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**ORIGINAL ARTICLE**

# Anthropometric and Physical Fitness Components Comparison between High- and Low-Performance Archers

**[1]Jiun Sien Lau[*], [1]Rosniwati Ghafar, [1]Hairul Anuar Hashim, [1]Erie Zuraidee Zulkifli**

[1]Exercise and Sports Science, School of Health Sciences, Universiti Sains Malaysia, Health Campus, Kubang Kerian, Kelantan, Malaysia.

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## ABSTRACT

**Background.** Archery is a sport that demands a high level of fitness due to its long hours of training and competitive nature. Thus, archers need to have high fatigue tolerance and body figure to perform successfully. **Objectives.** This study aims to compare and correlate the anthropometric and physical fitness variables on archery shooting performance. **Methods.** Participants were youth archers of the Terengganu state team and Malaysia Pahang Sports School from Malaysia (n=12; male: 9 and female: 3; Mean age: 16.0±1.6 years). They were divided into two groups (high-performance, HPA, and low-performance, LPA) based on their preliminary archery score obtained in the early stage of the study. The archery shooting performance was assessed by total shooting score (36 arrows shot from 70 meters distance). Anthropometric (height, body mass, body mass index, body fat percentage, skeletal muscle mass, and arm span), muscular strength and endurance, flexibility, balance, and aerobic fitness were assessed. **Results.** Mann-Whitney test showed that height, arm span, handgrip strength, and predicted $VO_{2max}$ showed significant differences between the groups ($p<0.05$). Spearman correlation showed that height, arm span, right-hand grip, and predicted $VO_{2max}$ significantly correlated with scores ($r=0.80, 0.82, 0.61, 0.68$). **Conclusion.** The result showed that archers with higher height and longer arm span have more advantages in archery. In terms of fitness level, muscular strength and aerobic capacity are essential for the archer to excel in this sport. This finding helps coaches and team managers when conducting talent identification programs and training programs for athletes.

**KEYWORDS:** ***Archery, Anthropometry, Performance, Physical Fitness.***

## INTRODUCTION

Although physical fitness and anthropometry are widely accepted as essential factors to sports performance, the relationship between both components toward archery shooting performance is still scarce. Understanding the relationship between fitness and shooting performance is expected to provide insight into further identifying which specific fitness components will contribute to successful performance.

Soylu et al. (2006) highlighted that archery is a sport that involves an interval of aerobic and anaerobic activities (1). Archers spend almost the whole day at the archery range for training and competition (2). They have to walk to check their score and retrieve the arrows 12 times at a 70-meter distance (3). Besides having adequate aerobic capacity, archers must have strong muscles of the arms, chest, shoulders, and back to execute the repetitive movement of drawing the bowstring (4). With advancements in computer technology, scholars have recently utilized artificial intelligence to predict archery performance based on the physical fitness

*. Corresponding Author:
**Jiun Sien Lau,** BSc
**E-mail:** laujiunsien.upsk12@student.usm.my

components (5-7). Most of the studies done showed that upper body strength, endurance, balance, and power were able to classify the performance of the archers.

Pelana et al. (2018) had investigated the relationship between anthropometry profile and muscle strength and concluded that height and arm span are positively correlated with muscle strength (8). Regarding muscle strength, Humaid (2014) study found that archer with stronger muscle strength and longer draw length can lead to better performance in archery (9). Thus, based on both findings it indicated that archers with a taller statue height and having longer arm span, when combined with stronger muscle strength subsequently will produced longer draw length are having more advantage. Conversely, Taha et al (2009) revealed that higher body height and arm length will lead to postural sway and caused detrimental in performance (7). Interestingly, Koley and Uppal (2016) study revealed that height was not significantly related to static standing balance (10) which is conflicting to the earlier study done by Taha et al. (2009).

Most archery specific studies that had been done investigated on the relationship between anthropometry with muscle strength (8), effects of muscle strength and draw length towards shooting score 9), identifying the essential physical variables in archery (11, 12), and anthropometry influence toward balance (10). However, to the best of the authors' knowledge, no study has yet to compared and correlate between high-performance and low-performance archers in terms of anthropometry and fitness parameter towards their shooting performance (score). Therefore, this study aimed to contribute to the existing body of knowledge in term of comparing and correlating the anthropometric and physical fitness variables on archery performance between high and low performance archers.

## MATERIALS AND METHODS

**Ethical Consideration.** Ethical approval was obtained from the Human Research Ethics Committee of University Sains Malaysia (USM/JEPeM/18070335). Also, official permission has been granted from the Director of Terengganu State Sports Council, the Principal of Malaysia Pahang Sports School, and all the coaches. Informed consent forms were given to all the participants after the briefing sessions. Only those participants who agreed and signed the consent form were recruited. Participants under the age of 18 years have their form approved and co-signed by their parents. All the protocols of this study were conformed to the ethical guidelines of the 1975 Declaration of Helsinki.

**Participants.** Twelve (n = 12; male: 9; female: 3) youth recurve archers with the mean age of 16.0 ± 1.6 years were recruited for this study. The participants were under the archery development program and represented their state at the national level tournament. Any archers with injuries in the past three months before the data collection process were excluded.

**Study Procedure.** This study was divided into two phases: (1) Phase 1: assessment of archery shooting performance and (2) Phase 2: measurement of anthropometric and physical fitness. Upon completing phase 1, the participants were further divided into two groups consisting of high-performance archers (HPA) and low-performance archers (LPA). The groups were assigned based on participants' score ranking (n = 12; HPA: 6 and LPA: 6).

**Archery Shooting Performance.** The archery shooting performance was evaluated by the total score achieved upon completing 36 arrows from 70 meters distance. The score of each arrow ranged from miss '0' to '10' points, and the maximum total score is 360 points-the archery score obtained in the early stage of the study.

**Anthropometric Dimension**. Height was measured using a wall-mounted stadiometer (Seca 206 body meter, Germany) and body mass on a calibrated digital scale (Ommron HBF-375, Japan). Height, body mass, and arm span measurements were done according to The International Society for the Advancement of Kinanthropometry (ISAK) protocol (13). All measurements were done two times, and a third measurement was obtained if the second reading was different by 1.5% from the first measurement. Body Mass Index (BMI) calculation was derived from the equation; BMI = weight (kg) / height (m)$^2$. The reading of body fat percentage and skeletal muscle mass were obtained from the standardized electronic digital scale directly. Arm span measurement was done in a standing position with the head looking straight ahead. Upon ready, participant outstretched (extended) both of their arms with palm facing forward to the sides and parallel to the ground at shoulder height. The arm span length was measured from the tip of the middle finger of the left and right hand (13).

**Fitness Test**. Maximum isometric strength (i.e., hand and forearm) was measured using a handgrip dynamometer (Jamar J00105, USA). Participants were requested to hold the dynamometer in the tested hand, with the arm at a 90-degree angle with the elbow by the side of the body. Upon ready, the participants grasped the dynamometer with maximum isometric effort and maintained for 5 seconds. The test was repeated for both hands alternately three times each.

Flexibility was measured using the Sit and Reach Test with the use of a sit-and-reach flexibility box (Lafayette LA-01285A, USA). The participants sat on the floor with the legs stretched out straight and soles of the feet placed against the box, and the hands were placed on top of each other in the ready position. Once ready, the participants reached out forward along the measuring line as far as possible. The distance was recorded once the participants reached out and hold the position for one-two seconds. Three trials of the test were performed.

Back strength was measured using back and leg tests utilizing isometric leg and back dynamometer (baseline, USA). First, the participants need to stand upright on the feet were shoulder-width apart, the arms straight, and the fingers extended down as far as possible on the fronts of their body. The position of the bar was adjusted to 1 to 2 inches below the fingertips for the participant to grasp the bar. The participants were then requested to bend their back forward slightly with the legs straight, and the head held upright. Once the test started, the participants were lifted the bar steadily without bending their knee. At the end of the test, the back of the participants should be almost straight. Three trials of the test were performed.

Muscle strength and endurance parameters were measured using a push-up and sit-up test. A digital stopwatch (Casio HS-3V, Japan) was used to time the test (1 minute), and a yoga mat was used to cushion participants on any hard surface. During the sit-ups test, the participants laid on their back with the sit-ups position, and the hands were put against their chest. The movement counted as a successful repetition when the participants touched their knees to both elbows during sit up and lay back to the floor. In this test, the participants sit up as many times as possible for one minute. In the push-up test, the participants were ready in the push-up position. As the starting position, the arms were pushed until fully extended and then lower their body until the chest or chin was parallel to the floor (no contact with the floor surface). This movement was implemented only by the arms and shoulders. Only the correct form of push up was counted for one minute.

Aerobic fitness was estimated by means of the 20-meter multistage fitness test (MSFT). The test was conducted to determine the maximal oxygen uptake of the participants. The participants were requested to run following the beat from the audio until she/he cannot keep up with the beat. The test was terminated when the participants could no longer keep up with the set pace and failed to reach the turning line on two consecutive occasions. The $VO_{2max}$ was expressed by checking the last level and ended the shuttle number at the time when the participant voluntarily resigned from the test. The formula used to calculate the predicted $VO_{2max}$ (ml/kg/min) was Multi-Stage Shuttle Run 20 m (MSR20 m) level 1 distance (meters) × 0.0084 + 36.4 (14).

The balance was measured using the stand stork test. The test measured the ability of participants to maintain their posture on one leg as long as possible. Participants were requested to place their hands on their hips while the non-supporting foot was placed against the medial part of the supporting leg. Once the timer started, the participants were instructed to raise their heel to balance their body on the ball of the foot. A stopwatch (Casio HS-3V, Japan) was used to record the time taken for the participants to maintain their balance in the correct form. The test was terminated once the participants lose their balance by moving their body or hands, or the non-supporting foot missed contact with the supporting leg. This test was repeated three times for each leg alternately.

**Statistical Analysis.** Statistical analyses were conducted using SPSS version 26.0, with significance set up at p-value < 0.05. To compare the anthropometry components and fitness components of the archers, the Mann-Whitney test was conducted as the variables were not normally distributed. The Spearman correlation test was used to understand the correlation between the anthropometry components and fitness components with the score in archery.

## RESULTS

**Descriptive Statistics of Anthropometry Components and Physical Fitness Components.** Table 1 presents the descriptive statistics of the variables tested. From the table, the minimum and maximum values, mean and standard deviations of the score, anthropometry components, and physical fitness components are displayed.

**Table 1. Descriptive Statistics of the Score, Anthropometry Components, and Fitness Components Tested (n = 12)**

| Variables | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| **Score** | 219 | 322 | 276.00 | 34.56 |
| **Anthropometry components** | | | | |
| Height (cm) | 153 | 177.3 | 165.98 | 8.47 |
| Body mass (kg) | 50.40 | 10180 | 72.64 | 14.83 |
| BMI ($kg/m^2$) | 20.92 | 34.45 | 26.24 | 4.20 |
| Body fat (%) | 12.90 | 31.40 | 22.19 | 5.85 |
| Skeletal muscle (%) | 26.20 | 39.10 | 32.57 | 3.84 |
| Arm span (cm) | 157.00 | 183.20 | 171.60 | 9.48 |
| **Physical fitness components** | | | | |
| Left handgrip (kg) | 20.00 | 43.44 | 30.11 | 8.00 |
| Right handgrip (kg) | 22.00 | 43.67 | 32.53 | 6.17 |
| Back and leg (lbs) | 93.33 | 196.67 | 130.44 | 28.46 |
| Sit and reach (cm) | -7.17 | 21.33 | 9.63 | 8.07 |
| Left standing stork stance (sec) | 10.89 | 83.61 | 30.66 | 19.67 |
| Right standing stork stance (sec) | 5.10 | 105.26 | 34.57 | 25.89 |
| Push up (rep) | 14 | 65 | 34.92 | 14.64 |
| Sit up (rep) | 11 | 28.00 | 20.25 | 5.74 |
| 20-m multistage fitness test (ml/kg/min) | 41.27 | 50.68 | 45.11 | 3.30 |

**Table 2. Comparison of the Score, Anthropometry Components, and Fitness Components between High-Performance Archers and Low-Performance Archers**

| | Median (IQR) | | Z- | |
|---|---|---|---|---|
| | **High-Performance Archers (n = 6)** | **Low-Performance Archers (n = 6)** | **Statistics** | **p-Value** |
| **Score** | 296.5 (32.8) | 253.0 (51.5) | -2.89 | 0.004* |
| **Anthropometry components** | | | | |
| Height (cm) | 173.1 (6.5) | 160.5 (12.7) | -2.40 | 0.016* |
| Body mass (kg) | 72.4 (33.7) | 71.2 (20.3) | -0.48 | 0.631 |
| BMI ($kg/m^2$) | 24.2 (9.1) | 26.0 (5.2) | -0.64 | 0.522 |
| Body fat (%) | 18.6 (10.7) | 24.3 (8.1) | -1.12 | 0.262 |
| Skeletal muscle (%) | 34.9 (5.0) | 29.9 (6.7) | -1.92 | 0.055 |
| Arm span (cm) | 181.0 (8.6) | 163.6 (8.6) | -2.57 | 0.010* |
| **Physical fitness components** | | | | |
| Left handgrip (kg) | 35.2 (11.0) | 23.8 (8.2) | -2.40 | 0.016* |
| Right handgrip (kg) | 33.8 (11.8) | 29.3 (5.8) | -2.57 | 0.010* |
| Back and leg (lbs) | 141.7 (46.6) | 112.5 (28.3) | -1.93 | 0.054 |
| Sit and reach (cm) | 11.6 (11.9) | 6.9 (12.3) | -0.64 | 0.522 |
| Left standing stork stance (sec) | 30.0 (20.8) | 22.2 (34.4) | -0.32 | 0.749 |
| Right standing stork stance (sec) | 36.1 (21.6) | 22.2 (43.8) | -1.44 | 0.150 |
| Push up (rep) | 40.5 (28.5) | 28.0 (16.0) | -1.04 | 0.296 |
| Sit up (rep) | 22.5 (10.3) | 19.5 (10.5) | -0.48 | 0.629 |
| 20-m multistage fitness test (ml/kg/min) | 45.9 (5.6) | 42.9 (3.7) | -2.09 | 0.037* |

**Comparison of Anthropometry Components and Physical Fitness Components.** Based on the result of the Mann-Whitney test, high-performance archers (HPA) have a significantly higher score than the low-performance archers (LPA) ($p<0.05$). For the anthropometry components, height and arm span shows significant differences between HPA and LPA. Meanwhile, for the fitness components, HPA shows a better fitness level than the LPA. The left handgrip, right handgrip, and predicted $VO_{2max}$ show significant differences between them ($p<0.05$).

**Correlation between Anthropometry Components and Fitness Components with the Shooting Score.** The Spearman correlation test shows a strong and positive correlation between height and arm span with the shooting score=0.799 and 0.822, respectively. However, other anthropometry variables did not significantly correlate with the shooting score (p>0.05). The right handgrip and predicted $VO_{2max}$ also positively correlate with the shooting score with r=0.614 and 0.682, respectively. Whereas, other physical fitness components did not show any significance in correlation with the shooting score.

**Table 3. Correlation between Anthropometry Components and Physical Fitness Components with the Score (n = 12)**

| Components | Score (n=12) | |
|---|---|---|
| | r | p-Value |
| **Anthropometry components** | | |
| Height (cm) | 0.799 | 0.002** |
| Body mass (kg) | 0.133 | 0.680 |
| BMI (kg/m$^2$) | -0.158 | 0.625 |
| Body fat (%) | -0.259 | 0.416 |
| Skeletal muscle (%) | 0.469 | 0.124 |
| Arm span (cm) | 0.822 | 0.001** |
| **Physical fitness components** | | |
| Left handgrip (kg) | 0.571 | 0.053 |
| Right handgrip (kg) | 0.614 | 0.034* |
| Back and leg (lbs) | 0.560 | 0.058 |
| Sit and reach (cm) | 0.200 | 0.534 |
| Left standing stork stance (sec) | 0.193 | 0.549 |
| Right standing stork stance (sec) | 0.368 | 0.240 |
| Push up (rep) | 0.049 | 0.879 |
| Sit up (rep) | 0.115 | 0.723 |
| 20-m multistage fitness test (ml/kg/min) | 0.682 | 0.014* |

## DISCUSSION

The objective of this study is to compare the anthropometric and physical fitness components of the high-performance archers (HPA) and the low-performance archers (LPA) as well as the correlation of the components with the scores in archery. This study shows that HPA gained advantages from their height and arm span length and their hands' strength and cardiovascular endurance.

In sports, athletes with body measurements that meet the necessity of sport may have a better advantage in their performance and outshine at a higher level in their sport (15). In the current study, we found that HPA is physically taller and having a longer arm span than the LPA. Also, the results showed that body height and arm span are positively correlated with archery scores. This finding agrees with the previous studies, which inferred that archers with higher height and longer arm span have better muscle strength, and better muscle strength can lead to better performance (8, 9). Humaid (2014) discussed that higher height and longer arm span would increase the length of the draw, which subsequently will increase the potential energy of the bow during drawing and cause the arrow released with higher speed. By increasing the arrow speed, it will lead to an increase in shot accuracy and finally producing a better score (9). Hence, we can conclude that body height and arm span do play important roles in archery.

Success in archery and other sports does not depend solely on one parameter. To anthropometry measures, the physical fitness of athletes is considered as one of the primary keys to success in sport-specific tasks (14). An athlete with good physical fitness is able to excel in their chosen sport. The findings of the current study revealed that HPA has a higher level of physical fitness than the LPA, especially in terms of handgrip strength and aerobic capacity. This finding agrees with the previous studies by Taha et al. (2018) and Musa et al. (2019). In their study, they inferred that physical fitness variables could be used in performance categorization. HPA has a better score in muscle strength and endurance (i.e., handgrip, push up, sit up), explosive power of the lower body (i.e., vertical jump), and static balance than the LPA (5, 7). Besides, Abdullah et al. (2016) reported that high potential athletes have a higher level of physical fitness than the low potential athletes regardless of the type of sports involved (16). Physical fitness is very important for serious archers as they requires approximately 3 to 4 hours/day and 5 times a week of training and exercise (2). Moreover, the weight of the bow string pulls back is ranged around 14 to 22kg. In a tournament day, an archer can lift up to 1440kg to complete their 72 arrows (17).

Archery is a sport that required strong forearm and shoulder girdle to perform during training and competition (4). This study showed that the right handgrip is positively correlated with performance. Similarly, the finding corresponds with Suppiah and scholars who revealed that handgrip is the essential variable in archery (11). Nicolay & Walker (2005) mentioned archers that we can control their bow and arrow with their strength can be more confident in their shooting technique and will be able to perform better (18). It is interesting to note that HPA having a better left handgrip than LPA, but there is no correlation found between the left handgrip strength with the score. In archery, the left hand is used to hold the bow and aiming while the right hand is used to pull the string and release the arrow. The pulling movement required the contraction of biceps brachii and brachialis muscles, while the pushing movement of the bow required the contraction of the deltoid (1). Thus, this indicates that the right hand is activated more than the left-hand during shooting.

The effect of cardiovascular fitness in sports has been widely acknowledged by scholars (19, 20). Based on the results of this study, it was reported that cardiovascular fitness is positively correlated with archery performance. This finding is consistent with the previous study by Kolayis et al. (2014), highlighting that archers with the right physical conditions can control their heart rate, resulting in better shooting accuracy and consistency (21). Musa and colleagues (2016) emphasize that cardiovascular endurance is fundamental for archery as archers are expected to do much work with or without bow and arrows (12). By having a more muscular cardiopulmonary system, archers can sustain their energy longer while executing the repetitive walking to retrieve their arrows. In addition to the sport (walking to check and retrieve arrows), archery is usually being done outdoor. External factors such as hot and humid weather will be taxing the archer. Therefore, an excellent cardiopulmonary system will help in carrying oxygen to the working muscles and removing waste products, it also helps in blood circulation and releasing of excessive heat. Hence, it is important to include aerobic type of training into the training program of archers.

Besides handgrip strength and cardiovascular endurance, balancing, and leg strength also play an essential role in archery. Studies have highlighted that elite archers have better control of postural movement than the novice archers and untrained athlete (22). Suppiah and colleagues (2017) suggested that core stability training can improve core strength and reduce postural sway during aiming, thus improving archery (23). Furthermore, the study had shown that leg strength is essential in maintaining postural balance during aiming and improve the shot accuracy (24). Thus, to excel in archery, one needs to have a good balance ability.

Finally, flexibility does in archery performance (11). Although in the current study, flexibility was not significantly correlated to shooting performance. We feel it is still an essential component in archery. Flexibility help athletes to execute movement with relative ease (25). There is a study indicating that athletes who possess greater flexibility have less risk of getting injured (25) and can perform a broader range of motion with ease (26) than the athletes with lesser flexibility.

In conclusion, archers should focus more on their arm strength and cardiovascular endurance to improve its performance. It is the most significant variable in achieving a high score in archery.

## CONCLUSION

The current study has successfully demonstrated that high-performance archers are taller, having longer arm span, more muscular handgrip strength, and having better predicted $VO_{2max}$ values compared to the low-performance archers. Secondly, the anthropometric dimension (i.e., height and arm span) and physical fitness (i.e., handgrip strength and cardiovascular endurance) of archers are positively correlated to shooting (score) performance in archery. This study is a cross-sectional study, and our results are inferential at best. Our study sample size could have been improved as well to obtain a better normal distribution of data. However, non-parametric statistical analyses are equally powerful to parametric tests when used appropriately (27).

To improve our anthropometric parameters, we suggest future studies to consider adding in other dimensions such as body part circumferences, skinfolds, and girth. This information may provide more information for the coaches on what type of body structure are most likely to produce talented archers. On the other hand, to improve our fitness protocol, we suggest future studies consider adding in an others fitness test that may investigate the importance of the lower body instead of focusing on the upper body region. Besides, the future study may invent or modify some fitness test which is more suitable and appropriate for archery, such as drawing a bow without an arrow, as well as draw and hold the bow. Other than that, it might be interesting to compare the fitness level of different levels of archers (i.e., international level, national level, and beginners).

Further studies are needed to support our current findings, and intervention studies in novice archers will be beneficial to inform in this area. More work can be done to understand the contribution of physical fitness towards the archery performance to improve the scores.

## APPLICABLE REMARKS

- According to the anthropometric dimension, height and arm span showed a positive correlation with the shooting score, and there are significant differences between the groups. Thus, from a coaching practice perspective, it is suggested that coaches could try to recruit archers with taller height and longer arm span into the team. Also, talent scouter and coaches would consider physical characteristics when conducting archery talent identification programs.
- According to the fitness test results, handgrip strength and cardiovascular endurance showed a positive correlation with the shooting score. Besides, high-performance archers showed a better fitness level than the low-performance archers. Hence, it is crucial to include a fitness program for the training schedule. Coaches and archers should always monitor the fitness level for improvement in performance.

## CONFLICT OF INTEREST

There is no conflict of interest reported between the authors.

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## AUTHORSHIP RIGHT

Study concept and design:

1- Study concept and design: Lau Jiun Sien, Rosniwati Ghafar, Erie Zuraidee Zulkifli, Hairul Anuar Hashim

2- Acquisition of data: Lau Jiun Sien

3- Analysis and interpretation of data: Lau Jiun Sien, Rosniwati Ghafar

4- Drafting of the manuscript: Lau Jiun Sien, Rosniwati Ghafar, Erie Zuraidee

5- Critical revision of the manuscript for important intellectual content: Hairul Anuar Hashim

6- Statistical analysis: Lau Jiun Sien, Rosniwati Ghafar

7- Administrative, technical, and material support: Lau Jiun Sien, Rosniwati Ghafar, Hairul Anuar Hashim

8- Study supervision: Lau Jiun Sien, Rosniwati Ghafar, Hairul Anuar Hashim, Erie Zuraidee Zulklfli

## ROLE OF THE SPONSOR

The funding organizations are public institutions and had no role in the design and conduct of the study; collection, management, and analysis of the data; or preparation, review, and approval of the manuscript.

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