuracy, with a p-value of 0.000 <0.05 and a coefficient of determination of 91.10%. Future researchers are expected to add other independent variables, so that the variables that affect archery accuracy can be identified more and the results can be generalized.

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