СПОРТИВНА МЕДИЦИНА, ФІЗІОЛОГІЯ ТА БІОХІМІЯ СПОРТУ

A systematic review of Malaysian archery biomechanics research

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Анотація. Через біомеханічні дослідження, науковці можуть встановлювати параметри, важливі для стрільби з лука. З цього вони можуть зрозуміти зв'язки певних параметрів з досягненнями у цьому виді спорту. Стаття має за мету забезпечити систематичний огляд літератури з біомеханічних аспектів стрільби з лука, зокрема у Малайзії. Численні бази даних було вивчено на наявність статей, пов'язаних з біомеханічними аспектами стрільби з лука; однак тільки роботи з кількісним аналізом було вивчено більш детально. Широкомасштабний та екстенсивний пошук виявив 38 публікацій, з яких 33 було вивчено після видалення повторюваних. З них 20 було визнано такими, що відповідали критеріям відбору для цього огляду. Після того як відібрані публікації було досконало вивчено з точки зору їх прийнятності, тільки 10 – включено та проаналізовано. Тематичний підхід було використано для класифікації усіх статей. Найбільш поширенними параметрами, що вивчалися у відібраних публікаціях, були рівень м'язової активації, лінія сили натягу, постуральне хитання та баланс. Встановлено, що рівень м'язової активації, постуральний баланс, рухи рук, лінія сили натягу, концентрація прицілювання, техніка стрільби та швидкість стріли відіграють важливу роль у передбаченні високих результатів. Дослідження підтвердили, що лучники, які краще контролюють постуральне хитання, особливо у фазі випуску стріли, здатні підвищити свою результативність. Враховуючи ці показники, тренери та лучники можуть виявити сильні та слабкі сторони. Усю інформацію отримано у ході дослідження, вона є важливою для підвищення майстерності лучників. Інформація може бути використана для допомоги тренерам та лучникам у корекції техніки та розробки тренувальних програм. Таким чином, дослідники мають віднаходити більше інформації з біомеханіки стрільби з лука заради покращення результатів у цьому виді спорту.
Ключові слова: стрільба з лука, біомеханіка, Малайзія, спортивні досягнення.

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A SYSTEMATIC REVIEW OF MALAYSIAN ARCHERY BIOMECHANICS RESEARCH

Abstract. Through biomechanical research, scientists can set parameters that are important for archery, and thus understand the relationship of certain parameters with the achievements in this sports event. The article aims to provide a systematic review of the literature on the biomechanical aspects of archery, particularly in Malaysia. Numerous databases have been studied for articles related to the biomechanical aspects of archery; however, only works with quantitative analysis have been studied in every detail. A large-scale and extensive search revealed 38 publications, 33 of which were studied after removing duplicates. Of these, 20 were found to meet the selection criteria for this review. After the selected publications were thoroughly studied in terms of their acceptability, only 10 were included and analyzed. The thematic approach was used to classify

Lau Jiun Sien, Rosniwati Ghafar, Erie Zuraidee Zulkifli, Hairul Anuar Hashim, Krasilshchikov O. A systematic review of Malaysian archery biomechanics research. Theory and Methods of Physical education and sports. 2020; 3: 91–96
DOI: 10.32652/tmfvs.2020.3.91–96

Лау Дзюн Сієн, Росніваті Гафар,Ері Зураїді, Хайрул Ануар Хашим, Красильщиков О. Системний огляд досліджень біомеханіки стрільби з лука в Малайзії. Теорія і методика фізичного виховання і спорту. 2020; 3: 91–96
DOI: 10.32652/tmfvs.2020.3.91–96

Introduction. Biomechanics is the science that applies the science of mechanics to the movement of living things [9]. Although biomechanics are widely intergrated into sport training, the research done between biomechanics and archery is still scarce. By applying the knowledge of biomechanics into archery is expected to better understand and explain the movement of muscles during shooting, to reduce the fatigue effects and to optimise performance [4].

Archery is a sport that uses a fixed sequence of movements which are bow holding, drawing, full draw, aiming, release and follow through [10]. All sequences of movement in archery will have forces that act on the body that will transfer along the bones and through the joints as well. According to the biomechanics principle, the risk of injury can be reduced by maximizing the force acting on bones and minimizing the force acting on the muscles [24]. Besides, Kristianslund and scholars mentioned that injuries can be prevented by understanding and applying the correct joint moment and the motion of the human body [12].

To study the biomechanical aspects of archery, different tools and equipment are needed. The most common study done on archery is to investigate the contraction of muscle during shooting. Scholars study the contraction and relaxation strategy of the forearm during release of the bow string with electromyography [6, 7]. They found that different type of contraction-relaxation strategy can be used in the drawing arm. Besides, another groups of researchers observe the activation patterns in shoulder girdle muscle during archery shooting with electromygraph and concluded that different muscles were activated during different phases of shooting [11]. Other than that, Mason and colleagues

all articles. The most common parameters studied in selected publications were the level of muscle activation, tension line, postural oscillation and balance. Muscle activation levels, postural balance, arm movements, tension line, aiming concentration, shooting technique, and arrow speed have been shown to play important roles in predicting high results. Studies have confirmed that archers who better control postural sway, especially in the arrow release phase, are able to increase their effectiveness. Given these indices, coaches and archers can identify strengths and weaknesses. All the information was obtained during the study; it is important to improve the skills of archers. The information can be used to assist coaches and archers in correcting technique and developing training programs. Thus, researchers need to find more information on the biomechanics of archery in order to improve results in this sports event.
Keywords: archery, biomechanics, Malaysia, sports achievements.

[14] studied the centre of pressure during shooting with force platform and concluded that better postural balancing can lead to better performance. Measurement of the joint angle during shooting through video recording and motion analysis, suggested that draw force line angle stabilization will improve the shooting and reduce fatigue [5].

Biomechanics related literature on archery has been focusing on various aspects such as muscle activity level [13, 8, 24], postural sway [19, 20] and draw force line [1, 5]. However, biomechanics studies related to archery in Malaysia is still limited. Therefore, the aim of the current review is to assess the literature pertaining to biomechanic research in archery in Malaysia.

Methods. A systematic review of the published literature was conducted to identify the articles providing authentic information on biomechanics field of archery in Malaysia. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram was used to depict the selection of articles included in this study [16].

Search strategy. A literature search was conducted using the available database from Google Scholar, Science Direct, and ProQuest. The literature search included terms commonly used by researchers: archery; bows; arrows; shooting; biomechanics; electromyography; postural sway; draw force line; technique; 3-D motion and Malaysia. Articles from the year 2000 to 2019 were considered for inclusion. In addition to the electronic search, a manual search was completed to ensure that the search was exhaustive and not subject to search bias.

Selection criteria and screening process. The selection criteria for this review were specified into three characteristics for this study. First, the articles do not include other sport. Second, the studies are related to the performance of archery. Finally, only articles published in English, with the year of publication from 2000 to 2019, and which were peer-reviewed and published in authentic citation-indexed journals were included in this systematic review.

The screening process was carried out in three steps. Firstly, articles were screened based on the titles and abstracts. Secondly, reference lists of the short-listed articles were also examined. Finally, based on the aforementioned selection criteria, final screening from the short-listed articles was done.

Data extraction. At first, the articles were separated for compatibility with the aforementioned selection criteria by their keywords, titles and abstracts. Next, all full texts of the studies were reviewed at length. A standard review form was used to extract data from those studies, including state of origin, methodology (i.e., including the type of study design, tested parameters, equipment or test used, and participants) and results.

Results. The wide-ranging and thorough search altogether produced 38 abstracts (fig. 1). After removing the duplicates, 33 abstracts were reviewed, and full-length articles were also produced. Among those 33 studies, 20 studies met the data extraction requirements and had sufficient information to include for this review. As a result, the rest of the studies (n = 13) were excluded from the review process. After that, the selected 20 studies were thoroughly assessed based on the eligibility criteria, and out of those studies only 10 were selected for conclusion in the review. Table 1 summarizes the characteristics of the included studies.

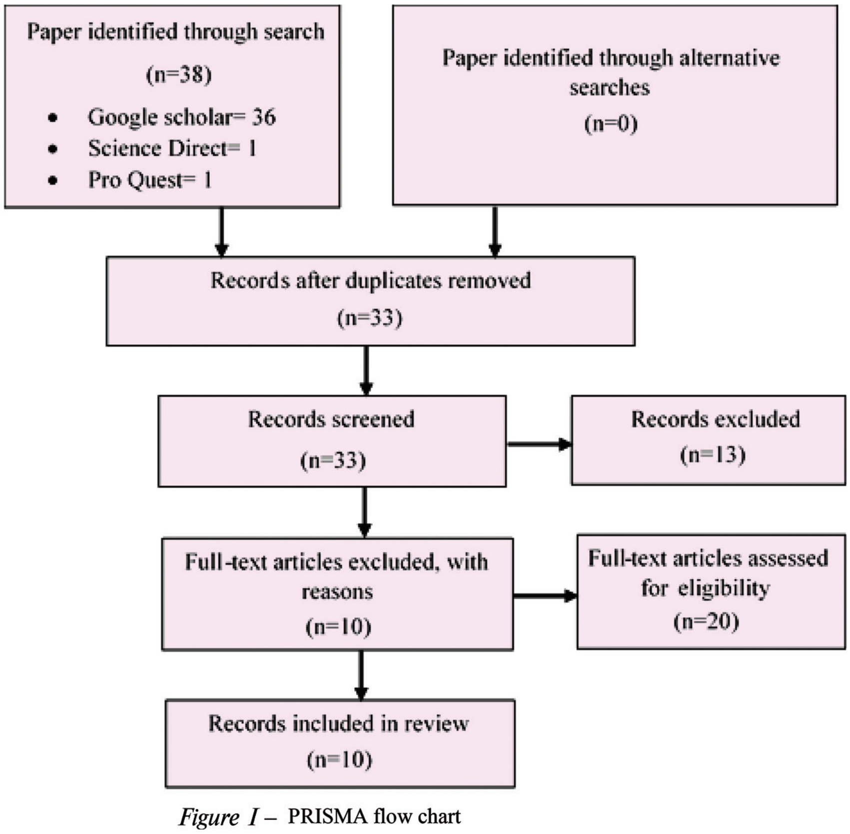

Figure 1 – PRISMA flow chart

State of origin. One cross-sectional analytical study was carried out jointly in Terengganu by the authors from Pahang, Kuala Lumpur and Terengganu (n=1), and another cross-sectional descriptive designed study was performed in the state of Terengganu by collaboration between authors from Pahang and Kuala Lumpur (n = 1). Apart from these two studies, three cross-sectional analytical studies had been done in the state of Selangor (n = 3), one of the studies was conducted by the National Sports Institute of Malaysia. One cross-sectional descriptive design study had been carried-out in the state of Terengganu (n = 1). Three case reports were included in this review, one from the state of Pahang (n = 1) while two from the state of Selangor (n = 2). There was one intervention study carried out in the state of Kelantan (n = 1).

Parameters tested. In this review, studies can be categorized based on the examined parameters. Based on the current review, there were four studies that focus on a combination of parameters tested, while other studies focus only on one parameter (fig. 2). Out of the four combination parameters studies, two studies focused on the effect of postural balance, movement of the bow, and muscular activation on recurve archery. Another research that studies several parameters investigated the importance of draw force line, muscle activity, weight balancing distribution and aiming concentration on recurve archery. One study was conducted on the national athletes to identify the correlation between muscle activation, arrow speed and performance in recurve archery. Two studies focused on the relationship between postural sway and archery performance. Another study explored the arms movement of archers by using accelerometers. There was only one study investigating muscle activity between skilled and recreational compound archers. Another study had investigated the wrist muscle activity level of a traditional bow archer. There is one study compared two shooting techniques in recurve archery with Qualysis tracking managers.

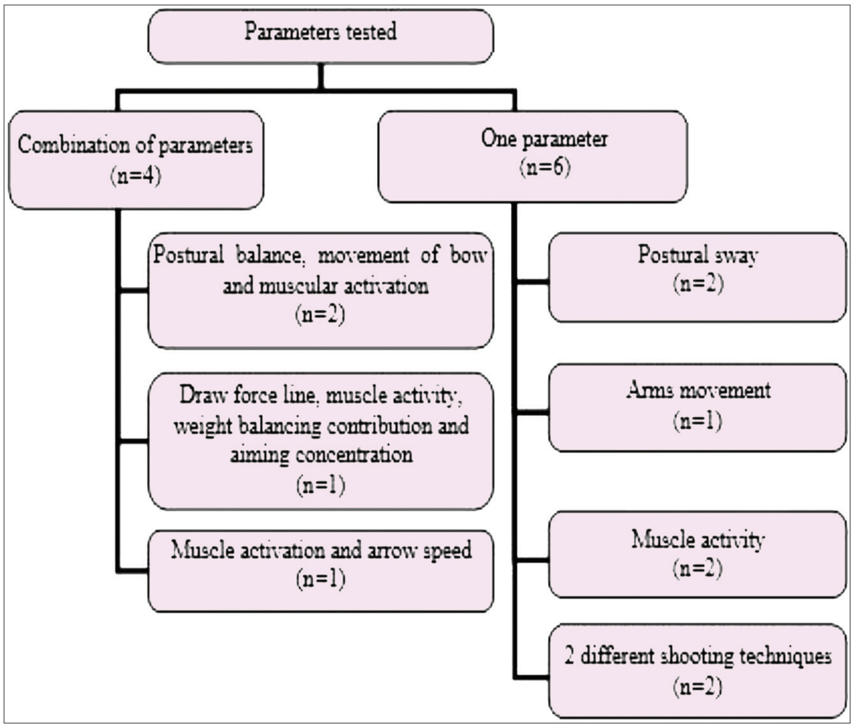

Figure 2 – Parameters tested

Discussion. Based on the outcome presented in this review study (Table 1), there were four cross-sectional analytical designed study [15, 21, 25, 22], two cross-sectional descriptive designed studies [23, 17], three case studies [1, 2, 3], and one interventional study was included in this review [18].

Each of the studies recruited different number of participants with various level of shooting performance in their research. They also conducted the study with different shooting distances, ranging from 10 meters to 70 meters. There are two studies that recruited 21 skilled archers as their participant and required to shoot at 30 meters [15, 25]. Sien and colleagues [18] had recruited 4 participants and the study required the participants to shoot at 10 and 30 meters. Musa et al. [17], they recruited 4 archers with one female medallist, one female non-medallist, one male elite and one male novice while the shooting distance was set at 50 meters away. Taha and colleagues [22] recruited 32 participants with 24 males and 8 females who are under a development program for both at university, and the state level with archery shooting experience ranging from 3 to 6 years. They were required to shoot at a distance of 50 meters. In another study by Taha et al. [23], they recruited two male university archers to shoot at 70 meters distance with accelerometers attached to their hand. Suwarganda and colleagues [21] recruited three national archers comprising of two male and one female with a shooting distance of 70 meters. Ariffin and colleagues [2] recruited one skilled compound archer and one recreational compound archer in their study, however, the shooting distance was not highlighted. In addition, Arrifin and colleagues [2] did another study which recruited a traditional bow archer who won the World Horseback Archery Championship Korea 2014. The shooting distance of the study was not mentioned. In contrast to the previous studies, Ahmad et al. [1] in their case study recruited a coach as their participant, however, the shooting distance was not mentioned. From these, most of the studies did not mentioned the distance shot. According to the rule of World Archery, recurve archers are competing at 70 meter. Thus, it is strongly suggested that study should be done at 70 meter in order to get the better outcome of the study.

Different parameters required different equipment to collect the data. The most common parameters that were investigated are muscle activation level, draw force line, postural sway and balancing. There are two studies that used

Table 1. List of Studies Included for Review (n = 10)

Authors	State of Origin	Bows	Parameters tested	Equipment used
Ariffin, Rambely, & Ariff, 2018	Selangor	Traditional	• Muscle activity level	EMG (6 wrist muscles) • Extensor carpi ulnaris (bilateral) • Extensor digitorum communis (bilateral) • Flexor carpi radialis (bilateral)
Musa et al., 2018	Terengganu	Recurve	• Postural balance • Movement of bow • Muscular activations	IMUs shimmer sensors (4) • Accelerometer – pelvic region • Accelerometer – bow hand • EMG (2) ○ Left flexor digitorum superficial ○ Left extensor digitorum
Arrifin & Rambely, 2017	Selangor	Compound	• Muscle activity level	EMG (12 muscles & 6 joints) • Flexor carpi radialis • Extensor digitorum communis • Brachioradialis • Biceps brachii • Medial deltoid • Medial trapezius • Triceps brachii
Sien, Ghafar, Ariffin, Mohamed, Mat Zain, 2017	Kelantan	Recurve	• Two different shooting techniques	Qualysis tracking manager with 26 reflective markers
Taha et al., 2017	Terengganu	Recurve	• Postural balance • Movement of bow • Muscular activations	IMUs shimmer sensors (4) • Accelerometer – pelvic region Accelerometer – bow hand • EMG (2) ○ Left flexor digitorum superficial ○ Left extensor digitorum
Taha, Mat-Jizat, Omar, & Suwarganda, 2016	Terengganu	Recurve	• Arms movement of the archer	Accelerometers (2) • Right wrist • Left wrist
Ahmad et al., 2013	Pahang	Recurve	□ Draw force line □ Muscle activity □ Weight balancing distribution □ Aiming concentration	1. EPIX high-speed camera □ Top view □ Sagittal view 2. Shimmer EMG □ Right deltoid □ Flexor digitorum □ Extensor digitorum 3. AMTI Force plate 4. Biofeedback device □ Blood volume pulse sensor
Zawi & Mohamed, 2013	Selangor	Recurve	□ Postural sway	Zephyr Bio-Harness device □ Xyphoid process under the sternum
Suwarganda, Razali, Wilson, & Pharmy, 2012	Kuala Lumpur	Recurve	□ Muscle activation level □ Arrow speed	1. EMG □ Triceps (bilateral) □ Left deltoid □ Right Trapezius 2. Radar gun
Mohamed & Azhar, 2012	Selangor	Recurve	□ Postural sway	Zephyr Bio-Harness device □ Xyphoid process under the sternum

four IMU's shimmer sensors to study the biomechanics parameters in archery. One sensor was attached at the pelvic region to study the postural balance, another sensor was attached to the bow hand to collect the data of bow movement and the rest were used as the EMG to read the muscular activations of left flexor digitorum superficial and left ex-

No of participants	Distance shot	Findings
1	Not mentioned	In the Mameluke technique, the bow arm has a higher force value than the draw arm. Flexor carpi radialis muscle generates a higher amount of force which signified flexion movement for both arms
4 (2 male, 2 female)	50 m	Elite and medallist archers are better in controlling their postural sway, reducing the movement of their bows and have greater activation of muscle extensors, hence achieved higher consistency and scores than the non-medallist and novice archers
2	Not mentioned	The recreational archers tend to have muscle fatigue which may cause serious injuries, due to recreational archers only used one maximum muscle while string-pulling, whereas skilled archers used two maximum muscles
4	10 m and 30 m	Biomechanical Efficient Shooting Technique (BEST) method improved the participants' performances
32 (24 male, 8 female)	50 m	Higher performance archers showed higher muscular extensor activations and lower postural sway with greater shooting score, whereas lower performance archers have higher postural sway with a lower shooting score
2 males	70 m	There is a correlation between the archers' arm movement and their score. Although the arm movement generated a similar displacement pattern for a higher score and a lower score, a high bow arms' movement in the transverse plane upon releasing the string may lead to a lower score
1	Not mentioned	Drawing technique, stabilization of weight balancing and aiming concentration has a direct relationship with the performance of the archer
21	30 m	Postural sway reduction during the release phase improved shooting accuracy, thus establishing a significant relationship between postural sway values with shooting performance of skilled archers
3 (2 male, 1 female)	70 m	Each archer has different muscle determinants influencing score and speed
21	30 m	Postural sway, specifically at the release phase can produce inconsistency in shooting techniques thus disallowing archers to obtain the best score

tensor digitorum [22, 17]. Another two studies that focus on the postural sway used Zephyr Bio-Harness device and attached it to the xyphoid process under the sternum [15, 25]. Surface EMG is commonly used to read the muscle activation level [21, 1, 2, 3]. Taha et al. [23] used accelerometers to detect the arms movement of the archers and it was placed at the wrist of the archers. In order to study the weight balancing distribution, AMTI force plate was used; while EPIX high-speed camera was used to record all the shooting movement, and a biofeedback device was used to detect the aiming concentration [1]. Sien et al. [18] utilized the Qualysis tracking manager to identify the differences between two different shooting techniques in recurve archery.

Based on all the reviewed studies, the outcomes show that biomechanics can play an important role in improving archery performance. Studies proved that archers who are better in controlling their postural sway, specifically at the release phase can improve their shooting accuracy, thus establish a significant relationship between postural sway values with shooting performance of skilled archer [15, 25, 22, 17]. A study concluded that there was not a single proximal muscle that can be described as a determinant for score or speed of arrows for all archers, as the finding showed that various muscle activity by the archers; thus indicating that each archer has different style or manner that will influence score and speed [21]. Studies that focus on the forearm muscle found out that greater activation of muscle extensor can lead to better performance [22, 17]. Ariffin and colleagues [2] found that recreational archers tend to have muscle fatigue due to the wrong muscles recruitment. In another study conducted by Ariffin and colleagues [2], they found that in Maleluke technique, the draw arm has lower force value than the bow arm. Besides, the flexor carpi radialis muscle generate a higher amount of force which signified flexion movement for both arms. Besides, Ahmad et al. [1] in their study claimed that it is important to shoot with a correct technique as it can prevent muscle fatigue. In addition, they also highlighted that stabilization of weight balancing and aiming concentration has a direct relationship with the archers' performance. Three studies have indicated that a high bow arms' movement in the transverse plane upon releasing the string may lead to a lower score [23, 22, 17]. Sien and colleagues [18] showed that the BEST method was able to improve the shooting performance in recurve archery. Thus, to excel in archery, archers should have well control in balancing, activate the correct muscle during shooting, use the correct shooting technique, and minimize the bow arm movement.

Limitations of this review and included studies. There are a few limitations in the current review. Firstly, there was no systematic review article included. Secondly, it is difficult to identify the importance of each parameter on the performance of archery as there were less analytical studies available. Thirdly, through the search of articles, there were some studies that were not retrievable due to the unavailable of full-text articles. Fourthly, due to the inclusion criteria, we had to exclude some of the studies and articles. Finally, since the search was restricted to articles published in English language only, the studies reported here may not be universal.

Conclusions. All the information gain from the researches are important in improving the performance of archery. Based on the current review, muscle activation level, postural balance, arm movement, draw force line, aiming concentration, shooting techniques, and arrow speed play an important role in predicting good performance. Therefore, the findings can be used as a guideline for the coaches and archers to correct their techniques and design an effective training program. Malaysian researchers should explore more information from biomechanics field in order to enhance archer performance and contribute to the existing knowledge in the field of archery.

Conflicts of interest. The authors have no conflicts of interest to declare.

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ІНФОРМАЦІЯ ПРО АВТОРІВ

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Надійшла 01.09.2020