A MONITORING OF ARCHERY PERFORMANCE PREDICTORS AMONG STATE-LEVEL ARCHERS

LAU JIUN SIEN

UNIVERSITI SAINS MALAYSIA

2023

A MONITORING OF ARCHERY PERFORMANCE PREDICTORS AMONG STATE-LEVEL ARCHERS

by

LAU JIUN SIEN

Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

September 2023

ACKNOWLEDGEMENT

I would like to take this opportunity to express my greatest gratitude to many wonderful people that have supported and motivated me during my journey toward Ph.D. First, I wish to extend my highest gratitude to my principal supervisor, Dr. Rosniwati Ghafar, and co-supervisors, Prof. Dr. Hairul Anuar Hashim and Sir Erie Zuraidee Zulkifli who gave me valuable guidance, persistent feedback, encouragement, patience, and continuous support for my research. It is my honour and privilege to have them along this challenging journey. Thank you for always being there whenever I need help and patiently guiding me as well as sharing valuable experience and knowledge with me.

A sincere appreciation to all the lecturers, laboratory staff, and students in the Exercise and Sport Science Programme for their kind assistance during this study. Furthermore, they always showed their concern for my study and gave me motivation when I was down.

My sincere appreciation goes to all the directors of Terengganu State Sports Council and the principal of Malaysia Pahang Sports School for approving my study. I would also like to take this opportunity to thank all the coaches, Coach Azeem, Coach Firdaus Isa, and Coach Fariza Razak for their kindness and hospitality throughout the data collection period. I would also like to thank all my research participants who have shown full cooperation and commitment during data collection.

Finally, I would like to dedicate this research work to my family members for their love, understanding, sacrifices, and encouragement. No words can describe how thankful and blessed I am to have such a loving and supportive family throughout my research study. This milestone would not have been possible without all of you.

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LIST OF SYMBOLS

B	Unstandardised coefficient
β	Standardised coefficient
df	Degrees of freedom
F	Variation between sample means
M	Mean
SD	Standard deviation
SE	Coefficient standard error
Sig.	Significant value
95% CI	95% confidence interval

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
ASI	Archery Skill Index
BEST	Biomechanically Efficient Shooting Technique
BRUMS	Brunel Mood Scale
DFL	Draw Force Line
EMG	Electromyography
FITA	Fédération Internationale de Tir à l'Arc
IMU	Inertial Measurement Unit
LE	Linear Envelops
MDA	Muscle Deltoid Anterior
MDM	Muscle Deltoid Middle
MDP	Muscle Deltoid Posterior
MED	Extensor Digitorum Muscles
MFDS	Flexor Digitorum Superficialis
MPMPC	Muscle Pectoralis Major Pars Clavicularis
MSN	National Sports Council
MTPA	Muscle Trapezius Pars Ascended
MTPD	Muscle Trapezius Pars Descended
MTPT	Muscle Trapezius Pars Transversa
NAAM	National Archery Association Malaysia
POMS	Profile of Mood States
POMS-A	Profile of Mood States- Adolescents
Post CASI	Post-clicker Archery Skill Index
Post CASI 2	Post-clicker Archery Skill Index 2
Pre CASI	Pre-clicker Archery Skill Index
SPSS	Statistical Product and Service Solutions
SUKMA	Malaysia Games
SVM	Support Vector Machine
$\dot{V}O_{2max}$	Maximal Oxygen Consumption

LIST OF APPENDICES

PEMANTAUAN TERHADAP PERAMAL PRESTASI SUKAN MEMANAH DALAM KALANGAN ATLET MEMANAH PERINGKAT NEGERI

ABSTRAK

Memanah merupakan sukan yang memerlukan teknik, keadaan fizikal, taktik dan psikologi tertentu untuk dilakukan. Ia adalah penting untuk memahami kriteria yang utama dalam memanah untuk membina pemanah yang cemerlang. Dengan demikian, kajian ini dijalankan bertujuan untuk menentukan peramal prestasi sukan memanah dalam kalangan pemanah *recurve* peringkat negeri. Sebanyak lapan belas orang pemanah peringkat negeri dari Majlis Sukan Negeri Terengganu dan Sekolah Sukan Malaysia Pahang telah direkrut dalam kajian ini dan tiga belas (13) orang peserta (purata umur = 16.23 ± 1.74) menamatkan kajian sehingga ke peringkat akhir. Tahap pengaktifan otot, garisan daya tarik, keadaan mood dan tahap kecergasan fizikal pemanah adalah peramal prestasi pemanah yang dipantau di dalam kajian ini. Keadaan mood peserta dinilai dengan soal selidik *Brunel Mood Scale* sebelum sesi memanah dijalankan. Semasa sesi memanah, tahap pengaktifan otot deltoid kiri, otot triseps kiri, otot trapezius kanan dan otot triseps kanan diukur dengan elektromiografi. Sementara itu, garisan daya tarikan semasa *anchoring* dan *releasing* dirakam dengan kamera rakaman dan dianalisa dengan perisian analisa pergerakan, *Kinovea.* Prestasi memanah ditentukan berdasarkan jumlah skor untuk 36 batang anak panah yang dilepaskan pada jarak 70 meter. Setelah selesai sesi memanah, tahap kecergasan fizikal peserta diukur dengan ujian fizikal termasuk tekan tubi, bangkit tubi, kekuatan genggaman tangan, ujian dirian bangau, ujian kekuatan belakang dan kaki, jangkaun melunjur dan ujian kecergasan pelbagai peringkat. Kesemua parameter diukur setiap dua bulan, iaitu lima

sesi pengukuran dilakukan sepanjang kajian. Hasil analisis regresi linear berganda menunjukkan tahap pengaktifan otot dan tahap kecergasan fizikal boleh digunakan sebagai panduan di dalam meramalkan prestasi memanah. Di antara otot-otot yang dikaji di dalam kajian ini, otot deltoid mempunyai perhubungan dengan prestasi memanah di sesi pengukuran kelima dengan signifikan. Selain itu, tahap kecergasan fizikal juga boleh meramalkan prestasi memanah secara signifikan di sesi pengukuran pertama, sesi pengukuran ketiga dan sesi pengukuran keempat. Komponen kecergasan fizikal yang mempunyai perhubungan dengan prestasi memanah termasuk kekuatan tangan kiri dan kanan, kekuatan belakang dan kaki, keseimbangan, kelenturan, daya tahan tubuh atas, daya tahan otot teras, dan daya tahan kardiovaskular. Manakala, keadaan mood dan garisan daya tarik tiada perhubungan dengan prestasi memanah yang signifikan. Kesimpulan, tahap kecergasan fizikal dan tahap pengaktifan otot pemanah mampu meramalkan prestasi memanah dalam kalangan pemanah peringkat negeri.

A MONITORING OF ARCHERY PERFORMANCE PREDICTORS AMONG STATE-LEVEL ARCHERS

ABSTRACT

Archery is a sport that required a certain level of techniques, physical conditions, tactics, and psychology to perform. It is important to understand the most crucial criteria in archery to build excellent archers. Thus, this study aimed to determine the predictors of archery performance among state-level recurve archers. Eighteen state-level recurve archers were recruited from Terengganu State Sports Council and Malaysia Pahang Sports School and 13 participants (mean age = 16.23 ± 1.74) had completed the whole study protocol. Muscle activation level, draw force line, mood states, and physical fitness level of the archers were monitored predictors of archery performance in this research. The mood states of the participants were evaluated with Brunel Mood Scale Questionnaire before the scoring session. During the scoring session, the muscle activation of left deltoid muscles, left triceps muscles, right trapezius muscles, and right triceps muscles were measured with electromyography. Meanwhile, the draw force line during the anchoring and releasing was recorded with a video camera and was analysed with Kinovea motion analysis software. The archery shooting performance was based on a total score of 36 arrows shot at a distance of 70 meters. After the scoring session, the physical fitness level of the participants was measured with fitness tests including push-ups, sit-ups, handgrip test, stork stand test, back and leg test, sit and reach test, and multistage fitness test. All the parameters were measured five times, with each measurement taken at a two-months interval. The results of the Multiple Linear Regression (MLR) revealed muscle activation level and physical fitness level can be used as a guideline in predicting the

archery shooting performance. Among the muscles tested in this study, the left deltoid is the only muscle that is associated with the archery shooting performance in the fifth measurement session. Furthermore, physical fitness level also able to predict the shooting performance significantly in the first measurement session, third measurement session and forth measurement session. The physical fitness components that were associated with the archery shooting performance included left and right handgrip strength, back and leg strength, flexibility, balance, upper muscle endurance, core muscle endurance, and cardiovascular endurance. However, the mood states and the draw force line of participants are not associated with the archery performance. It is concluded that the physical fitness level and muscle activation level of the archers can predict the archery shooting performance among state-level archers.

CHAPTER 1

INTRODUCTION

1.1 Background and scope of the study

Archery is a non-contact sport that used a bow to launch arrows toward a set target (Dhawale et al., 2018; Lee, 2009). According to archaeological records dating back to 65,000 B.C., archery has been practiced as a survival and hunting skill for millennia (Lombard, 2011). Nowadays, it has become a competitive and recreational game, and its gain attention worldwide (Singh and Lhee, 2016). Since 1900, archery is included in the Summer Olympic games. It is regulated by World Archery, an international federation for the Olympic and Paralympic sport of archery.

Around the world, archery is competed at different levels, from the scholastic level to the international level. The major events held by World Archery include continental games, Archery World Cup Series, and the Olympics Games. The categories that are competed in modern archery are recurve and compound categories. However, in the Olympics Games, only recurve category is contested.

Archery shooting skills can be explained as a three-phase movement from drawing, aiming, to releasing (Ertan et al., 2003). Some researchers further detailed the movements into six phases, which are bow hold, draw, full draw, aim, release, and follow-through (Nishizono et al., 1987). In addition, Lee and Benner (2009) proposed the Biomechanically Efficient Shooting Technique (BEST), with 13 steps system that are stance, hook and grip, mind-set, set-up, draw, loading, anchor, transfer, hold and aim, expansion, release, follow-through, relaxation and feedback. Archers need to use consistent and stable movements in every shot to achieve high performance (Park et al., 2016; Stuart and Atha, 1990).

The performance in archery is based on the total scores of the arrow shot by the archers within a given time frame (Musa et al., 2016). The score of an arrow ranged from ‘0’ (miss) to 10 points. In general, the performance of archery can be affected by various factors including the internal factors and external factors. Internal factors consisted of the shooting skill, psychological condition, and physical fitness level (Kolayis and Ertan, 2016). Meanwhile, the external factors comprise of the material of the equipment, weather condition, and the environment condition (Suppiah et al., 2017b).

The performance in sports is affected by a combination of physical, mechanical, physiological, and psychological factors (Foster and Porter, 1987; Gould et al., 1993). While for archery, findings from a few studies implicated that archery performance relies on the mental, skill, and fitness level of the archers (Kim et al., 2015; Nasrulloh et al., 2022). Besides, biomechanics and anatomic factors also play important roles in determining performance (Hidayat, 2014). Thus, high-level archery skills can be achieved through high morale, excellent technical skills, and readiness for competition (Bolotin and Bakayev, 2017).

As highlighted earlier, archery shooting skills consist of sequential movements in the upper and lower body that can be studied through motor skill assessment during the voluntary kinematical process (Nishizono et al., 1987). Generally, the upper body were involved in the pulling and holding of the bow until the arrow is released. Meanwhile, the lower body were involved in maintaining the postural stability of the archers during the shooting movement. In this regard, muscles are important in maintaining the correct posture and releasing of the arrow (Suwarganda et al., 2012). However, it has been suggested the upper limb muscles are more active than the lower

limb muscles as the archer needs to pull and hold the bow until the arrow is released (Leroyer et al., 1993). Thus, the performance of an elite archer can be affected by effective control of upper extremities muscles (Simsek et al., 2018; Soylu et al., 2006).

The specific anatomical structure of the upper body involved in archery shooting is the shoulder girdle (Ertan et al., 2005; Mann, 1994; Mann and Littke, 1989) and forearm muscles (Mann and Littke, 1989). More specifically, researchers found out that the trapezius, extensor digitorum, brachioradialis, triceps brachii, deltoid, and biceps brachii muscles are the main muscles involved in performing archery shooting movements (Clarys et al., 1990). Additionally, the shoulders and upper back muscles involved in archery shooting include rhomboids, levator scapulae, latissimus dorsi, and rotator cuff muscle group (Sharma et al., 2015).

As mentioned, various muscles are activated in the archery shooting actions and each of the muscles have a distinct role. The left deltoid muscle is used to lift the arm and acts as the main carrier of the bow weight (Kolayis and Ertan, 2016). The deltoid muscles also help to pull the head of the humerus into the shoulder socket to increase stability while holding the bow at full draw (Reddy and Al-smadi, 2015). Meanwhile, trapezius muscles act as the initiator of the drawing movement that involves the elevation of the arm and scapula (Clarys et al., 1990). It also helps in the adduction of the scapula and symmetrically in both arms to share the drawing weight of the drawing arm (Kolayis and Ertan, 2016). Furthermore, triceps brachii muscles are the antagonist of the biceps muscles. Hence, it is important to reduce the contraction of the biceps muscles in archery shooting motion (Shinohara and Urabe, 2017).

It is essential to have a correct strategy while using the muscles to perform in archery. Studies had shown that during the drawing stage, the back and shoulder muscles are effectively more active than the arm muscles (Nishizono et al., 1987; Suppiah et al., 2017a). Furthermore, it is more appropriate to use the bigger proximal muscles than the smaller distal muscles as proximal muscles have a higher tolerance to fatigue and can promote consistency in archery (Larven, 2007). For instance, beginner archers are commonly having the problem of improper contraction which may lead to incorrect techniques and cause fatigue in the muscles (Liao et al., 2003; Simsek et al., 2018).

Several studies had investigated the relationship between muscle activation levels and the performance of archers and utilised electromyography (EMG) to measure the muscle activation level (Ertan, 2009; Simsek et al., 2018; Soylu et al., 2006). Several studies have indicated that elite and beginner archers have different patterns of muscle activity levels (Musa et al., 2018; Shinohara and Urabe, 2017; Simsek et al., 2018). Furthermore, several studies had focused on the muscle activation level during the release phase and concluded a well-balanced and highly reproducible release can lead to better performance (Ertan et al., 2011; Nishizono et al., 1987). Thus, it is important to understand the activation of the muscle during archery shooting to improve performance.

In addition to the muscle activity level in archery, the consistency of shooting posture is one of the important performance factors in archery as well (Kim et al., 2014). The shooting postures can be analysed based on the draw force line. A draw force line (DFL) is formed when the archer pushes the bow towards the target with an extended arm while the drawing arm pulls the bowstring towards the anchor from the

beginning of the drawing phase until the release phase (Leroyer et al., 1993). The DFL is a perfectly straight line of force that exists between two extreme points of applications and may be observed from any direction except axially. The extreme points of application are the touch point of the bow handle with the bow hand and the joint of the drawing arm elbow (Axford, 2017).

The angle and position of the elbow play an important role in subjecting force to the shoulder (Debnath and Debnath, 2016). According to the principle of biomechanics, it is ideal to maximise the forces acting on the bones while minimizing the force acting on the muscle as bones do not get tired and fatigued if compared to muscles (Ahmad et al., 2014). Although it is commonly found that the elbow position of recurve archers is not completely aligned with the DFL (Ahmad et al., 2014), it is highly recommended that archers align the elbow position with the DFL as perfectly as possible to reduce the force that applied on the muscles (Hu and Tang, 2005).

The DFL should always be maintained at the same position to reduce the lateral forces of the arm and vibration of the body (Ahmad et al., 2014) as well as to improve the aiming consistency and shooting performance (Axford, 2017). A poor DFL in which the drawing elbow is too high or too low will require the drawing arm biceps and triceps to take all the force and create unnecessary fatigue and cause injury (Larven, 2007; Shinohara et al., 2014). Thus, it is important to keep the draw elbow within the DFL. The DFL can be studied using different methods such as 3-dimensional motion analysis and 2-dimension motion analysis.

Psychology preparation is also crucial for an archer. One of the main parameters in psychology is mood. The mood is a state or quality of feeling at a specific time and mood changes from time to time and place to place (Basumatary and

Pramanik, 2014). According to Cox (2012), a mood state is psychological response that are situation specific and transient to an environmental stimulus. Meanwhile, Lane and Terry (2000) defined mood as a collection of impermanent feelings that fluctuate in intensity and duration and often involve more than one emotion. In daily life, moods are firmly pervasive in human functioning and influenced an individual's effort, behavioural responses, decision-making, attention, memory, and interpersonal interaction (Lerner et al., 2015; Ruiz and Robazza, 2020).

Over the past decades, the relationship between mood and sports performance has been studied widely by researchers (Lane, 2006; Lazarus, 2000; LeUnes, 2000; LeUnes and Burger, 1998; Morgan, 1980; Terry, 1995) and different theories and measurement of the mood construct had developed through the extensive studies (Lane and Terry, 2000; D. McNair et al., 1992; McNair et al., 1971a; Terry et al., 2003). Evidence showed that individuals often experience strong psychological states when striving to accomplish important performance goals (Lane and Terry, 2000; Lazarus, 2000) such as in sporting competitions (Beedie et al., 2000; Terry, 1995) and examinations (Thelwell et al., 2008). Studies indicated that athletes report having significant emotions before, during, and after the competitive event (Lane, 2006; Terry and Lane, 2000; Terry et al., 2003, 1999). Meanwhile, the psychological states of athletes especially the pre-competition mood states had often been used by researchers as predictors of sports performances (Henschen et al., 1990).

According to Terry (1995), mood states are an effective predictor of performance when certain conditions are met. Scholars have highlighted that mood affects performance and poor performance is due to the failure of getting into the right mood (Basumatary and Pramanik, 2014; Lane and Terry, 2016). Athletes tend to

perform better in a neutral mood condition when compared to anger, fear, or relaxation inductions (Kavanagh and Hausfeld, 1986; Murphy et al., 1988). However, many athletes can perform in practice sessions but are unable to repeat their practice session abilities and capabilities during the competition (Esfahani et al., 2011). Lane et al. (2010) proposed that the negative mood states of athletes during the competition will reduce motivation, concentration, and other sport-related mental skills and thus impair the performance outcome. Conversely, studies had proven that unpleasant moods can sometimes aid excellent performance, whereas pleasant moods may be related with underperformance (Beedie et al., 2000; Hanin, 2007).

In a sports setting, mood profiling is an assessment technique commonly used by sports psychologists in their work with athletes. Emotional states such as feelings and moods are typically assessed using self-reported scales such as Profile of Mood States (POMS) (McNair et al., 1971a) and Brunel Mood Scale (BRUMS) (Terry et al., 1999).

The mood dimensions of BRUMS were described as follows: (1) Anger is characterised by feelings ranging from mild annoyance or aggravation to fury and rage, and is related to the autonomic nervous system (Spielberger, 1991), (2) Confusion is suggested to be a state of feeling marked by astonishment and uncertainty, associated with a general inability to manage attention and emotions, (3) Depression is related with a negative self-schema marked by hopelessness, personal insufficiency, worthlessness and self-blame (Beck and Clark, 1988), (4) Fatigue is characterised by a sense of mental and physical exhaustion, (5) Tension is typified by a variety of feelings, including nervousness, apprehension, worry, and anxiety, (6) Vigour is defined by sensations of excitement, attentiveness, and physical vitality.

The BRUMS has adequate predictive, concurrent, criterion, and factorial validity, as well as adequate test-retest reliability (Terry et al., 2003, 1999). In addition, the BRUMS have been widely utilised in the sport fields and exercise psychology to examine the antecedents, correlates, and behavioural consequences of mood; more specifically, the influence of moods on athletes' performance and psychological well-being (LeUnes and Burger, 2000). Researchers utilised BRUMS to examine the mood and performance of athletes in both individual and team sports, such as athletics (Lane and Wilson, 2011), cyclists (Lastella et al., 2015), and football (Basumatary, 2014). According to Lane and Jarrett (2005), mood measurements have been most successful in predicting performance in individuals in sports with short durations and sports groups with similar skills.

In the studies of mood states in sports and exercise, the BRUMS has been used to anticipate dichotomous (win/lose) results in a variety of sports tournaments (Lane et al., 2005). Additionally, the BRUMS has been demonstrated to have predictive validity (Lane and Chappell, 2001), responsive to exercise effects (Lane and Lovejoy, 2001), and be effective in the athletes' screening process (Galambos et al., 2005). Furthermore, the BRUMS also used to detect the over-training syndrome among Brazilian athletes (Rohlfs et al., 2008).

The BRUMS contained 24 items to measure six identifiable mood states: tension, depression, anger, vigorousness, fatigue, and confusion through a self-report inventory (Brandt et al., 2016). The respondents rated a list of adjectives, on a 5-point Likert scale from 0 (not at all) to 4 (extremely), based on how they had been feeling (Brandt et al., 2016). Due to the need for greater cross-cultural generalizability of research findings, the BRUMS has been translated and validated in many languages,

including Malay (Hashim et al., 2010; Lan et al., 2012), Hungarian and Italian (Lane et al., 2007), Farsi (Terry et al., 2012), Chinese (Zhang et al., 2014), French (Rouveix et al., 2006) and Brazilian Portuguese (Rohlfs et al., 2008).

Commonly, there are three distinct mood profiles, namely iceberg profile, inverse iceberg profile, and Everest profile. The iceberg profile is characterised by low levels of tension, depression, anger, fatigue, and confusion combined with a high level of vigour (Morgan, 1980; Morgan et al., 1987). This profile is associated with positive mental health and good sports performance. The inverse iceberg profile is the profile with the combination of above-average tension, depression, anger, fatigue, and confusion with below-average vigour. The inverse iceberg profile is related to underperformance and risk of pathogenesis (Budgett, 1998). The Everest profile is characterised by a lower level of tension, depression, anger, fatigue, and confusion while a higher level of vigour is known for superior performance in sports settings (Terry, 1995).

Other than the three distinct mood profiles, four novel mood profiles also have been identified among the general populations, including the inverse Everest profile, shark fin profile, surface profile, and submerged profile (Parsons-Smith et al., 2017). The inverse Everest profile is characterised by low scores in vigour, a high score in tension and fatigue, and a very high score in anger, depression, and confusion. The shark fin profile is the combination of high fatigue with below-average tension, depression, vigour, anger, and confusion. The surface profile is characterised by average scores on all mood dimensions while the submerged profile is characterised by below-average scores on all mood dimensions.

In many sports, sufficient levels of physical fitness are the keys to achieve successful sport-specific tasks (Abdullah et al., 2016; Limonta et al., 2016). Archery is a sport that requires certain fitness components which include strength, flexibility, and endurance to shoot accurately and without physical fatigue (Ertan et al., 2003; Martin et al., 1990; Vivek and Mishra, 2015). This is due to archery being an energy-demanding sport as archers need to carry, lift and pull the bow during shooting whilst maintaining a static balance frequently throughout the training and competition (Musa, 2019). By maximizing the fitness level, an archer will be able to perform better.

Muscular strength can be defined as the power of the neuromuscular system that results in a force that resists any external resistance (Bompa and Calcina, 1993). It can also be defined as the capacity of a muscle or group of muscles to contract, either pushing or pulling maximally against resistance in the form of a lifted load (Nasrulloh et al., 2021). In archery, the muscles that are used to execute the shots are the arms muscles and upper back muscles (Sivamani, 2014). Archers need adequate upper muscle strength especially the handgrip strength to control the bow during drawing and holding correctly while minimizing the hand tremor and fatigue (Hidayat, 2014; Laishram et al., 2008) as the arm muscles do not exert too much tension during the drawing process (Back and Ji, 2015; Suppiah et al., 2017b). The test that can be used to examine the arm muscular strength is the handgrip test.

Other than the handgrip strength, the back and leg strength was also crucial in archery. Archers were required to stand upright for a long duration during the shooting and they needed to maintain the postural balance (Tinazci, 2011; Musa et al., 2016). It is important for the archers to reduce the postural sway as it can affect the accuracy of

archery. The test that can used to examine the back and leg strength is back and leg test.

Flexibility can be defined as the range of motion of a joint. Flexibility exercises increase the range of motion of the joints, elongate the muscles, provide a warm-up and cool-down of the body, and decrease the risk of injury (Musta, 1999). Previous studies had proven that flexibility can increase muscle mass and strengthen fibrous tissue of archers and reduce injury risk (Berthelot et al., 2010; Busso et al., 2002). Besides, better flexibility may enhance performance in aerobic training and muscular conditioning (Stathokostas and Vandervoort, 2016). Archers should stretch at least once an hour during competitions and training to maintain optimum muscle performance. A comprehensive post-workout stretching program increases the range of motion of the joints and is the perfect way to relax the body and mind after a long day of training (Ruis and Stevenson, 2004). Flexibility can be tested through sit and reach tests.

Balance stability is one of the components that will affect the accuracy of an arrow shot in archery (Ertan, 2009; Musa et al., 2016). A previous study showed that as the archer has better stability, the angle of the arrow trajectory will become narrower (Suppiah et al., 2017a) and helps in reducing the interference from the external elements in the direction of the arrow and enhancing the precision of the shot (Spratford and Campbell, 2017). Besides, the stability of the lower body is more important than the upper body as it affects more on the whole body's stability. An unstable lower body will make the archers face difficulties in keeping balance and concentrating on aiming when their bodies are unstable (Han et al., 2015). During the shooting, archers need to lift the bow up and down, this will change the position of the

centre of the body. Thus, better body stability can minimise unnecessary movement and improve shooting precision (Norton et al., 1996).

Muscle endurance is defined as the capacity of the whole organism to withstand fatigue under the long-lasting expenditure of strength (Frank et al., 1978). It also can be defined as the ability of a group of muscles to apply submaximal force repeatedly over a long duration (Haible et al., 2020). Archery is an upper muscle endurance demanded sport as the training and competition involved continuous shooting (Gaurav et al., 2011; Landers et al., 1991). Thus, endurance exercises that require slow-twitch muscle fibres enable to give advantages to the archers to repeat the movement at ease and without showing any undue fatigue, especially the upper muscle (Ruis and Stevenson, 2004). Muscle endurance gains are achieved by using a lightweight dumbbell, a resistance band, or body weight and a higher number of repetitions. Tests that can be used to examine upper muscle endurance include push-ups test.

Besides upper muscle endurance, core muscle endurance also plays a role in the achievement of higher sports performance. Core strength is known as the abdominal muscles' ability to sustain repeated activation without getting fatigued easily (Abdullah et al., 2016). Core muscle endurance is involved in maintaining body posture and allowing the athlete to move freely during sports (Prieske et al., 2016). In archery, core muscle endurance is correlated with shooting performance as it helps in improving the body posture and reducing the postural sway during the aiming phase (Suppiah et al., 2017 a). The common tests used to measure core strength include a 1-minute sit-up test.

Cardiovascular fitness is the ability to deliver and use oxygen under the demands of intensive, prolonged exercise or work (Plowman and Smith, 2014). It is

an important fundamental attribute of sports performance as the heart controls the oxygen flow to all the working muscles (Miyamoto et al., 2016). Cardiovascular endurance plays important role in archery due to the nature of archery which involves long duration training and competition (Carrillo et al., 2011; Musa et al., 2016; Tinazci, 2011). In high-level national and international archery tournaments, archers might reach heart rates of up to 150 beats per minute (Johnson et al., 2013). Hence, heart rate deceleration experienced by athletes before executing a shot has been reported and showed associated with good performance (Robazza et al., 1999). Cardio training is a natural way to decrease stress and improve moods as well as help the body regulate oxygen (Johnson et al., 2013). The common test to examine cardiovascular endurance includes the Shuttle run test, Cooper test, YMCA step test, and Rockport walking test.

To summarise, previous studies had showed that muscle activation level, shooting postures, mood states and physical fitness level of archers will affect their archery shooting performance. However, to the best of my knowledge, no data exist regarding determining the predictors of archery shooting performance. Therefore, the primary aim of this study is to determine the predictors of archery shooting performance and their association with archery shooting performance.

1.2 Problem statement

Archery is listed as one of the focus sports in Malaysia by the National Sports Council of Malaysia (MSN) after successfully qualifying during the Athens 2004 Summer Olympic Games. Since then, the Malaysian archery team has never failed to qualify for the Summer Olympic Games. In the year 2019, Malaysia's top seeded recurve men archer won a silver medal in ‘S-Hertogenbosch 2019 Hyundai World Archery Championships. Following this positive development, MSN and the National

Archery Association of Malaysia (NAAM) had carried out various plans to produce and prepare more capable athletes for both local and international competitions. In addition, MSN and NAAM had actively collaborated with various parties to organise major tournaments that focus on developing archers, such as Malaysia Games (*Sukan Malaysia*, SUKMA), the Interschool tournament (*Majlis Sukan Sekolah-Sekolah Malaysia*), and *Sirkit Remaja Kebangsaan*.

Furthermore, MSN had created a national module related to sport development programme which cater for various levels and categories of athlete (e.g., Talent Identification and development, TID; Multilateral, *Program Bakat, Pelapis Negeri, Pelapis Kebangsaan,* and Podium programme). Referring to the year 2023 statistics, it has been reported that there are 453 archers located at State Training Center (*Pusat Latihan Negeri*), and 388 archers from *Program Bakat* (Majlis Sukan Negara, 2023). With the current number of developmental level pool of archers, they have the chances to progress to the next level namely under the *Pelapis Kebangsaan* (National Backup) and further to the Podium Programme. Progressing from one level to the next, will definitely require fully committed and determined coaches to handle the athletes. Currently, the ratio between coaches to athlete (archers) is 1 to 16 for State Training Centres (*Pusat Latihan Negeri*) and 1 to 20 for *Program Bakat* (Majlis Sukan Negera, 2023). Therefore, with the high ratio number between coaches to archers as highlighted, it will be a challenge for coaches working at the developmental level. Coaches need to cover various aspects of the sports for example the technical, tactical, physical fitness, psychological and nutrition aspects to a certain extend in order to develop an archer. Thus, this led to the question of 'how coaches prioritise what and/or which aspect to invest most of their time during training?'.

Acknowledging these interesting and challenging situation for coaches to plan their daily training program, at the same time trying to fulfil numerous factors that need to be grasped by their archers in order for them to develop (i.e., especially during the developmental phase) includes technical skill, mental preparation and physical fitness (Kim et al., 2015). Coaches and archers must understand the criteria that are essential for archery. As an example, archery is a sport that involved different muscles and the strategy of muscle contractions can affect performance (Ertan, 2009; Ertan et al., 2005). It also required endurance and strength of the upper body to pull and hold the bow during shooting (Ahmad et al., 2014). However, what criteria can be used to predict the performance of the archers is still scarce.

Therefore, this study aims to investigate the predictors of archery performance, especially among developmental (state) level archers. Instead of determining the predictors such as the shooting techniques, psychology, and physical fitness, it is also important to find out the association of each predictor with the archery shooting performance. With this information, it is hoped that it will help coaches to focus what and/or which aspect to invest most of their time during their coaching practice.

1.3 Terminological definitions

In this study, the following terminologies are defined as follows:

(a) Archery

Archery is a sport that uses a bow to launch an arrow toward a set target (Lee and Benner, 2009).

(b) Recurve bow

A recurve bow is a type of bow with the top and bottom limbs curving back away from the archer at each tip (World Archery Federation, n.d.).

(c) Archery shooting performance

Archery shooting performance is defined as the ability to hit the centre of the target accurately with arrows (Ertan et al., 2005; Leroyer et al., 1993; Martin et al., 1990) and can be assessed with the total points collected (Kolayis et al., 2014).

(d) Electromyography

Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles (Robertson et al., 2014).

(e) Muscle activation level

Muscle activation level may be defined as the number of active motor units, and the frequency of action potentials they receive (Holt and Azizi, 2016).

(f) Deltoid muscles

The deltoid muscle is a thick, triangular shoulder muscle. The main function of deltoid muscles includes (1) flexion and internal rotation of the arm; (2) abduction of the arm beyond the initial 15°; (3) extension and external rotation of the arm (Netter, 2018).

(g) Triceps brachii muscles

The triceps brachii muscle is a three-headed muscle that consists of a long, medial, and lateral head. It located at the posterior part of the arm and spanning almost the entire length of the humerus. The main functions of triceps brachii muscles include:

(1) extension of the forearm at the elbow joint; (2) extension and adduction of the arm at the shoulder joint (Netter, 2018).

(h) Trapezius muscles

The trapezius muscle is a pair of large triangular-shaped muscles located on the posterior aspect of the neck and thorax. The main function of the trapezius muscle is to control the movements of the shoulder girdle (Netter, 2018).

(i) Draw force line

The draw force line is the ideal alignment where the nock of the arrow, the bow, and the hand and elbow of the drawing arm are in the same straight line (Larven, 2007).

(j) Anchor phase

The anchor phase is the phase that the draw hand place along the jawline and the string touch the tip of the nose and chin (Needham, 2012).

(k) Releasing phase

Releasing phase is the time the archer relaxes their fingers to allow the string to slip out from their fingers and launch the arrow toward the target (Horsak and Heller, 2011).

(l) Mood

Mood can be defined as a state or quality of feeling at a specific time and varying in intensity and duration (Basumatary and Pramanik, 2014).

(m) Physical fitness

Physical fitness can be defined as the ability to carry out daily task with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure-time

pursuits and to meet unforeseen emergencies (Clarke, 1971). The physical fitness components can be categorised into two groups: (1) health-related components and (2) skill-related components (Pate, 1983).

1.4 Operational definitions

In this study, operational terms have been defined with customizing them to align closely with the study's scope and objectives.

(a) Archery shooting performance

The archery shooting performance was evaluated by the points of each arrows that were shot from a 70 meters' distance towards a 122 cm full ring target face. The score ranges from miss (0) to 10 points based on the rings on the target face.

(b) Muscle activation level

The muscle activation level was determined using electromyography (EMG) electrodes that placed on the participant's left deltoid, left triceps, right trapezius and right triceps during archery shooting. The EMG captured and recorded the electrical activity generated by the targeted muscles throughout the movement. The signals were then processed and analysed to calculate the average muscle activation level throughout the shooting movement. A higher value indicates greater muscle activation during the archery shooting movement.

(c) Draw force line

The draw force line was evaluated and measured with video analysis. The draw force line during the anchor phase and release phase were measured in this study. A straight line was drawn from the left radial styloid process to the right Lister's tubercle and another line was drawn from the right Lister's tubercle to the right Olecranon

process, the angle between the lines was the degree of draw force line. Higher value indicated that the Draw force line are more deviated.

(d) Mood state

Mood state was measured using a standardised self-report questionnaire, Brunel Mood Scale (BRUMS) questionnaire. The BRUMS questionnaire measures six mood dimensions that included anger (annoyed, bitter, angry, bad-tempered) confusion (confused, mixed-up, muddled, uncertain), depression (depressed, downhearted, unhappy, miserable), fatigue (worn out, exhausted, sleepy, tired), tension (panicky, anxious, worried, nervous), and vigour (lively, energetic, active, alert). The participants will rate on a Likert scale from 0 (not at all) to 4 (extremely), indicating the extent to which they are experiencing various mood states. The scores of each dimension will be summed. Higher scores on the vigour indicate a more positive mood state, while higher scores on the other dimension suggest a more negative mood state.

(e) Handgrip strength

Handgrip strength was measured using a handgrip dynamometer. The participants were instructed to squeeze the dynamometer with maximum isometric effort for about 5 seconds and the test were conducted 3 times. The handgrip strength was quantified in kilograms. A higher reading indicates greater handgrip strength.

(f) Back and leg strength

Back and leg strength was measured using a back isometric dynamometer. The participants were instructed to lift the bar steadily and keeping their legs straight and feet flat on the base of the dynamometer. The test was conducted 3 times. The back

and leg test was quantified in kilograms. A higher reading indicated greater back and leg strength.

(g) Flexibility

The flexibility was assessed using the sit and reach test. The test was utilised the sit-and-reach flexibility box. The flexibility was quantified based on the distance reached in the sit and reach test. The test was performed three times. A further distance reached indicated a greater flexibility on the lower back and hamstring.

(h) Balance

The balance of the participants was measured using the standing stork test. The participants were required to maintain their static balance while standing on one leg. The time taken to compete the test was recorded with stopwatch. The test was performed three times for each legs respectively. A longer time indicated the greater balance ability on single leg.

(i) Upper muscle endurance

The upper muscle endurance of the participants was assessed using the push up test. The participants were required to perform as many repetition as they can within one minute. A higher number of completion indicated the greater upper muscle endurance.

(j) Core muscle endurance

The core muscle endurance of the participants was assessed using the sit up test. The participants were required to perform as many repetition as they can within one minute. A higher number of completion indicated the greater core muscle endurance.

(k) Cardiovascular endurance

The cardiovascular endurance was assessed using the multi-stage fitness test. The participants were instructed to run following the beat from the radio until he/she cannot keep up the beat. The last completed stage and level were recorded and used to quantify the cardiovascular endurance. A higher stage and level indicate greater cardiovascular endurance.

1.5 Research objectives

The objective of the study was divided into general and specific with the following aims:

1.5.1 General objective

The main objective of this study is to investigate the predictors of archery performance among state-level archers.

1.5.2 Specific objectives

The specific objectives of this study include:

1. To investigate the association between muscle activation levels and archery shooting performance.

2. To investigate the association between draw force line and archery shooting performance.

3. To investigate the association between mood states and archery shooting performance.

4. To investigate the association between physical fitness levels and archery shooting performance.

1.6 Research questions

1. What are the most important criteria that will affect archery shooting performance?

2. Is there any association between muscle activation level and archery shooting performance?

3. Is there any association between draw force line and archery shooting performance?

4. Is there any association between mood states and archery shooting performance?

5. Is there any association between physical fitness level and archery shooting performance?

1.7 Hypotheses

To achieve the study objectives, the following hypotheses are formulated:

Hypothesis 1:

Alternative hypothesis (H_{1A}): There is an association between muscle activation levels and archery shooting performance.

Hypothesis 2:

Alternative hypothesis (H_{2A}): There is an association between the draw force line and archery shooting performance.

Hypothesis 3:

Alternative hypothesis (H_{3A}): There is an association between mood states and archery shooting performance.

Hypothesis 4:

Alternative hypothesis (H_{4A}): There is an association between physical fitness levels and archery shooting performance.

1.8 Significance of the study

This study provides a few significant contributions to archery. First, it determined the most essential criteria that can affect archery shooting performance. Furthermore, the findings offer insight to the coaches, archers, and other relevant parties to understand the association between muscles activation, draw force line, physical fitness, and mood states with archery shooting performance. This information can potentially be useful in designing a training program based on sports science knowledge. Besides, this information can become the benchmark for talent identification programs.

Adding on, most of the previous studies focused on one parameter whereas the combination of a few parameters is seldom evaluated. Besides, most of the studies focus on the comparison of the parameters between different levels of archers (elite, intermediate, and novice). In this study, 4 parameters are analysed to find out the weightage towards archery shooting performance as well as their relationship with the performance. This may give more information on the connection between the parameters and the archery shooting performance.

Furthermore, in this study, the developmental athletes from state teams were recruited as they are the main sources of a future champion. Thus, knowing the relationship between the parameters chosen and archery shooting performance at the earlier stage of sports participation can give them a higher chance to reach their peak performance at the correct timing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to archery

Archery is one of the oldest sports that required a high level of concentration and techniques (Aryavart et al., 2014). It is commonly known as a sport that used a bow to launch arrows toward a target in the movement of shooting (Dhawale et al., 2018). Besides, archery can be described as a static, non-contact sport that demands upper body strength and endurance, especially the forearm (Mann and Littke, 1989) and the shoulder girdle (Ertan et al., 2005; Mann, 1994; Mann and Littke, 1989).

The skill in archery can be defined as the ability to hit a set target with arrows with accuracy and precision (Leroyer et al., 1993). Archery is a fine and gross motor skill sport that requires continuum accuracy with the precision of movement (Taha et al., 2018a). According to Haywood (1989), archery is an individual sport that involved repetitive consistent and fine movements, as well as self-paced, closed skill under constant environmental conditions. Environmental factors such as strong winds and rain may affect the decision of the archers but it does not entirely affect the movement of the archers to draw or release (Acikada et al., 2004).

Vrbik et al. (2015) mentioned that general and specific motor skills and different psychological factors play an important role in archery performance. The general motor skills refer to strength, endurance, balance, and flexibility while specific motor skills are intermuscular coordination, rhythm, timing, and precision. Meanwhile, the most essential psychological factors include concentration, relaxation, and different types of attention accompanied by visual focusing (Lee and Benner, 2009).