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Literature Review

Oxygen Consumption of the Heart during Horse Riding

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Abstract

Horse riding has three disciplines: show jumping, dressage and endurance. (Singapore Sports Council, 2020) During jumping the rider demonstrates his/her ability to command the horse to jump over obstacles. In dressage, the rider needs to accurately control the horse and perform a series of exercises. During endurance, the rider has to guide the horse through artificial and natural obstacles. There are three different horse gaits: walk, trot and canter (British Dressage, 2021). The walk is a marching pace with a 4 time tempo. The trot is a two beat rhythmic pace, with four different types. Canter is a three beat pace with four different types, similar to trot. The aim of the study is to investigate the oxygen consumption of the riders during the three different disciplines and compare VO2 and heart rate during the different disciplines. This knowledge will assist instructors and riders while planning training sessions and preparing for competition.

Keywords: *Horse riding, Heart physiology, Oxygen consumption*

1. Introduction

Physical exercise in general benefits the body in many ways as it strengthens the heart, lowers cholesterol, lowers blood pressure, improves blood sugar levels, reduces body weight, strengthens muscles, bones and joints, improves endurance, reduces stress and improves sleep quality. Mild aerobic exercise lasting at least 30 minutes and at least 4 times a week such as swimming, cycling, walking, etc. is generally recommended. The intensity of exercise usually divides the trainees into 3 categories (Stephen et al., 2017).

Professional elite athletes who train intensively for more than 10 hours a week, regular athletes who train at least 6 hours a week and common athletes who exercise 4 hours a week. It is known that high levels of physical activity and fitness are associated with low overall mortality, low rates of cardiovascular disease and lower levels of malignancy cases (WHO, 2010).

Exercise, and especially intense and endurance exercise, requires a significant increase in cardiac output, which is the volume of blood that the heart pushes to the aorta (in liters / minute). For example, in some endurance athletes and specifically in cyclists, a cardiac output approaching 40 liters / minute has been measured when the intensity of the exercise reaches its maximum (La Gerche et al., 2013). This increased cardiac output implies increased cardiac workload. However, the workload performed by each ventricle of the heart is not necessarily equal: The left ventricle (LV) pushes blood into the systemic (or large) circulation, which is characterized by a significant ability to reduce resistance and increase compliance. The right ventricle (RV), on the other hand, leads to the pulmonary circulation, which is maximally supplied with blood at rest, and has low resistance and high compliance. Thus, the pulmonary circulation shows less ability to adapt and receive the ever-increasing blood flow during exercise. In other words, the same amount of blood per unit of time that must be promoted in the large circulation of the body must also be promoted in the pulmonary circulation. This requires proportionately more effort than the right ventricle (Buckberg et al., 2018).

The increase in right ventricular (RV) function during exercise has been demonstrated by many researchers, using ultrasound techniques and other measurements which find an almost linear increase, of the order of 1-3mmHg, in the mean pulmonary artery pressure per liter in the increase of the right ventricular supply (Buckberg et al., 2018). In highly trained high-performance athletes, this means a significant increase in pressure and workload (keeping in mind that the work produced by each ventricle of the heart can be estimated approximately multiplying the pressure with the pulse volume) (Lewis et al., 2013).

$VO2_{Max}$ is the maximum amount of oxygen an athlete can use for a given period of time e.g. one minute. Therefore, it is considered a measure of aerobic fitness and is a marker of the oxygen that is used by the tissues of the body. Recent studies have shown that a high $VO2_{max}$ is associated with a lower risk of heart attack and mortality. To make comparisons between people of different body size, the total amount of oxygen used is divided by body weight. The measurement is made in ml of oxygen per kilogram of body weight for a period of one minute (ml / kg / min). However, this comparison is not entirely correct because people differ mainly in adipose or muscle tissue and not in other organs such as the heart, liver or brain, which have their own oxygen requirements.

It is noteworthy that for elite athletes, the VO_{2max} alone does not predict top performance. For example, the winner of a marathon is not the athlete with the highest VO_{2max} value. As the intensity of the exercise increases, at some point there is a vast accumulation of lactic acid in the blood resulting in fatigue. In world-class athletes, lactic acid brings fatigue to 70-80% of VO_{2max} but there is a difference between athletes which ultimately affects the performance. In addition, for marathon runners, the diet and the type of macronutrients that provide energy (glucose or fat) are very important.

Based on the above, it is evident that VO_{2max} alone is not a predictor of oxygen consumption of the heart or other organs needed oxygen. Different types of exercise need different amounts of oxygen for muscles and heart function. Especially for horse riders that cover a great variety of exercise needs, endurance, dressage and jumping there is a need for identifying other markers for defining oxygen consumption of the heart throughout the exercise. In the present study, the main aim is to review the published studies of the literature in order to identify possible markers for oxygen consumption by the heart of an athlete in horse riding during different types of exercise and compare them for validity and specificity.

2. Heart physiology during resting and exercise

The rapid flow of blood to the whole body is produced by the pressure created by the function of the heart, as a pump. As discovered by the British physiologist William Harvey (1628), the cardiovascular system forms a cycle, so that the blood that is effused from the heart and flows into a series of vessels, returns to the heart through a different arrangement of vessels. There are two systems of vessels that start and end up in the heart. Each system contains cavities: an atrium and a ventricle (Vander et al., 2011). Blood is pumped through the pulmonary circulation, from the right ventricle through the lungs and then into the left atrium. Through the systemic circulation, from the left ventricle through all the tissues of the body except, from the lungs, and onwards it returns to the right atrium. In both systems, vessels that carry blood away from the heart and arise from the ventricles are called arteries, while those that carry blood, either from the lungs or back to the heart, are called veins. The function of the heart as a pump is the blood circulation which is distinguished in the systemic and pulmonary circulation. In the systemic circulation, blood leaves the left ventricle through a single large artery, the aorta (Buckberg et al., 2018). Systemic arteries originate from the aorta and are divided into two successively smaller branches. The smallest arteries branch into arterioles, which in turn branch into very small vessels, the capillaries, which are joined together to form vessels of greater diameter, the venules. The arterioles, capillaries and venuses are the microcirculation of the system (Classen et al., 2010). The venules in the systemic circulation are joined afterwards to form larger vessels, the veins. The veins from the various peripheral vessels and tissues meet to create two large veins, the lower vena ciliary vein and the upper vena ciliary vein which end up in the right atrium of the heart.

The heart is, in essence, a double pump, after the vessels meet and then, almost immediately, the ventricles contract. The contraction of the heart muscle, like other types of muscle, is triggered by the depolarization of the cytoplasmic membrane (Buckberg et al., 2018). Myocardial cells are joined together by chasmatic connections. These allow energy dynamics to propagate from one cell to another. So, the initial stimulation of a myocardial cell results in stimulation of all cells. This initial depolarization is normally manifested by a small group of cells of the conduction system, the sinus node or SA node, located in the right atrium near the entrance to the upper vena. The energy potential is then propagated by the sinus node throughout the heart in such a way that it causes contraction of the atres first and then of the ventricles (Barrett et al., 2011). The depolarization of the sinus node, which is the normal pacemaker of the heart, creates in normal conditions the electric current that leads to depolarization of all other cells of the heart muscle, and thus the rate of its discharge determines the heart rate, that is, how many times, the heart contracts per minute (Vander et al., 2011).

The energy potential that starts from the sinus node is spread throughout the myocardium, passing from one cell to another through the chasmatic connections. The spread throughout the right atrium and from the right to the left atrium does not depend on fibers of the conduction system. The propagation is fast enough for the two in order to contract virtually simultaneously (Vander et al., 2011). The propagation of energy potential in the ventricles is more complex and involves the rest of the conduction system. The link between the depolarization of the atrials and ventricles is a part of the conduction system called the atrial node or AV node and is located at the base of the right atrium. The energy potential that propagates through the right atrius causes depolarization of the atrial node. This node displays a feature of particular importance: For various reasons related to the electrical properties of the cells of the atrial node, the propagation of energy dynamics through the atrial node is relatively slow (it takes about 0.1 seconds). With this delay it becomes possible to add with the contraction of the sinuses additional blood to the ventricles before the contraction of the ventricles takes place (Barrett et al., 2011).

After leaving the atrioventricular node, the push penetrates the wall between the two ventricles (the interventricular septum) through the fibers of the conduction system called the Bundle of His (or atrioventricular bundle) in honor of the researcher who discovered it.

It should be emphasized that the AV node and the His bundle are the only electrical link between the attices and ventricles. There is no other such connection, since a layer of non-conductive connective tissue, into which the bundle His penetrates, completely separates each atrium from the corresponding ventricle. The His bundle is then divided into the diaphragm into the right and left branches, which eventually leave the diaphragm to enter the walls of the two ventricles. These fibers in turn come into contact with the Purkinje fibers (they are also called myocardial conduction fibers or Purkinjefibers), large conduction cells that quickly distribute the impulse to many parts of the ventricles. Finally, Purkinje fibers come into contact with ventricular cells that do not belong to the conduction system, through which the push is spread to the remaining parts of the ventricles (Classen et al., 2010). The rapid treatment of impulses along the Purkinje fibers and the diffuse distribution of these fibers causes depolarization of all right and left ventricular cells almost simultaneously and ensures a single coordinated contraction. In fact, depolarization and contraction begin slightly earlier in the lower part (apex) of the ventricles and spread upwards.

2.1 Heart markers of oxygen consumption

Cardiac output

Cardiac output is the main indicator of the functional ability of the circulation to cope with the demands created during physical activity. The heart supply, as in any pump, is determined by the rate at which it contracts (heart rate) and by the amount of blood promoted with each pulse (pulse volume). Cardiac output is calculated by the formula:

$$\text{Cardiac output} = \text{Cardiac frequency X pulse volume}$$

Measuring cardiac output

Measuring the flow rate of a pump, or cannula is a relatively simple process. It is enough to open the valve and collect and measure the volume of fluid ejected over a certain period of time. But things differ when it comes to calculating cardiac output. Even if an immediate technique is applied, stopping the continuity of the main extractive vessel in the closed circuit of circulation will dramatically alter the actual value of the supply. Various methods have been applied to humans for this purpose; these include the Fick method, CO_2 values and various dilution methods (Mcardle, Katch, Katch 2001), (Wilmore, Costill 2006).

Fick's method

Cardiac output can be calculated if we know the subtle oxygen intake of a person and the average arteriovenous oxygen difference (difference a-$\bar{v}$O2). The question that remains to be answered is: What is the amount of blood that needs to be released in one minute in order to have the given oxygen uptake, if we know the difference a-$\bar{v}$O2? The formula expressing the relationship between cardiac output, oxygen uptake and the difference a-$\bar{v}$O2 contains the principle formulated by Fick in 1870 and called Fick's equation:

$$\text{Cardiac output (ml/min)} = [\text{ Intake of } O_2 \text{ (ml/min)} / \text{difference a-}\bar{v}O_2 \text{ (ml/100 ml of blood]} \text{ X } 100$$

Although the principle of Fick is simple, in practice measurements with this technique are complex and its clinical application is limited only to cases where the benefits exceed any potential risk. Measuring the difference, a-$\bar{v}O_2$ is more difficult. It requires taking a representative sample of arterial blood, which is done from some accessible artery, such as femoral, radial, or humeral. Although their localization is easy, their puncture can be traumatic for the patient. To accurately measure the average oxygen content of mixed venous blood it is necessary to take blood from a cavity with small blood such as the right atrium, the right ventricle, or even the pulmonary artery. This is achieved by promoting an elastic catheter through the brachial vein into the upper vena and then into the cavities of the right heart. Both the arterial and mixed venous blood samples are taken at the same time period that oxygen uptake is measured (Mcardle, Katch, Katch 2001), (Wilmore, Costill 2006).

Cardiac Output at Rest

Untrained People

For the average person, cardiac output of 5 liters is usually maintained with a heart rate equal to 70 beats per minute. If the heart rate value is replaced in the equalization of cardiac output, the pulse volume is calculated at 71 ml per pulse. The values for the rate of the pulse in women are usually 25% less than those measured in men. This difference between the two sexes is usually due to the smaller physical size of an average woman in comparison with a corresponding man. (Mcardle et al., 2001; Wilmore & Costill 2006).

Cardiac output during Exercise

Blood flow increases in proportion to the intensity of the exercise. During the progressive transition from rest to steady-rhythm exercise, the cardiac output initially undergoes a rapid increase, followed by gradual ascent, until a plateau is reached. At this point, the blood flow is sufficient to meet the metabolic demands created during exercise (Mcardle et al., 2001; Wilmore & Costill 2006).

Pulse Volume during Exercise

In an experiment on the change of pulse volume in two groups of men during the exercise of increasing intensity, which is performed in an upright position, one group consisted of 6 trained endurance athletes who have trained for many years. The other group includes three students who had a sedentary lifestyle. Changes in heart function during exercise were evaluated before and after years over a period of 55 days, during which they followed a training program aimed at improving aerobic fitness (Mcardle et al., 2001; Wilmore & Costill 2006).

Pulse Volume and VO_2max

The data come from three groups, athletes, healthy but untreated individuals, and patients with mitral stenosis, a valvular disease, which does not allow the complete emptying of the left ventricle. The differences inVO_{2max} between the different groups are closely related to the differences observed in the pulse volume. In patients with mitral stenosis, the functional capacity and the maximum pulse volume amounted to about 58% of the values observed in healthy controls. The maximum oxygen intake of the athletes was 62% higher than that observed in the untrained subjects. At the same time there was a 60% increase in pulse volume. As the maximum heart rate in both groups was similar, the difference in cardiac output (and VO_{2max}) is attributed only to the differentiation of the maximum values for pulse volume (Mcardle et al., 2001; Wilmore & Costill 2006).

Pulse volume: Relationship of Systolic Emptying and Diastolic Filling

There are two physiological mechanisms that regulate pulse volume and contribute to varying degrees to the increase observed during exercise. The first is due to endogenous properties of the myocardium and requires a large filling of the heart cavities which will lead to a strong contraction. In the second mechanism, neurochemical factors play a regulatory role. A normal filling of the ventricles is required accompanied by a large volume of pulse, which is due to the strong contraction that leads to a greater degree of emptying of the cavities (Buckberg et al., 2018).

During exercise

A person with a maximum cardiac frequency of 200 beats per minute and a pulse volume of 80 ml produces a maximum cardiac flow rate of16 litres (200 χ 80 ml). Even during exercise of maximum intensity, the saturation of hemoglobin with oxygen is almost complete, so that every litre of arterial blood carries about 200 ml of oxygen (Buckberg et al., 2018). Every minute, through a cardiac output of 16 liters, circulate 3,200 ml of oxygen (16 liters X 200 ml). If the possible removal of the entire amount of oxygen from the 16 liters of blood, which constitute the cardiac output, as they travel to the body, the largest possible VO_{2max} would be 3200 ml. Of course, this is theoretical. The needs in oxygen of some tissues, such as the brain, do not increase significantly with exercise, however these tissues acquire a rich and continuous blood supply (Mcardle et al., 2001; Wilmore & Costill 2006). Any increase in maximum cardiac output directly affects a person's ability to distribute oxygen. According to the previous example, if the pulse volume increases from 80 to 200 ml and the maximum heart rate remains constant at 200 pulses per minute, the maximum cardiac output will increase significantly and become equal to 40 liters of blood per minute.This means that the amount of oxygen circulating during the maximum exercise each minute will increase about 2.5 times, that is, from 3200 ml to 8000 ml (40 liters X 200 ml O_2). The increase in the maximum cardiac output clearly leads to a proportional increase in the potential of aerobic metabolism (Mcardle et al., 2001; Wilmore & Costill 2006).

Direct Correlation of Maximum Cardiac Output and VO_{2max}

The relationship is not open to question. Low capacity for aerobic exercise is closely related to low maximum cardiac output, since the production capacity of 5 or 6 liters of VO_{2max} is always carried out by a cardiac output of 30 to 40 liters (Mcardle et al., 2001; Wilmore & Costill 2006).

Oxygen Uptake: The difference a-$\bar{v}$O2

If the only way to increase the oxygen flow to the tissues was blood flow, then the cardiac output should be increased from 5 litres per minute at rest, to 100 litres per minute at maximum exercise, in order to cover the 20-fold increase in oxygen intake.

These oxygen intake levels are often observed in fit individuals. Fortunately, during exercise, such a large cardiac output is not necessary, since hemoglobin, when passing through the active tissues, releases a greater amount of oxygen. We can conclude that the human body has two endogenous mechanisms to increase the uptake of oxygen from the tissues. The first consists of accelerating the rate of blood flow, i.e., increasing cardiac output. The second consists of pumping a greater amount of oxygen from the amount of blood supplied (Buckberg et al., 2018). The important relationship between cardiac output, the difference a-$\bar{v}O_2$ and VO_{2max} is summarized in the modified version of the following Fick test:

$$VO_{2max} = \text{Maximum cardiac output X Maximum difference a-}\bar{v}O2$$

(Mcardle et al., 2001; Wilmore & Costill 2006).

3. Horse riding as an exercise type

Horse riding has three disciplines: show jumping, dressage and endurance (Singapore Sports Council, 2020). During jumping the rider demonstrates his/her ability to command the horse to jump over obstacles. In jumping obstacles, the goal of riders and their horses is to complete a route with 12 to 14 jumps. There is a specific penalty which is given in case of throwing an obstacle, exceeding the time limit or a horse's refusal to make the jump. Depending on the type of event, the winner is the athlete who is given the fewest penalty points, completes the route in the fastest time or earns the most points (Singapore Sports Council, 2020).

In dressage, the rider needs to accurately control the horse and perform a series of exercises. In Equestrian Craftsmanship or otherwise dressage, which is often called the "ballet of riding", skills are required from both the rider and his/her horse to perform all the technical exercises included in the program. In dressage, riders and their horses perform specific movements and exercises, such as pirouettes, passages or piaffe, in a rectangular track with dimensions of 60 meters x 20 meters. The programs are graded by a panel of seven judges in terms of the quality of the movement, as well as the general impression of harmony, lightness of movement and the smooth flow of the test. At the Olympics, the dressage consists of team and individual events, which are held simultaneously. In the first two rounds, called the Grand Prix and Grand prix special, all riders perform the same tests and the scores are combined for the final award of the medals in the team event. The 18 riders with the best scores in the Grand Prix Special lap then qualify directly to the Freestyle Grand Prix, in which the riders perform their own programs with background music, and the winner of every round is determined by the final scores (Hobbs et al., 2020).

During endurance, the rider has to guide the horse through artificial and natural obstacles. Endurance riding is the most challenging type of equestrian exercise, as it presents as demanding in terms of speed, inducing a vast increase in metabolic, musculoskeletal, and cardiovascular work. At the Olympics, it is held in the space of four days and the first thing that is tested in the first two days of triathlon is the harmonious relationship of the rider with his horse. Riders must then demonstrate their endurance by performing a course with physical obstacles on the third day, as their goal is to complete a six to seven km journey, which includes more than 40 physical and fixed obstacles, within a certain time frame.

On the fourth day there is an impressive jumping race, which requires precision, agility and technique to overcome obstacles and complete an impeccable route. In the first round of jumping, the winners of the team medals are highlighted and in the second round the gold winner of the individual is highlighted.

According to the specialists in horse riding, there are three different horse gaits: walk, trot and canter (British Dressage, 2021). The walk is a marching pace with a 4 time tempo. The trot is a two beat rhythmic pace, with four different types. Canter is a three beat pace with four different types, similar to trot.

The sequence of the horse's gait pattern is left back foot, left front foot, right back leg, and right front foot. During the thrust the left back leg begins the initial swinging phase. During this push, the horse's pelvis leans laterally left, causing a left lateral tilt of the rider's pelvis. The rider's torso is lengthened by the left side, and diminishes from the weight-bearing side, which is the right side. For the swinging leg, the horse's spine should be bent sideways, and the pelvis is rotated forward. This causes the rider's pelvis to rotate forward. The swing phase also shifts the rider's weight, causing a posterior pelvic swing. The hit phase begins as the left back leg comes into contact with the ground. As this happens, the horse's center of gravity shifts to that side, causing a right lateral displacement of the rider's pelvis. This phase is considered the deceleration phase, which causes an anterior shift in the rider's center of gravity leading to an anterior pelvic inclination (Heine, 1997). The same sequence is repeated on the right side and is repeated constantly with the pace of the horse.

These three-dimensional oscillations of the horse's torso are transferred to the rider’s body, and through the pelvis they are transferred to the trunk, the neck and the shoulder. Similarly, these oscillations affect the limbs (Riesser, 1993). As a result, the rider exercises passively. The best exercise is the balance acquisition and maintenance.

The rider needs to acquire a relationship of trust and unity with the horse in order to work together in the exercise. The horse influences the rider in such a way that he/ she can indulge in these oscillations, assimilate them, while not harassing the rhythm/ pace with his/ her own movements. The already mentioned three-dimensional oscillations of the horse's trunk at the specific point of "walking" provide the rider with such a pattern of movement, which is proportional to the pattern of movement of the human gait. If you observe the way of movement of the hips, pelvis, torso, shoulder and arms of a rider who sits completely loosely on the horse and compare them with the movements of a rider who walks next to him, one will find that the way they both move is very similar (Riesser, 1993).

The rider, during the time he is on the horse is forced to respond each time to the movement of the horse by adjusting its balance position (because the horse never remains completely immobile). For this adaptation to the pace of the horse, the movement of the joints and, mainly, of the spine, shoulders and pelvis is required (Tsimaras, 2012). Varying the pace, direction and speed of the horse can alter the degree of stimulus produced to distract a shift in the center of gravity from the rider. The path of the horse can be in circles, between cones and distinct paths. The horse's bounce during the session requires an increased response to balance and increases the sensory stimulation of the rider (Bertoti, 1988).

It is imperative to mention that the energy and oxygen consumption of the horse during the exercise is in line with the rider's needs. There are specific markers that point out the significance of the oxygen consumption by the rider throughout different types of exercise in horse riding. In the present study, we focus on oxygen consumption of the heart of the rider during various types of exercise in horse riding in order to define novel markers of the cardiovascular capacity in horse riding.

4. Oxygen consumption during horse riding: literature review

In order to evaluate the oxygen consumption of the heart during dressage, endurance and jumping sessions, we should define which type has the most energy requirements. It is evident that endurance is the type of exercise that is the most challenging in terms of musculoskeletal, metabolic and cardiovascular needs. Dressage and jumping need balance and concentration, which both are metabolic and oxygen challenging.

The aim of the present study is to investigate the oxygen consumption of the riders during the different disciplines and types of exercise and compare VO_2 and heart rate during the different disciplines. This knowledge will assist instructors and riders while planning training sessions and preparing for competition. This data will become valuable not only for elite and professional riders but also for riders in therapeutic horse riding.

The literature search was conducted in large databases such as PUBMED and COCHRANE LIBRARY to identify articles published from January 1999 to January 2021 comparing the different types of exercise as for their oxygen consumption of the rider's heart. The following search terms and their combination was investigated: "oxygen consumption", "oxygen uptake", heart oxygen consumption", "horse riding", "dressage", "endurance in horse riding", "jumping in horse riding". We came up with various studies and excluded those that did not meet the criteria we posed above. So, we included five studies that are presented below.

Oxygen uptake, heart rate and blood lactate levels in female horseback riders during the obstacle test track

In Hyttinen et al., 2020, 42 female horseback riders were tested during an obstacle track for the heart rate and oxygen consumption by the heart. The values VO_{2peak}/VO_{2mean} and HR_{peak}/HR_{mean} during the obstacle track were measured to be 34.4(5.0)/26.4(4.0) ml/kg/min and 184.4(9.6)/178.1(10.2) bpm. Blood lactate concentration of the rider group was higher in the obstacle track to 7.6(2.2) mmol/L. There were no differences in eventing and show jumping as with the obstacle track. In this study, it was shown that the obstacle track is a challenging form of exercise, requiring energy and fitness from the rider.

Energy expedition of horse riding

In the study of Devienne et al., 2000, oxygen consumption (VO_2), ventilation (VE) and heart rate (HR) were the parameters, measured in 5 recreational riders using a portable oxygen analysing system. In a dressage, endurance and jump test that was included in the study, the parameters were assessed. A progressive increase in VO_2 in the dressage test from a mean value of 0.70 (0.18) l x min (-1) was referred compared to a walk, to 1.47 (0.28) l x min (-1) at a trot, and 1.9 (0.3) l x min (-1) at a canter. As for the jump test, VO2 was measured to be 2 (0.33) l x min (-1) with a mean HR of 155 beats x min (-1) in canter, in the obstacle trot and obstacle canter. The most increased VO_2 and HR measurements compared to mean values of 2.40 (0.35) l x min (-1) and 176 beats x min (-1) were spotted in the jump test for the rider. As for the VO_2 maximum value that was spotted, 75% was achieved. In this study, it was confirmed that the energy expedition in horse riding is high especially in the sessions that include endurance and speed. So, the rider needs to be physically active and achieve a good fitness state.

Cardio-metabolic responses during horse riding at three different speeds

In the study of Sainas et al., 2016, 19 competitive riders exercised in walking, trotting and cantering and different cardiometabolic parameters were measured. This study concluded that only cantering can lead to moderate exercise levels of energy and oxygen expenditure in riders.

Equestrian expertise affecting physical fitness, body compositions, lactate, heart rate and calorie consumption of elite horse riding players

In the Song et al., (2015) study, professional elite riders were compared to common riders, in different parameters such as blood lactate, heart rate, energy expenditure body mass. Blood lactate and heart rate was found to be significantly increased in professional athletes compared to common riders. Also, the amateur and the professional riders had the same energy expenditure pattern. To sum up, this study deciphers the increased energy needs and heart rate that is needed by the professional riders compared to the amateurs.

Oxygen Cost of Recreational Horse-Riding in Females

In the study of Beale et al., 2015, 16 female recreational riders were used during exercises of walking, trotting and cantering. The mean VO_2 value for trotting/cantering (18.4 ± 5.1 ml·kg-1·min-1; 52 ± 12% $VO_{2peak;}$ 5.3 ± 1.1 METs) was measured to be close to the value for walking/ trotting (17.4 ± 5.1 ml·kg-1·min-1; 48 ± 13% VO2peak; 5.0 ±1.5 METs) but was significantly increased compared to work without stirrups (14.2 ± 2.9 ml·kg-1·min-1; 41 ± 12% VO2peak; 4.2 ± 0.8 METs) (P = 0.001). In this study, it was clear that a certain fitness state of the female rider is needed in order to follow the recreational horse riding routine. The higher energy needs are required in trotting and cantering.

5. Conclusions

From the already mentioned data of the studies, it is evident that riders should maintain a certain level of physical and exercise fitness. In this way, they can meet the physical demands of horse riding. In cardiometabolic aspects, heart rate and energy expenditure are higher in the exercise types that include endurance and speed. VO_2 is not the only cardiac parameter that is commonly used in measuring the heart circulatory oxygen demands. In the present work, we referred other parameters as well, for example heart rate, blood lactate or energy consumption. In conclusion, horse riding is an exercise type that need certain level of fitness of the rider, and this should be the case when a new exercise and training plan is to be designed.

References

1. Beale, L., Maxwell, N. S., Gibson, O. R., Twomey, R., Taylor, B., & Church, A. (2015). Oxygen cost of recreational horse-riding in females. *Journal of Physical Activity and Health*, *12*(6), 808-813.
2. Sung, B. J., Jeon, S. Y., Lim, S. R., Lee, K. E., & Jee, H. (2015). Equestrian expertise affecting physical fitness, body compositions, lactate, heart rate and calorie consumption of elite horse riding players. *Journal of exercise rehabilitation*, *11*(3), 175.
3. Devienne, M. F., & Guezennec, C. Y. (2000). Energy expenditure of horse riding. *European journal of applied physiology*, *82*(5), 499-503.
4. Hyttinen, A. M., Ahtiainen, J. P., & Häkkinen, K. (2020). Oxygen uptake, heart rate and blood lactate levels in female horseback riders during the obstacle test track. *International Journal of Performance Analysis in Sport*, *20*(4), 584-595.
5. Jetté, M., Sidney, K., & Blümchen, G. (1990). Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical cardiology*, *13*(8), 555-565.
6. O'Reilly, C., Zoller, J., Sigler, D., Vogelsang, M., Sawyer, J., & Fluckey, J. (2021). Rider Energy Expenditure During High Intensity Horse Activity. *Journal of Equine Veterinary Science*, *102*, 103463.
7. Kiely, M. A., Warrington, G. D., Mcgoldrick, A., O'loughlin, G., & Cullen, S. (2018). Physiological demands of daily riding gaits in jockeys. *The Journal of sports medicine and physical fitness*, *59*(3), 394-398.
8. Sainas, G., Melis, S., Corona, F., Loi, A., Ghiani, G., Milia, R., ... & Crisafulli, A. (2016). Cardio-metabolic responses during horse riding at three different speeds. *European journal of applied physiology*, *116*(10), 1985-1992.
9. Swain, D. P. (2000). Energy cost calculations for exercise prescription. *Sports Medicine*, *30*(1), 17-22.
10. Westerling, D. (1983). A study of physical demands in riding. *European journal of applied physiology and occupational physiology*, *50*(3), 373-382.
11. Witte K, Schobesberger H, Peham C, (2009), Motion pattern analysis of gait in horseback riding by means of Principal Component Analysis. Hum Mov Science, 28(3):394-405. doi:10.1016/j.humov.2009.04.002

12. La Gerche, A., Claessen, G., Van de Bruaene, A., Pattyn, N., Van Cleemput, J., Gewillig, M., ... & Heidbuchel, H. (2012). Cardiac MRI: a new gold standard for ventricular volume quantification during high-intensity exercise. *Circulation. Cardiovascular Imaging*, *6*(2), 329-338.
13. Lewis, G. D., Bossone, E., Naeije, R., Grünig, E., Saggar, R., Lancellotti, P., ... & Rubenfire, M. (2013). Pulmonary vascular hemodynamic response to exercise in cardiopulmonary diseases. *Circulation*, *128*(13), 1470-1479.
14. Barrett, K., Barman, S., Boitano, S., Brooks, H., (2011). Ιατρική Φυσιολογία. Αθήνα: Πασχαλίδης.
15. Buckberg, G. D., Nanda, N. C., Nguyen, C., & Kocica, M. J. (2018). What is the heart? Anatomy, function, pathophysiology, and misconceptions. *Journal of cardiovascular development and disease*, *5*(2), 33.
16. Classen, M., Diehl, V., & Kochsiek, K. (2010). Εσωτερική Παθολογία Και Διαφορική Διαγνωστική., Τόμος 3., 2η Έκδοση., Ιατρικές Εκδώσεις Π. *Χ. Πασχαλίδης., Αθήνα*, 1259-1262.
17. Downing, J., & Balady, G. J. (2011). The role of exercise training in heart failure. *Journal of the American College of Cardiology*, *58*(6), 561-569.
18. Elkayam, U., Roth, A. R. I. E., Weber, L., Hsueh, W. I. L. L. A., Nanna, M. I. C. H. E. L. E., Freidenberger, L. I. N. D. A. L. E. E., ... & Rahimtoola, S. H. (1985). Isometric exercise in patients with chronic advanced heart failure: hemodynamic and neurohumoral evaluation. *Circulation*, *72*(5), 975-981.
19. Hobbs, S. J., St George, L., Reed, J., Stockley, R., Thetford, C., Sinclair, J., ... & Clayton, H. M. (2020). A scoping review of determinants of performance in dressage. *PeerJ*, *8*, e9022.
20. McArdle, W. D., Katch, F. I., & Katch, V. L. (2001). Φυσιολογία της Άσκησης, Τόμος Ι. *Επιστημονική επιμέλεια: Κλεισούρας, Β.. Αθήνα, Ιατρικές Εκδόσεις ΠΧ Πασχαλίδης*.
21. McKelvie, R. S. & Ko, J. K., (2005). The role of exercise training for patients with heart failure. *European Journal of Physical and Rehabilitation Medicine*, *41*(1), 35.
22. Millar, P. J., Bray, S. R., McGowan, C. L., MacDonald, M. J., & McCartney, N. (2007). Effects of isometric handgrip training among people medicated for hypertension: a multilevel analysis. *Blood Pressure Monitoring*, *12*(5), 307-314.
23. Morris, J. N., & Crawford, M. D. (1958). Coronary heart disease and physical activity of work. *British medical journal*, *2*(5111), 1485.
24. Powell, L. M., Slater, S., & Chaloupka, F. J. (2004). The relationship between community physical activity settings and race, ethnicity and socioeconomic status. *Evidence-Based Preventive Medicine*, *1*(2), 135-44.
25. Παπαλάμπρος, Ε. (2011). Χειρουργική από το Διδακτικό και Ερευνητικό Προσωπικό του χειρουργικού τομέα. Ε.Κ.Π.Α Ιατρική Σχολή. Αθήνα: Πασχαλίδης
26. Schmidt, S. C., Tittlbach, S., Bös, K., & Woll, A. (2017). Different types of physical activity and fitness and health in adults: an 18-year longitudinal study. *BioMed research international*, *2017*.
27. Vander, A. (2011). Φυσιολογία ΤΟΥ ΑΝΘΡΩΠΟΥ-Μηχανισμοί της Λειτουργίας του Οργανισμού.
28. Wilmore, J., & Costill, D. L. (2006). Φυσιολογία της άσκησης και του αθλητισμού. *Ιατρικές Εκδόσεις ΠΧ Πασχαλίδης, Αθήνα*, 226-227.
29. Hajo Riesser, από το "Παιδιά με κεντρικά κινητικά προβλήματα -Υποστήριξη και ΘΕΡΑΠΕΙΑ",Dusseldorf 1993. Μετάφραση από τα Γερμανικά: Ελένη Μαραθάκη - Αναστασάκη.
30. Τσιμάρας, Β. (2012). Προσαρμοσμένη Φυσική Δραστηριότητα Ι. Σημειώσεις. Θεσσαλονίκη
31. Bertoti, D. B. (1988). Effect of therapeutic horseback riding on posture in children with cerebral palsy. *Physical therapy*, *68*(10), 1505-1512.

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