ANTHROPOMETRIC PROFILE, BALANCE ABILITY, REACTION TIME AND BONE HEALTH STATUS AMONG HORSEBACK RIDING ATHLETES IN KELANTAN

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by

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LIST OF ABBREVIATION

F	=	Flat Jockey
H	=	Hunt/ Jump Jockey
UPST	=	Unipedal Stance Test
BMI	=	Body Mass Index
HBT	=	Human Benchmark Test
EO	=	Eyes Open
EC	=	Eyes Closed
CoG	=	Centre of Gravity
PA	=	Physical Activity
IQR	=	Interquartile Range
KG	=	Kilogram
M	=	Meter
% BP	=	Percentage Body Fat
S	=	Seconds

PROFIL ANTROPOMETRI, KEUPAYAAN KESEIMBANGAN TUBUH, TINDAKBALAS MASA DAN STATUS KESIHATAN TULANG DIKALANGAN ATLET BERKUDA DI KELANTAN

ABSTRAK

Tujuan penyelidikan ini adalah untuk mengkaji perbezaan profil anthropometri, keupayaan keseimbangan tubuh, tindakbalas masa dan status kesihatan tulang antara dua kumpulan berbeza mengikut aktiviti fizikal mereka iaitu kumpulan sedentari dan kumpulan atlet berkuda. Seramai 10 orang peserta yang sihat berusia dari 20 hingga 39 tahun telah dipilih untuk mengambil bahagian dalam kajian ini. Para peserta telah dipadankan mengikut umur kemudian dikumpulkan kepada kumpulan sedentary (n=5) dan kumpulan atlet berkuda (n=5) berdasarkan kepada kategori mereka. Pengukuran data telah dilakukan di Makmal Sains Senaman danSukan. Parameter peratusan jisim lemak, berat badan dan BMI peserta diukur dengan menggunakan alat analisis komposisi badan (Omron diagnostic scale).Ujian berdiri sebelah kaki (UPST) dilakukan dengan mata dibuka dan tertutup untuk kedua-dua belah kaki iaitu kaki dominan dan bukan dominan. Purata masa dari tiga ujian UPST diukur untuk semua keadaan. Dua ujian tindakbalas dilakukan dengan menggunakan ujian tanda aras manusia iaitu ujian reaksi masa dan ujian ketepatan sasaran. Kepadatan tulang berdasarkan halaju bunyi (*SOS)* diukur menggunakan alat sonometer tulang pada tulang 'tibia' kaki dan tulang 'radius' lengan. Pengukuran dibuat untuk lengan dan kaki yang dominan dan bukan dominan. Nilai signifikan telah ditetapkan pada tahap *confidence interval 95%.* Dalam analisis ujian Mann-Whitney, kajian ini mendapati bahawa kumpulan atlet berkuda menunjukkan keputusan yang signifikan dalam peratusan jisim lemak yang lebih rendah berbanding kumpulan sedentary. Keputusan UPST menunjukkn bahawa tiada perbezaan yang signifikan secara statistik samada dalam keseimbangan mata terbuka dan tertutup bagi kedua-dua kaki dominan dan bukan dominan antara kumpulan atlet berkuda

dan kumpulan sedentari. Perbezaan yang signifikan dalam kepadatan tulang melalui halaju bunyi 'SOS' dapat dilihat pada bahagian bukan dominan kumpulan penunggang kuda berbading dengan kumpulan sedentari. Aktiviti fizikal seperti berkuda mampu memberi kesan kepada tubuh individu seperti pembakaran kalori melalui aktiviti menunggang dan juga memberi kesan positif pada kesihatan tulang. Adalah diharapkan bahawa keputusan kajian ini dapat diaplikasikan untuk pembangunan latihan spesifik atlit berkuda atau sebagai sumber rujukan bagi aktiviti rekreasi menunggang berkuda sebagai pemilihan aktiviti fizikal yang memberi manfaat kepada tubuh badan.

ANTHROPOMETRIC PROFILE, BALANCE ABILITY, REACTION TIME AND BONE HEALTH STATUS AMONG HORSEBACK RIDING ATHLETES IN KELANTAN

ABSTRACT

The purpose of this research was to explain the differences in the anthropometric profile, balance ability, reaction time and bone health status between two different groups according to their physical activity i.e., sedentary group and equestrian athlete group. A total of 10 healthy participants aged 27.60 (±8.01) years old were selected to participate in this study. Participants were matched according to age then grouped into the sedentary group (n = 5) and horseback riding group (n = 5) based on their category. The measurements were performed in the Exercise and Sports Science laboratory. The parameters of body fat percentage, weight and BMI of participants were measured using a "body composition analyzer" (Omron diagnostic scale). Unipedal stance test (UPST) was performed with the eyes open and closed for both sides of the leg i.e., the dominant and non-dominant legs. The mean of three UPST tests was measured for all conditions. Two reaction tests were performed using the Human Benchmark Test namely The Reaction Time Test and The Aim Trainer Test. Bone speed of sound (SOS), a marker of bone density, were measured on the dominant and non-dominant tibial and radial using a bone sonometer. The p-value was set with a confidence interval value of 95%. In a Mann-Whitney test analysis, this study found that the horseback riding group had a lower body fat percentage than the sedentary group. The UPST results showed that there was no statistically significant difference either in the open or closed eye conditions for both–dominant and non -dominant legs between the horseback riding group and the sedentary group. A significant difference in the bone speed of sound, SOS can be seen scientifically in the non-dominant part of the 'radius' of the arm and 'tibia' of the foot of the horseback riding group compared to the sedentary group. Based

on the results, significant differences were found in the percentage of body fat, as well as radial and tibial SOS for non-dominant hands and legs. Physical activities such as horseback riding can affect the individual body by burning calories through riding activities and have a good effect on bone health although equestrian sports are categorized as non-weight bearing exercise. It is hoped that the results of this study can be applied to the development of specific training of equestrian athletes or as a reference source for recreational activities of equestrian riding as a selection of physical activities that benefit the body. It is hoped that the community will be more aware and act in changing the sedentary lifestyle to a more active lifestyle in the future.

CHAPTER 1

INTRODUCTION

1.1 Study Background

In most sporting events, physical training plays an important role as the foundation for physical fitness, which is a key factor in determining an athlete`s level of performance. Physical fitness refers to the ability of the body system to function efficiently, resulting in the healthy and unrestricted activity of daily living (Corbin and Masurier, 2014). Participation in the equestrian event requires a high level of skill. An online survey conducted by Wood, (2020) found that the most important physical fitness for successful equestrians is balance, reaction time, strength and power, agility, aerobics endurance, body size and composition and speed.

In many sports, the benefits of physical activity have been demonstrated through various studies including body composition, balance and bone health (Chiu *et al.*, 2017; Davlin, 2004; Norsuriani & Ooi, 2018). However, limited investigation regarding these areas found in horseback riding. The study of anthropometric profiles in horse riders is important due to the weight restriction in most equestrian events. Generally, horses should not carry more than 25% of their body weight to avoid muscle soreness and strains (Powell *et al.*, 2008). Overloading is related to the effective performance and welfare of the horse (Bukhari, McElligott and Parkes, 2021). In horseback riding activity, it is a challenge for the rider to aligning their low body mass with the required weight of the horse (Dunne *et al.*, 2020). Dolan *et al.*,(2012) reported that chronic weight restriction in-jokey was induced by low energy availability as the primary predictor of bone mass.

The importance of physical activity in relation to bone health is widely recognized through the effect of mechanical loading. (Lin & Hsieh, 2005). Horseback riding is a sport classified as a non-weight bearing exercise that carries a risk of developing low bone mineral density(Andersen *et al.*, 2018; Home Health Care, 2018; Vlachopoulos *et al.*, 2018a). Research related to bone health in horseback riding has come out to a similar conclusion with lower bone mass and low bone mineral density (Dolan *et al.*, 2012; Jackson *et al.*, 2017). Alfredson *et al.* (1998) also reported that there is no significant difference in bone mineral density of the dominant and non-dominant hand and leg in show jumping and dressage riders subjected to weight-bearing loading in a seated position and that the impact forces acting on the spine and hip, especially during the landing phase, are not as high as in other weight-bearing sports.

Skill-related fitness consists of components of physical fitness and generally defined as agility, balance, coordination, power, speed, and reaction time which is lead to enhanced performance in sports and motor skills (Corbin, Pangrazi and Franks, 2000). Balance is an important component of motor skills ranging from maintaining posture to executing complex sports skills (Davlin, 2004). Many studies report that the horse`s gait is similar to human pelvic movement. Changing the horse gait from trot to canter and gallop stimulates the rider`s balance reaction (Kim and Kim, 2015). The riders will effectively learn to maintain balance by adjusting angle and weight, aligning their body skeleton with gravity throughout the movement. Muscle tension and strength are critical to support a stable position and adapt to movement and changes in force (Kristen Nelsen, 2011). In horseback riding, maintaining equilibrium while riding is a very challenging task that requires a complex sensorimotor process while sitting on a moving base of support. The rider must adapt the horse`s movement while taking in information from the environment to guide the horse in the desired direction or movement (Hamaoui *et al.*, 2017).

A successful rider needs the ability to react quickly in the saddle to stabilize their position and avoid falling off the horse. Reaction time is a critical skill in all equestrian events where the rider must show skillful manipulation of the horse. (Standing and Best, 2019). Nylund,(2014) reported that jockeys respond better to an auditory stimulus, i.e., starting gun, a visual stimulus, i.e., a light turns to green when another jockey or a horse fall into their line of sight, and a kinaesthetic stimulus, i.e., tripping, falling, or foot coming out of the stirrup. A study conducted by Williams and Barnett, (2013) found that rider`s reaction time was not significantly different between left and right hands (right hand RT= 0.29 ±0.06s, left hand RT=0.29±0.06s), as they appeared to exhibit hand dominance due to striving for balance during rein contact.

1.2 Problem statement

The lack of studies on a special characteristic of the horse, the distinctive horse-rider relationship, as well as scientific evidence on the anthropometric profile, balance ability, reaction time and bone health status among horseback riding has spurred me to investigate the physical fitness and bone health status of the rider in Malaysia. Though ideally, they would be a positive relationship between riding, physical fitness and bone health status are built, the question is whether all fitness components have a similar effect on equestrian athletes in Malaysia. Previous studies regarding equestrian sports in Malaysia only focused on horse welfare, riding arena, and prevalence of injuries related to riding, while there are no studies reported regarding rider`s physical fitness (Majeedkutty and Khairulanuar, 2017; Mohd Rajdi *et al.*, 2018; Fadilah Darmansah *et al.*, 2019). Therefore, this study aims to investigate the anthropometric profile, balance ability, reaction time and bone health status among horseback riding athletes in Kelantan.

1.3 Objectives of the Study

1.3.1 General Objective

To investigate the anthropometric profile, balance ability, reaction time and bone health status among horseback riding athletes in Kelantan

1.3.2 Specific Objectives

1. To determine the differences of the anthropometric profiles between horseback riding athletes and a sedentary group.
2. To determine the differences of the balance ability among horseback riding athletes and a sedentary group
3. To determine the differences in the reaction time among horseback riding athletes and a sedentary group
4. To determine the differences in the bone health status of the dominant and non-dominant arm and leg in horseback riding athletes and compared to a sedentary group.

1.4 Hypothesis of the study

H_{01}: There are no differences in anthropometric profile between horseback riding and a sedentary group.

H_{A1}: There are differences in anthropometric profiles between horseback riding athletes and a sedentary group.

H_{02}: There are no differences in balance ability between horseback riding athletes and a sedentary group.

H_{A2}: There are differences in balance ability among horseback riding athletes and a sedentary group.

H_{03}: There are no differences in reaction time between horseback riding and a sedentary group.

H_{A3}: There are differences in reaction time between horseback riding athletes and a sedentary group.

H_{04}: There are no differences in bone health status between horseback riding athletes and a sedentary group.

H_{A4}: There are differences in bone health status between horseback riding athletes and a sedentary group.

1.5 Significance of the study

Horseback riding is popular worldwide as a recreational and competitive sport. Horseback riding is classified as a non-weight bearing exercise because the activity does not require riders to place their full weight on their feet. Nonetheless, horseback riding offers health benefits such as building core strength, improving balance and coordination, increasing muscle tone and flexibility, and providing cardiovascular exercise. Recreational riding offers relaxing and calming experiences which can relate to mental exercise. According to various positive reports on the therapeutic effects of horseback riding, the results can be associated with an anthropometric profile, balance ability and bone health status among horseback riders. To our knowledge, studies on the anthropometric profile, balance ability and bone health status in horseback riding in Malaysia is still unknown. Therefore, this study is proposed to investigate the effects and benefits of horse riding. The results obtained from this study may provide new scientific information on the anthropometric profile, balance ability and bone health status for both recreational and professional horse riding in Malaysia. The result of this research can be used as a rehabilitation program for osteoporosis, bone fragility and to improve pelvic stability in the elderly as well as a rehabilitation program for sports injuries. It is hoped that the results obtained from this study can be applied to the community to maximize the health benefits of horseback riding.

CHAPTER 2

LITERATURE REVIEW

2.1 Horseback riding in Malaysia

Horseback riding or equestrian sports in Malaysia has developed since the 1980s. Since the introduction of horse racing and horse polo by the British, a passion for equestrian sports has developed in Malaysia and was quickly embraced by the Sultans and their allies. Nowadays, many equestrian clubs in Malaysia offer recreational riding, polo, dressage, show jumping and endurance riding (Equestrian Asia, 2017). The Equestrian Association of Malaysia (EAM) is the governing body that responsible for the development, promotion and represents the interest of Malaysian equestrian interest in all matters of Federation Equestre Internationale (FEI) such as interpretation of event and competition rules, horse registration, horse grading and selection of national riders for competitions such as Olympic Games (Equestrian Association of Malaysia, 2020).

Horses are amazing creatures designed for speed, agility, and survival. This 1,000-pound animal can run incredibly fast and physically react at lightning speed. Humans have always been fascinated with horses, symbolizing them like a spirit of power, strength, and freedom. From transportation to the root of military tradition, horse riding has become a popular recreational and competitive sport. These special ungulates (mammals with hooves) have long tails, short hair, muscular bodies, long, thick necks and elongated heads. Horses can reach 175cm from hoof to shoulder and weigh up to 998 kg (Bradford, 2015). Most equestrians know that horses have a distinct temperament that shapes their behavior. As a rider, knowing the horse's temperament and behavior can improve communication with the horse and make it easier to handle and train the horse (Fought, 2020). Horses have strong leadership behavior in their natural herd; therefore, horses can challenge the rider by trying to control the ride. Horses even have a sturdy flight response and will react suddenly to unfamiliar environments or scenarios that could cause them to panic. The rider must be compelled to build trust through experience and patience with the horses

Equestrian sports include the disciplines of jumping, eventing, dressage, and endurance. In the jumping event, riders must maintain their posture, keep the body out of the seat and carry the weight through the legs to gallop the horse, change direction and assisting the horse jump obstacles with different heights and sizes within the time limit. (Stefánsdóttir *et al.*, 2017). Dressage requires the horse and rider to perform a walk, a rising trot, a sitting trot, and a sitting canter with the rider in a vertical position (ear, shoulder, hip, and ankle) and in sitting contact with the horse. (Stefánsdóttir *et al.*, 2017). Eventing is an equestrian variation of triathlon. It consists of three disciplines: Dressage, cross-country gallop and shows jumping. It requires the rider to be experienced in all aspects of equestrianism and covers all aspects of horsemanship (Equestrian Association of Malaysia, 2020). Endurance riding is a long-distance race where riders have to ride more than 160 km. Both riders and horses have to push their limits (Stefánsdóttir *et al.*, 2017). Malaysia has also organized well-known events such as Sultan Mizan Cup (endurance riding), and National Horse Show (dressage and show jumping). All these events were officially supervised by the Equestrian Association of Malaysia (EAM).

Horse riding requires humans and horses to communicate through a unique language that is built through training, adaptation, and trust. A horse can understand the rider`s desire based on its body weight, position on the horse and slight pressure from the rein and legs. This action and response between the species bring collaboration and bodies into sync (Maursatad, et al., 2013). While riding, a rider is involved in the natural gaits of the horse that is: Walk, trot, canter and gallop. The common symmetrical gaits in quadrupeds are walk and trot, while the asymmetrical gaits are canter, and gallop (Justine, et al., 2007). The walk is a “quadruple” lateral gait, with four distinct hoofbeats at each stride as the feet alternately strike the ground (Clinton, 2004). It is the horse’s most natural and slowest gait without any suspension with an average pace of 55 strides per minute (Clayton, 2004). The trot is a two-beat gait with two phases of walking and two phases of suspension. In the sitting trot, the rider attempts to absorb the horse`s movement through the pelvis at an average pace of 99 strides per minute (Clayton, 2004). The Canter is a rhythmic gait with three beats that is faster than the average trot speed, but slower than the gallop. While the walk and trot have a regular rhythm, the canter is considered an irregular gait (Wolframm, et al., 2013). The canter is an asymmetric gait with high speed and four beats. The fastest galloping horse was recorded in the Quarter Horse race (approximately 400 meters) with an approach speed of nearly 88.5 km/h (America`s Horse Daily, 2014).

2.2 Anthropometric Profile

Anthropometric measurement is a series of quantitative measurements of muscle, bone, and adipose tissue to assess body composition with height, weight, body mass index (BMI), body circumferences and skinfolds thickness are among the core elements of anthropometry. Anthropometric measurements are an important diagnostic criterion for obesity which is related to health conditions such as cardiovascular disease, diabetes, and hypertension. (Casadei & Kiel, 2020).

Previous studies, on the anthropometric profile of horse riders, have found it to be related to weight class, performance prediction and rider health. (Jackson *et al.*, (2017), Dunne *et al*.,(2020), Jeon *et al.*,(2018), Douglas., (2017), Alfredson et al., (1998)). The study of anthropometric profiles in riders is important due to the weight limitation in riding. Most parameters used in the previous studies of anthropometry in riders included height, weight, body mass index (BMI) and body fat percentage. The height and weight parameters were examined via standard measuring equipment such as the Seca scale or bioelectrical impedance analysis (BIA). Percentage of body fat parameters examined via dual-energy X-ray absorptiometry and skinfold measurement. BMI was calculated using the equation BMI=weight/height^2. The anthropometric values of the previous study under horseback riders are shown in Table 1.

Based on the data in Table 1, we can assume that most of the horseback riding athletes were within the normal BMI range of 20.18 to 25.3kg/m^2 for males and females. Jackson *et al.*,(2017) found that male flat jockeys were smaller and lighter than jumper jockeys, but taller and heavier than female jockeys. A comparison with horse jockeys and boxers by Dolan *et al.*,(2012) found that there were no differences in BMI between these two groups. As weight-bearing athletes, many jockeys have extreme weight loss only 1 or 2 days before the competition, mainly associated with caloric restriction or dehydration (Jeon *et al.*, 2018). A comparison in other disciplines found that there are also no significant BMI differences between active and inactive females riders but inactive female riders have a higher fat percentage than the active female riders (Alfredson *et al.*, 1998).

Table 1: Anthropometric profile reported in the previous study

Authors	Study Population	Gender	Height (m) (M±SD)	Weight (kg) (M±SD)	BMI (kg/m²) (M±SD)	Body fat (%)
Dunne, et al., 2020	72 Professional Jockey	Male	1.71±6.2	60.9 ±5.7	**	**
Sæthorsdóttir, 2019	15 2 National Team	Male Female	1.73±5.9	80.0± 0.0	25.3 ± 2.2	
Jeon, et al., 2018	10 Professional Jockey	Male	1.57±4.52	50.6±1.87	20.5 ±1.38	7.3±1.24
Jackson, et al., 2017	79 (f) 37 (f) 26 (h) Professional Jockey	Male Female Male	1.67±0.06 1.57±0.05 1.76± 0.05	52.9±2.9 51.6±4.0 63.7±3.6	** ** **	7.6 ± 1.3 12.4 ± 2.4 9.9±1.7
Douglas, 2017	11 novices 9 intermediates 7 advances	Female	1.64±3.4 1.69±5.6 1.68±9.9	66.6 ± 8.1 65.7±8.9 62.6±10.4	23.1± 2.0 24.1±3.2 21.9±1.6	28.6± 5.2 30.1±12 26.9±1.6
Dolan, et al., 2011	14 (f) 16 (h)	Male	1.65 ±0.0 1.72±0.0	54.63±3.6 64.3±3.34	20.18±1.6 21.92±1.2	4.43±1.5 8.67 ± 3.9
Alfredson, et al., 1998	20 Active rider	Female	1.65±4.5	61.8±7.0	**	28.6 ± 6.5

(f) = flat jockey (h) = Hunt/Jump Jockey

The relationship in rider`s weight and the horse`s welfare is often debate and is likely to be influenced by many factors, including the horse`s fitness and muscle development, conformation, discipline (e.g., jumping or dressage), training intensity, rider fitness, skill, balance, and equipment used. One study showed that increasing the rider to horse weight ratio by 15% and 25% did not significantly alter the horse's behaviour, gait symmetry, heart rate variability and concentration (Christensen *et al*., 2020). However, the anthropometric profile and body characteristic of the rider can influence successful performance by affecting horse racing speed (Henry, 2020), determining weight and aligning nutritional strategies with weight requirements in horse-racing competition (Wilson, et al., 2014). Rider weight can also affect horse performance and a pilot study was conducted by Dyson, et al.(2019) to evaluate the gait and behavioural response of horses to different rider body weights using six non-lame horses with 4 different rider BMI: L 23.2 kg/m^2, M 26.3 kg/m^2, H 28.0 kg/m^2, VH 46.9kg/m^2. The conclusions and clinical relevance of the study revealed that larger body size may induce transient enervation and inconsistent behaviour in horses due to musculoskeletal pain. Undoubtedly, it makes sense that a horse can perform better in any discipline if it carries a low weight, a lower body weight is more beneficial for successful equestrian performance (Sæthorsdóttir, 2019). Furthermore, in terms of horse performance, it is believed that the rider´s weight, riding style or both influence tempo racing, which is very demanding for the horse with anaerobic efforts (Stefánsdóttir *et al.*, 2017).

2.3 Balance Ability

Balance is a major component of motor skills that range from maintaining posture to executing complex sports skills (Davlin, 2004). Balance can be divided into two categories which are dynamic and static balance. Static balance is defined as an equilibrium that is maintained for one stationary position. Dynamic balance refers to preserving balance during motion or restoring balance through rapid and successive changing positions. Both static and dynamic balance involves the incorporation of sensory input from the visual, vestibular and somatosensory systems (Davlin, 2004). Locomotion and human body equilibrium happened through the internal and external forces as well as displacement and positioning environment. The inner force of the human body should exceed the force of gravity, the body's weight, balancing segments, air pressure, environmental resistance, accelerating force, and reaction force (Diana Cotoros and Mihaela Baritz, 2010). To maintain an erect posture, visual information and sensory information of the joints and muscles must integrate with visual, somatic sense and vestibular system through the central nervous system (Su, Chae and Sil, 2014). According to Kristen Nelsen (2011), a horse rider needs to know how to balance a horse by aligning the body skeleton with gravity at all times during motion. Riders need to develop internal balance, angle and weight to allow the body to create stability from front to back, right to left and top to bottom. Riders need to have optimum muscular tension and strength to support a stable position while coping with an outside force. Also, enough relaxation and suppleness allow a full range of joint motion to adapt motion and changes in force.

According to Douglas et al. (2012) during a horse's progress through gaits, the rider`s heart rate and oxygen consumption increase due to a higher level of tonic muscular contraction particularly of the upright trunk position. During seated position, weight-bearing is predominantly through the pelvis meanwhile in faster gaits and jumping, riders need to adapt to ‘forward’ riding position and weight-bearing will be through the rider's leg. These modes of riding will increase metabolic cost and, increase the level of blood lactate to meet some anaerobic demand. Contraction of the rider`s muscles is important for stabilization, controlling the rider`s position and coordination throughout movements. The upper and middle trapezius, middle deltoid, and flexor carpi radialis muscle act to stabilize the rider`s neck, wrist, and scapula. The riders' trunks are stabilized by the rectus abdominis and allow the body to follow the horse`s upward movement by swinging the pelvic forward and upward. The flexor carpi radialis, bicep brachii and triceps brachii contract to flex and extend the elbow joint during rein tension by maintaining the distance between the rider`s hand and horse`s bit (Terada, et al., 2004) The rider`s physical fitness and muscular endurance is important to find the balance and the right posture with ears, shoulders, hips and ankles aligned in the saddle to have better control of the horse and hold the right posture in a longer period especially in endurance events. (Stefánsdóttir *et al.*, 2017).

In equestrian, maintaining equilibrium while riding is a very challenging task, and it requires a complex sensorimotor process while sitting on a moving base of support. Riders need to adapt the horse movement while picking up information in the environment to direct the horse towards the intended goal (Hamaoui *et al.*, 2017). Maintaining postural stability is very crucial for horseback riders to ensure safety and avoid injuries (Olivier *et al.*, 2019). Unbalance rider position can lead to asymmetry of muscular activity in the back and may induce spinal instability due to axis rotation (Kraft *et al.*, 2007) and connection with shoulder angle displacement will increase muscular stress to riders (Symes and Ellis, 2009). Orthopaedic injury among horse riders happened due to falling from a horse. According to Young *et al.* (2015) common injuries in orthopaedic cases in the US come from female riders and high prevalence cases were on upper extremity fracture followed by joint dislocations, head and neck injuries.

Notwithstanding all the risks of injuries and challenges in horse riding, equine-assisted therapy became a popular rehabilitation program as a complementary strategy to facilitate the normalization of muscle tone and improve motor skills through riding experience. Therapeutic effects of horseback riding on balance were found in a study involving patients with multiple sclerosis, cerebral palsy, acute stroke patient, improving range of motion in older people, treating arthritis and Parkinson in the older adult (Muñoz-Lasa *et al.*, 2011; Drnach, O'Brien and Kreger, 2010; Pohl *et al.*, 2018; White-Lewis *et al.*, 2019; Gousdy *et al.*, 2019) Findings from various studies showed that riding lead to improve coordination, increase head and trunk control through precise, smooth, rhythmic and repetitive movement in response to rhythmic three-dimensional movement of the horse gait that mimicking to mechanics of human gait that focus in trunk stability, posture and pelvic mobility (Zadnikar and Kastrin, 2011; Muñoz-Lasa *et al.*, 2011; Drnach, O'Brien and Kreger, 2010; Pohl *et al.*, 2018).

The most common testing methodology in measuring balance ability in horseback riding is using a Good Balance System (GBS) (Su, Chae and Sil, 2014) and a force platform (Agnès Olivier *et al.*, 2019). These two tests investigate (1) static balance condition on rigid floor, (2) unstable posture in the anterior-posterior direction (AP dynamic balance), and (3) unstable posture in mediolateral direction (ML dynamic balance). This testing procedure was analyzed with eyes open, eyes closed and with foam on the force platform, Functional movement screen (FMS) was also used within equestrian to assess on 7-point FMS (deep squat. hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability and rotary stability (Lewis *et al.*, 2019; Sæþórsdóttir, 2019; Agnès Olivier *et al.*, 2019). Based on the previous research, there is positive feedback on horseback riding may enhance both static and dynamic balance, increase stability and may stimulate proprioceptive sense input in neurological terms (Su, Chae and Sil, 2014; Olivier *et al.*, 2019).

2.4 Reaction Time

Reaction time is essential when performing a fast movement. According to Corbin, Pangrazi and Franks, (2000), reaction time refers to the amount of time that takes place between when an organism perceived something to when it responds to it. Having good reaction time allows humans to be agile and efficient when responding to stimuli and situations in daily lives and playing sports. Good response time may benefit in many ways depending on how received information is properly processed. However, reaction time may change due to several factors, i.e. age, gender, condition, fatigue, high altitude, alcohol, nicotine and use of a psychotropic substance (Tülin and Pelin, 2014). Reaction time differ from individuals who are the same age and do the same activities because it depends on the individual's ability to detect, process and respond to a stimulus (Taskin, Karakoc and Dural, 2016).

Reaction time depends on various factors that working together with such as perception (seeing, hearing or feeling stimulus), processing (focus and understand the information well) and response (motor agility) and its plays a very important role that can affect many aspects in sports (Turkeri *et al.*, 2019). In a sports context, a stimulus can be either visual, auditory, or kinesthetic which is depends on athletes` situation. Reaction time is determined by the speed of neural transmission to the central nervous system (CNS), decision making, motor program activation and signal transmission to the muscle (Darbutas *et al.*, 2013). When a signal is perceived through the sensory system, the brain will quickly process the information and responds by sending a message down to the spinal cord to the right muscle and creates a contraction but the physical response from the muscle is not the same as processing speed, which describe how fast an individual can detect a signal (Daniel, 2015).

Reaction time is a crucial skill in all horseback riding events. Equestrian sports are recognized as high-risk and enhanced motor and cognitive reactions that can minimize the impact on performance and maximize safety for both rides and horses (Williams and Barnett, 2013). The reaction time may manifest skilful manipulation of the horse, the performance of sudden acceleration or decelerations, and the ability to respond to the unpredictable situation (Standing and Best, 2019). Horse behaviour is a major factor in many equestrian injuries. Unpredictable nature of the horse and the nature of the performance, i.e., jokey, jumping, polo and dressage requires horse rider to react smarter and quicker to achieve lighter clearer aid and keep balance on the saddle (Williams and Barnett, 2013; Ohtani *et* *al.*, 2017; Standing and Best, 2019). According to Nylund,(2014), response time in horse jockey be faster compared to track riders. Horse jockey made up of reaction time 100ms compared to average reaction Olympics sprinter in range 146-210ms. Jockeys can react to an auditory stimulus, i.e., starter guns, visual stimulus, i.e., a light turn to green when another jockey or hose falling in their line of sight, and a kinaesthetic stimulus, i.e., tripping, falling or foot coming out from stirrup. Polo performance requires the concomitant integration of multiple actions, i.e., times for rider to react, application of pressure to the horse and horse corresponding movement could be suggested that raw reaction time of Polo player may not be as beneficial to performance (Standing and Best, 2019). Horse-riding is a sport that requires familiarization of the aids involved to attain success and safety, even at a low competitive or leisure level, equestrian can be considered as a sport that requires the assessment of stimulus-response via reaction, not response times and which may not conform to Hick's Law that describes the relationship between the time taken to prepare a movement response and the number of possible movement response alternatives or "choice reaction time" (Williams and Barnett, 2013; Proctor and Schneider, 2018)..

There are a few studies were found that aimed to investigate reaction time among the equestrian population. A study conducted by Williams and Barnett, (2013) involves n= 53 active riders (8±6.9 hours a week) that engaged in showjumping, eventing and dressage equestrian disciplines were tested using electronic game using computer and external mouse with incorporated visual and auditory stimuli. Authors found that motor response in the hands was deemed the most suitable method to measure response by a rider as this mimic's rider`s response to horse reaction (rein adjustment) because of stimuli. A total of six trials were required in both dominant and non-dominant hands. Results show that there is no significant difference was found between the reaction in both left and right hands (right hand RT= 0.29 ±0.06s, left hand RT=0.29±0.06s). Authors find that participants did not appear to exhibit hand dominance due to striving for balance rein contact. This study also identified an increase in reaction time was associated with an increase in age ($r=0.744$, $P<0.05$).

Another study conducted by Standing and Best, (2019) aiming strength and reaction time characteristics among n=19 New Zealand`s polo players in assessing the relationship strength and reaction time to player handicap. Reaction time was assessed via Flight reaction lights (Ontario, Canada). Eight lights were mounted on two tables positioned at a right angle and arranged in a fan-like shape around the participant; lights were not placed behind the participants as to when mounted on a horse a player cannot leave the confines of the saddle, and to play behind the saddle is considered dangerous. The Flight system would randomly activate one of the eight lights (30-sec sample duration, with 0.1sec delay between lights) and participants had to wave their hand directly over (approx. 1–3 cm distance from light) to record a single point, this in turn randomly activated another of the eight lights. The total number of lights successfully recorded per 30s trial was recorded. The result on reaction time shows a non-significant relationship to handicap ($P= 0.889$). According to the authors, interactions between the rider and the horse ultimately create an action based on the rider's perception of what is required. As handicap increases players likely foster an ability to read the game, respond more efficiently and how to manipulate their horses accordingly. These skills are contributors to 'horsemanship' and 'playing skills', two of the categories considered when the player handicap is awarded.

Horseback riding has also been shown to improve the ability to perform Go/No-go tasks. A study was conducted by Ohtani *et al.*, (2017) examined the effect of horseback riding on the Go/No-Go task among 106 healthy children aged 10-12 years old. The Go/No-go task is a behavioural test that determines the ability to take appropriate action (Go reaction) and to show appropriate restrain (No-go reaction) depending on the situation. The task for Go/No-Go experiment was conducted using a 15” computer screen (Sony, Tokyo, Japan). The “Go” reaction required the pressing of the space bar on the keyboard when blue or yellow was displayed, while the ‘No-go’ reaction required that no key was pressed for more than 2,000ms when red was displayed. Incorrect answers were recorded if the “Go” reaction/colour was displayed and the space bar was not pressed for more than 2,000ms and if the “No-go” reaction/colour was displayed and any key was pressed. The colours were presented, in a random order, 10 times each. In addition, the intervals between the colour presentations were chosen at random from 2,000, 2,500, or 3,000ms. In this experiment, the children were seated on a chair placed in front of the 15″ monitor with the keyboard on a desk after the first 10 min of riding, walking, or resting. Results showing that horseback riding produces better Go/No-Go results than walking and resting. 25-54 children (46.3%) reported increasing their performance after 10 minutes of riding compared to 10 minutes walking 7-26 children (26.9%). Authors stated that horseback riding might improve the ability to recognize the appropriate action depending on the situation (Go reaction) and the appropriate self-control (No-go reaction) in children, possibly through the activation of the sympathetic nervous system. Some horse riding may reduce stress through the activity of the parasympathetic nervous system.

2.5 Bone Health

Bone is a special connective tissue. On the organ level, bone is made up of cartilaginous joints, calcified cartilage of the growing bone plate marrow space and the mineralized cortical and trabecular and trabecular bone structure. Meanwhile, on a tissue level, bone consist of a mineralized and non-mineralized matrix with bone-forming osteoblasts, some entrapped into the mineralizing bone matrix and become osteocytes and the bone-reabsorbing osteoclast (Gasser and Kneissel, 2017). The bony skeleton provides mobility, support, and protection for the body and as a reservoir function for essential minerals called calcium and phosphorus. The skeleton structure can remarkably adapt to provide adequate strength and mobility to prevent fracture due to substantial impact or load during vigorous physical activity (Office of the Surgeon General, 2004).

Calcium and phosphate are critical to human physiology and skeletal mineralization. The skeleton contains over 99% of body calcium and 90% phosphorus (Copp, 1957). Bone plays a vital role as a reservoir of skeletal calcium and is controlled through the regulatory pathway of the gastrointestinal tract (GI) and kidney (Shaker and Deftos, 2013). Calcium being absorb from the diet in the GI tract and unabsorbed calcium passes into feces and substantial losses can occur during pregnancy and lactation in a woman (Shaker and Deftos, 2013). All through life bones keep changing in shape, size and position through modelling and remodeling processes. Remodeling predominates by early adulthood and is stimulated by hormones and mechanical load through local factors, (Office of the Surgeon General, 2004) meanwhile bone modelling is the process either formed on the existing bone surface by osteoblast without prior resorption. Both processes aim to alter the shape of the bone and adapt it to changes in mechanical loading (Gasser and Kneissel, 2017).

Physical activity has shown positive feedback in bone health through the effect of mechanical loading (Lin and Hsieh, 2005). Engaging in physical activity induces an anabolic or homeostatic effect on bone via “mechanotrasduction”: the fluid movement within the extracellular matrix of bone force on osteocytes and bone lining cells and triggers the release of nitric oxide and prostaglandins which lead to separation and differentiation of osteoprogenitor cells. Pre-osteoblast consequently matures to osteoblast cells and attach to the surface of the matrix to begin the production of new bone (McMillan *et al.*, 2017). To optimizing bone accrual, physical activity is very important. According to mechanostat theory, bone is continuously adapting its content, mass and structure to the loads to which its expose (Koedijk *et al.*, 2017). Several studies have identified a positive association between the level of physical activity and bone mineral density in children. Findings showed that physical activity during a period of maturity (Khan *et al.*, 2000) and before menarche (Haapasalo *et al.*, 1994; Hasselstrøm *et al.*, 2007) plays a vital role in optimizing peak bone mass and that may extend the benefits into adulthood. Haapasalo *et al.(*1994), and Hasselstrøm *et al.*(2007), also report that dominant-to-nondominant difference is larger in those who engaged with sports before menarche than those who start later, showing that skeleton seems most sensitive to mechanical loading.

Weight-bearing exercise is the best bone-building exercise and provides an osteogenic stimulus to the bones (Creighton *et al.*, 2001). High impact exercise tends to involve jumping and jolting (Dynamic Physio, 2019), plyometrics and gymnastic (Kohrt *et al.*, 2004) movement applied stress and forces towards the bone and help to improve bone density (Kohrt *et al.* 2004; National Institute of Health 2018; Dynamic Physio 2019). There are many studies to evaluate bone health in weight-bearing sports that come out with positive results when using comparison with non-weight bearing sports and sedentary population. Creighton *et al.,* (2001) have come out with a study to evaluate bone mineral density (BMD) in 41 female athletes who engage with high impact (basketball and volleyball), medium impact (soccer and track) and non-impact sports (swimming), this study found that total body BMD was higher in the high impact group (4.9±0.12) followed medium impact (4.5±0.14) and non-impact sports (4.2±0.14). These indicate that women who participate in high and medium impact sports tend to have higher BMD compared to non-impact sports. Activity indexes also have a strong correlation with BMD in combat sports athletes particularly with the whole body (74%), legs (63%), L2-L4 (25%) and arms (25%) (Nasri *et al.*, 2015). Children and adolescents who practice karate are also shown to have more bone mass in comparison to the control group regardless of gender (De Oliveira Barbeta *et al.*, 2017).

Non-weight bearing exercise or weight-supported exercise is an exercise activity or motion without supporting own body weight such as swimming, yoga, cycling (Drugs.com, 2020), rowing and horseback riding (Home Health Care, 2018). Athletes who engaged in non-weight bearing exercise are at risk of developing low bone mineral density (Andersen *et al.*, 2018; Vlachopoulos *et al.*, 2018b) due to lack of osteogenic stimulus (Vlachopoulos *et al.*, 2018b). Research related to bone health among horseback riding has come out with similar findings with lower bone mass and low bone mineral density. A previous study conducted by Dolan *et al,* (2012) found a significant difference in bone mass between the jokey group (flat and hunt), control group versus boxer group. Flat jockeys displaying the lowest measure followed by national hunt and boxer groups consistently display the greatest amount. The tendency towards significant difference was shown between national hunt and control group for L2-4 BMC and L2-4 BA (p = 0.07 and 0.0054 respectively) with a total ratio of body BMC showing flat jockey group had significantly lower TBBMC: LM (48.1±3.5) than boxer (56.0±3.8) and control group (54.0±5.1). Another study comparing BMC and BMD between male and female flat and hunt jockey conducted by Jackson *et al.*,(2017) found that BMC and BMD at all skeletal significantly lower in male flat jockey than in male jump jockey. Male flat jockeys also had lower BMC at the spine than female flat jockeys. The difference between BMD at the spine and total hip was lower in male jockey. However, a comparison study between female horseback riders from horse jumping and dressage events versus nonactive population conducted by Alfredson *et al.*, (1998) found that there is no significant difference in BMD of dominant and nondominant humerus, lumbar spine, hip, femoral, diaphysis, distal femur, proximal tibia and tibial diaphysis between both groups. Authors indicate that in both events (horse jumping and dressage), the rider is subjected to weigh-bearing loading in a sitting position, and during horse jumping the impact forces acting on the spine and hip especially during the landing phase create strains and have an osteogenic effect towards the bone but not as high as other weight-bearing sports.

Maintaining a strong and healthy bone is a complicated process. Many factors may lead to bone disease such as genetic abnormalities: osteogenesis imperfecta, nutritional deficiency: particularly vitamin D, calcium, phosphorus and medication such as glucocorticoids (Office of the Surgeon General, 2004). A decline in bone mass during the ageing process in men and women may increase the risk of fracture. Primary osteoporosis is the most common in the elderly (age-related osteoporosis) defined as osteoporosis that is not caused by some other specific disease (Office of the Surgeon General, 2004). Engaging with horseback riding activity will have a high possibility to fall from the horse due to horses' unpredictable nature, height and speed, and event-related factors such as jumping, polo and racing tend to be at high risk of falling regardless of the rider`s level of experience (Gates and Lin, 2020). According to Schicho *et al.*, (2015), 59 spinal fractures were recorded between May 2005 and October 2012 and the frequency or severity of the injuries by horseback riders increased with age. In another study conducted by Schröter *et al.*, (2017), 503 injury cases treated were falling from recreational horse riding between 2006 and 2011 with the most common injuries in upper extremities, thoracic and lumbar spine. Meanwhile, participating in weight-bearing sports like soccer, handball and basketball mostly like to have a common diagnosis of soft tissue injuries comparing to fracture (Yde and Nielsen, 1990; Giza *et al.*, 2005).

A bone density test is the only test that can diagnose osteoporosis and helps to estimate bones and the chance of breaking a bone. There are few types of bone density tests and National Osteoporosis Foundation recommends a bone density test using dual-energy x-ray absorptiometry (DXA) on the hip and spine meanwhile central DXA test is on the radius bone in the forearm. A peripheral test or a screening test to measure bone density in the lower arm, wrist, finger, or heel can use peripheral dual-energy x-ray absorptiometry (pDXA), quantitative ultrasound (QUS) and peripheral quantitative computed tomography (pQCT). Dual energy x-ray absorptiometry is the most popular method found in evaluating bone health status in both weight-bearing (Haapasalo *et al.*, 1994; Khan *et al.*, 2000; Creighton *et al.*, 2001; Nasri *et al.*, 2015; Andersen *et al.*, 2018; Vlachopoulos *et al.*, 2018a, 2018b) and non-weight-bearing (Alfredson *et al.*, 1998; Dolan *et al.*, 2012; Wilson *et al.*, 2013; Jackson *et al.*, 2017; Andersen *et al.*, 2018; Vlachopoulos *et al.*, 2018b) research. The peripheral test was also found using quantitative ultrasound on the phalanges bone to measure the bone density in young karate practitioners (Hasselstrøm *et al.*, 2007).

To our knowledge, to date information on the anthropometric profile, balance ability, reaction time and bone health status in horseback riding athletes in Malaysia are still lacking. Therefore, the present study was proposed.