Research Article

Sensitivity Prediction Analysis of the Contribution of Physical Fitness Variables on Terengganu Malaysian Youth Archers' Shooting Scores

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ABSTRACT

Successful performance in archery may require certain physical fitness attributes due to the long hours it takes during both training and competition. It is essential, therefore, to determine the actual role physical fitness variables could play on the shooting performance of the archers. This study aims to explore the role of physical fitness variables on the shooting performance of youth archers as well as to predict the discriminating fitness variables that can play a significant role in archery performance. A total number of 16 youth archers with mean age 14.6 participated in the study. Standard physical fitness measurements were carried out prior to their shooting practice, and a simulated shooting competition area was set up, and all the archers' shot 12 arrows over a distance of 50 meters. Standard linear multiple regression was employed to predict the association between the shooting scores (DV) with the physical fitness variables (IVs). A significant regression equation was obtained $F (8, 7) = 6.40$, $p < 0.05$, $R2 = 0.88$ indicating that the model accounted for approximately 88% variability of the whole data set. Sensitivity prediction analysis of the contributions of the best model after leave-one-out method revealed that handgrip has the highest contribution in the model while standing broad jump has a low contribution in the entire model. However, correlations were found between the DV and muscle strength, handgrip, leg power and balance, $r = 0.60$, 0.55, 0.31 and 0.74 respectively.

Keywords: Archery, Physical fitness variables, Shooting scores, Sensitivity, Prediction analysis.

INTRODUCTION

Archery is a sport that involves driving arrows with a bow to the target in the course of shooting.[1] It can also be seen as a closed skill sport that requires strength and endurance of the upper body, specifically the forearm and the shoulder girdle. In archery, competitors contest for points by shooting a set number of arrows within a stipulated time frame. The possession of certain physical fitness variables such as motor skills, body flexibility, stamina, core body strength, upper body strength, handgrip, and leg power might be possible outcomes of effective performance in the sport of archery.[2-4]Previous researchers inferred that the nature of archery involves interval aerobic and anaerobic activities. As a result of this, therefore, all the major muscle groups are activated during the shooting process.[5] Nevertheless, these connected physical fitness factors serve as the vital requirement for effectual delivery of performance through the enhancement of body resistance and subsequently tailored to the adaptation of the playing techniques involve in the sport.[6]

Emphasizing the need of physical fitness, subsequent researchers revealed that archery is a sport that required endurance and muscular strength to meet up with the nature of the sport since the sport involved continuous shooting and movement forth and back.[7] Therefore, muscular strength and endurance would provide substantial benefits to the archers to perform at their peak. Moreover, other researchers expressed that archery needs an upper body as well as core muscle strength which activates the main muscle groups.[8] The ability of the main muscle groups to respond to the demand placed upon them in the course of the sport helps the archers to shoot the arrow to the target efficiently. However, previous studies have shown that body flexibility is essential in the successful performance in archery because it strengthens muscle mass and strengthens fibrous tissue and, by doing so, reduces injury risk.[9-10] Power, flexibility and handgrip capabilities assist the archers to endure the period taken during the sport.[10-11]

Despite the fact that several researchers have attempted to offer insight into the need for the archers to possess certain physical fitness variables, to date, there has been little effort to investigate the actual roles the various physical fitness variables that contribute to the successful performance of the sport and to determine the discriminating fitness variables that can play a significant role in archery performance. The findings of the study investigating the aforementioned factors could serve as the basis for restructuring the training program to suit the need of the sport. In view of this background, the current study aims to examine the role of physical fitness variables in the shooting scores of youth archers.

MATERIALS AND METHODS

Participants

A total of 16 youth archers (M = 9; F = 7) between the ages of 13-19 (14.6 ± 2.0) participated in this study drawn from Terengganu Sports Council, Malaysia. The participants were under an archery development program and targeted to be promoted to state and national archers respectively. The relevant stakeholders were informed of the purpose of the study, and the participants gave their written consent. All the procedures, protocol, and equipment for this study were approved by the Research Ethics Board of the Terengganu Sports Institute (ISNT) with a reference number 04-04/T-01/Jid [2].

Experimental Approach to the Problem

Sit ups test: The test was executed according to the recommended method for physical fitness tests.[12]The archers laid on their back with their knees bowed at around right angles while both feet were situated level on the floor. They placed their hands crossed over their chest where they should stay throughout the test. In the test process, a spotter held the archers' feet on the ground. The archers sat up until they touched their knees with both their elbows; then, returned to the start position. The movement was repeated until they could no longer execute the correct technique. At that moment, the test ended, and the spotter totaled and recorded the quantity of the right sit-ups test completed. The test was measured once attributable to the impact of exhaustion.

Push up test: The archers undertook a horizontal position on the floor with the hands directly beneath the shoulders, legs stretched and together, and toes tucked under so they are in contact with the floor, (push up position). The archers then push with the arms until they are fully extended and then lower their body until the chin or chest touches the floor. At this point, the line from the head to the toes was straight. All of these actions were implemented only by the arms and shoulders. The score was determined by the number of push-ups while maintaining correct form completed. The test was performed until the onset of fatigue.

Plank test: Plank test was applied to evaluate the archers' core strength and endurance. The archers assume the start position with their elbows on the ground, feet approximately hip width apart and body straight with no arching or bowing. The hands are placed flat on the ground. The head was facing toward the ground and not looking forward. The archers maintain a straight body for as long as possible ensuring that regular breathing is maintained. When the archers can no longer keep their body straight i.e. they excessively arch or bow then they are to stop the test. The researchers then record the time that the archers maintain a good position.

Body Flexibility: As proposed by the previous researchers throughout a meta-analysis, the flexibility of the lower back and hamstrings was determined by the sit and reach test.[13]The archers performed two trials, and the best was recorded for further analysis.

Standing stork test: Standing stork test was implemented to assess the ability of the archers to maintain stability while standing on one leg. The general aim of the test is to evaluate the capability of the archers to balance on the ball of their foot. To surface this test, the archers were instructed to remove their shoes and place their hands on their hips, then position the non-supporting foot against the inner part of the supporting leg. The archers raise their heel to balance on the ball of the foot. A stopwatch was used to time the period taken to complete the test in the correct form. The tests stopped when the archers move to any direction, and the non-supporting foot misses contact with the knee or the heel of the supporting foot touches the floor. The archers alternate both legs and the average of the total scores from both legs were utilized for statistical analysis.

Handgrip test: Handgrip was used to measure the maximum isometric strength of the hand and forearm muscles of the archers. To implement this test, handgrip dynamometer was used, and the archers were requested to grasp the dynamometer in the hand to be examined, with the arm at right angles and the elbow by the side of the body. The knob of the dynamometer is adjusted according to the size of the individual archer. The base of the handgrip was placed on first metacarpal (heel of palm) while the handle rested in the middle of four fingers. When the archers were ready, they were permitted to squeeze the dynamometer with maximum isometric effort, which is maintained for about 5 seconds. No other body movement was allowed. The archers were strongly encouraged by the researchers to give a maximum effort. Both the hands were alternated.

Standing broad jump test: The standing broad jump test was administered to evaluate the explosive leg power of the archers. A long jump landing mat was placed on the flat synthetic surface, and the take-off line was clearly indicated from behind the mat. The archers stood behind the line marked on the ground with feet slightly apart. A two-foot take-off and landing are utilized, with the swinging of the arms and bending of the knees to provide forward drive. The archers were instructed to jump as far as possible and land on both feet without falling backward. Three attempts were permitted, and the best distance was taken for statistical analysis.

Vertical jump test: A Vertex testing gadget (M-F Athletic Co., Cranston, Rhode Island) was utilized to decide vertical jump height (cm), which has been a legitimate and solid measure of lower body power.[14] To implement this test, a prepared tester attuned the height of the color-coded plastic vanes such that it paralleled to the archer's standing reach height. The vane stack was then raised to a standardized distance (corresponding to the participants' anticipated jump) so the archers would not jump higher or lower than the arrangement of vanes. Utilizing a countermovement, the archers flexed the ankles, knees, and hips and swung the arms in an upward movement tapping the highest conceivable vane with the fingers of the dominant hand. Every archer performed three jumps with 40-60 seconds' rest between every jump. The best of three trials was documented and utilized for statistical analysis.

Application of Multiple Linear Regressions into the Study

Multiple linear regressions (MLR) is a statistical technique that permits us to forecast the variability between the independent variable and the dependent variable as well as to calculate the percentage of the contribution of each parameter in a given set of data.15 The general multiple linear regression models have k independent variables, and there are n observations. Hence, the regression model can be written as in. Equation (1) (Eq. 1).

$$Y_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_k x_{ki} + \varepsilon_i \qquad \text{(Eq. 1).}$$

Where i = 1, ...n and β1 are the regression coefficients while x1 means independent variables and ε is the error associated with the regression.

The coefficient of determination, R2, Adjusted R2 and Root Mean Square Error (RMSE) are the values that need to be considered in the best fitting regression linear equation. R2 is the fundamental measurement of the goodness of the fit of a linear model and is described as the proportion of the variability in the dependent variable which is accounted for by the regression equation [16]. R2 is calculated for all potential subset models. Using this method, the model with the largest R2 is declared the best by considering all the possible number of variables that the model is based on since R2 tends to over-estimate the attainment of the model when applied to the real world. The RMSE is calculated for all the possible subset models. The model with the smallest RMSE is taken as the best linear model.

The MLR analysis was implemented in the current study to predict the equation for the physical fitness variables as well as the contribution of each fitness variables to the prediction of the archers' shooting scores. In this study, the dependent variable was the archers' shooting scores while the independent variables were the eight physical fitness variables (max. push up, 1 min sit up, plank test, hand grip, sit and reach, standing broad jump, vertical jump and standing stork test. All the statistical analysis was performed at p ≤ 0.05 alpha level of confidence using XLSTAT 2014 add-in software USA.

RESULTS

Table 1 displays the descriptive statistics of the variables examined. From the table, the total number of observations, the minimum and maximum scores, mean as well as standard deviations are displayed.

Table 2 provides the summary of the model. The total observations, the sum of weight, the degree of freedom, R-square, and adjusted R-square, mean square error and root mean square error are shown. From the table, it can be observed that the model has accounted for a total of 88% prediction which explained the ability of the model to predict the variables examined correctly.

Table 3 presents the analysis of the variance conducted for the model. From the table, it can be seen that the overall regression model is significant which further emphasized that ability of the model to make a good prediction based on the variables examined.

Table 4 shows sensitivity prediction analysis of the contributions of the best model after leave-one-out method. From the table, the input of each physical fitness variable to the prediction of the shooting performance of the model is shown. It can be observed that the best-predicted model is shown to be model six after standing broad jump (SBJ) is left out from the analysis with an R2 of 0.88. However, when handgrip is removed from the model, it shows a low prediction with the R2 of 0.66. This result indicates that HG is the highest contributor from the model and SBJ has a low contribution in the entire model.

Table 5 highlights the summary of the individual fitness variables percent contribution in the model. It can be noticed from the table that, the handgrip has the highest contribution in the ability to predict the shooting score from the model (55%), which explained that handgrip is the most significant fitness variable that can predict the effective archery performance.

Table 5 projects the Multicollinearity statistics and the associations between the physical fitness variables and the shooting scores. It can be seen from the table the 4 physical fitness variables specifically plank test, handgrip, standing broad jump and standing stork test positively and strongly correlated with the shooting scores. These results portrayed the requirement of the correlated fitness variables for the successful execution of archery.

DISCUSSION

The major finding of this study showed that handgrip is the most significant fitness variable required for the effective archery performance. The finding also revealed that there is a positive, strong linear relationship between the archery shooting score and plank test, handgrip, standing broad jump and standing stork test. These results further reiterate the requirement of the correlated fitness variables for successful performance in archery. Similarly, the results also indicate that efficient performance in archery requires numerous physical fitness variables specifically; hand grip, muscular strength and endurance, leg power as well as balance.

The muscle strength of the arms plays a vital role in archery technique. An individual might perform a correct archery procedure when he/she has adequate arms muscle to draw and hold the bow. With a precise end goal to perform a correct archery technique; a competitor must have the capacity to feel and control his/her strategy well.[17] Control upon procedure is possible when the competitor is in a comfort zone that is he/she should be in a relieved condition (not encountering extreme muscle tension) thus; the purpose concentration is for the archer to focus more on the archery technique.18 The strength of arms muscles might take a competitor into a comfort zone, in light of the fact that at the time of drawing the bow, arms muscles in contraction do not encounter extreme tension because a high load of the bow being drawn is far lower than the maximum threshold of muscles strength. Due to this, it can be accepted that there is a direct influence of muscle strength with archery technique. However, a previous study revealed that leg power and balancing ability or otherwise called stability is one of the factors that influence the accuracy in archery.[19] The higher the stability of the archer will result in a smaller angle of the trajectory of the parabola of the arrow. This will reduce any obstacle from the impact of external factors which can change the course of the arrow.[20] Precisely, when drawing and holding the bow, the athlete needs maximum stability. Hence, the control over the technique and target shall be more focused. In the long term, it may lead to the regularity of technique. Therefore, based on this explanation it can be understood that there is a direct influence of gripping abilities, muscular strength and endurance, leg power and balance to perfection in archery technique. Similarly, the capability to put master archery technique plays a major role in determining the archery accomplishment.

Nevertheless, prior researchers indicated that from a power-driven viewpoint, the precision in archery and subsequent release of the arrow from the bow is much predisposed by climate influence, in this circumstance, wind blow.[21] The greater the wind blow, the greater is the deviation of the arrow direction. In order to make a pull using a weighted bow, there is a requirement of great strength of arms muscle to draw the bow as well as the balancing ability to maintain stability. Hence, there is a direct influence of certain physical variables such as arms muscle strength, balance, and grip to archery achievement of the FITA recurves round. Moreover, other researchers inferred that possession of fitness variables in archery is exceptionally valuable. It helps in controlling the development of muscles and exhaustion impacts that might occur which causes severe injuries in the long run .[22] However, it was explained that the study of joint function during an archery performance is vital in dissecting the movement of the human body and to comprehend about how or why the injury happens.23 Therefore, by acquiring needed fitness variables in archery, the forces acting on the bones could be maximized while force acting on muscles might be minimized with a specific aim to lessen the damaging effect to the archer and consequently achieve a greater score.[24]

CONCLUSION

The current study has successfully examined the roles of physical fitness variables in the prolific performance of archery. Although handgrip has been discovered to be the most vital in the effective performance of the sport other physical fitness variables discussed in this article are required. This finding has shed more light that some specific components appeared to be more needed for the successful performance of archery than the others. The finding of this study, however, can be useful to coaches and sports managers to determine and to recognize the physical fitness variables that significantly affect the performance of the sport which could go a long way in helping the coach and the trainers alike to structure training programs to suit the need of the sport in relation to the fitness attributes.

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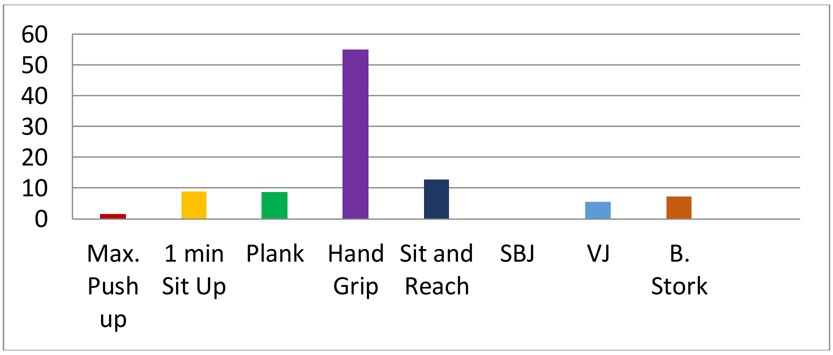

Figure 1: Graphical Illustrations of The Variables' Percent Contribution in The Model.

Table 1: Descriptive Statistics of the Variables

Variables	Observations	Minimum	Maximum	Mean	Std. deviation
S. Scores	16	292.33	309.67	299.30	4.53
Max. Push up	16	16.00	80.00	36.69	16.69
1 min Sit Up	16	25.00	57.00	38.44	8.69
Plank	16	62.40	245.07	185.08	44.06
Hand Grip	16	39.60	95.40	65.52	17.33
Sit and Reach	16	22.00	47.50	35.44	6.58
SBJ	16	120.00	230.00	169.88	37.49
VJ	16	10.00	22.00	15.91	2.91
B. Stork	16	13.15	46.00	36.71	10.52

Max. Push up = Maximum push up, SBJ = Standing broad jump, VJ = Vertical jump, B. Stork = Standing stork test.

Table 2: Summary of the Equation Model Scores

Observations	16.00
Sum of weights	16.00
DF	7.00
R^2	0.88
Adjusted R^2	0.74
MSE	5.30
RMSE	2.30

Table 3: Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	P value
Model	8	271.14	33.89	6.40	0.012*
Error	7	37.07	5.30		
Corrected Total	15	308.21			

Significant at $*p < 0.05$

Table 4: Sensitivity Prediction Analysis of the Contributions of the Best Model After Leave-One-Out Method

S/N	Leave-Out V. = In Variables	R^2
1	L-MPU = 1MSU, Flank, HG, SNR, SBJ, VJ, B. St	0.87
2	L-1MSU = MPU, Flank, HG, SNR, SBJ, VJ, B. St	0.84
3	L-Plank = MPU, 1MSU, HG, SNR, SBJ, VJ, B. St	0.84
4	L-HG = MPU, 1MSU, Flank, SNR, SBJ, VJ, B. St	0.66
5	L-SNR = MPU, 1MSU, Flank, HG, SBJ, VJ, B. St	0.83
6	L-SBJ = MPU, 1MSU, Flank, HG, SNR, VJ, B. St	0.88
7	L-VJ = MPU, 1MSU, Flank, HG, SNR, SBJ, B. St	0.86
8	L-B. St = MPU, 1MSU, Flank, HG, SNR, SBJ, VJ	0.85

MPU = Maximum push up, 1MSU= 1Sit ups, SBJ = Standing broad jump, VJ = Vertical jump, B. St = Standing stork test.

Table 5: The Summary of the Percentage Individual Contribution in the Model

Variables	R^2	$\Delta R^2 = R^2$ (ref) - R^2 (w)	% Contribution
MPU	0.8734	0.0063	1.55
1MSU	0.8436	0.0361	8.90
Plank	0.8445	0.0353	8.69
HG	0.6558	0.2239	55.16
SNR	0.8273	0.0524	12.90
SBJ	0.8791	0.0007	0.16
VJ	0.8572	0.0225	5.55
B. St	0.8509	0.0288	7.10
		$\sum \Delta R^2 = 0.406$	

Table 6: Relationships Between the Physical Fitness Variables with The Shooting scores.

Variables	1	2	3	4	5	6	7	8	9
1. Max. Push up	1								
2. 1 min Sit Up	0.495	1.000							
3. Plank	0.530	0.204	1.000						
4. Hand Grip	0.035	0.477	0.104	1.000					
5. Sit and Reach	0.241	0.209	0.203	0.345	1.000				
6. SBJ	0.442	0.712	0.295	0.645	0.048	1.000			
7. VJ	0.551	0.576	0.205	0.487	0.059	0.800	1.000		
8. B. Stork	0.095	0.087	0.653	0.383	0.095	0.414	0.374	1.000	
9. S. Scores	0.016	-0.017	0.604*	0.548*	0.060	0.306*	0.130	0.740*	1
Multicolinearity statistics:									
Tolerance	0.21	0.38	0.21	0.34	0.62	0.18	0.21	0.24	
VIF	4.65	2.65	4.74	2.96	1.61	5.62	4.85	4.21	

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