

RIDER ENERGY EXPENDITURE DURING HIGH INTENSITY HORSE ACTIVITY

A Thesis

by

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ABSTRACT

Over the last century, horseback riding has evolved from a necessary mode of transportation to primarily a recreational activity. Despite the fact that horseback riding is a popular sport, there is little information available on horseback riding as a physical activity and the health benefits which could be obtained through horseback riding. Twenty subjects (age=22.4±3.4yrs, height=168.1±7.3cm, weight=67.5±15.5kg) were subjected to three riding tests, a 45min walk-trot-canter ride (WTC), a reining pattern and a cutting pattern while wearing the Cosmed K4b² telemetric gas analyzer kit. Anthropometric data was obtained for each subject through DEXA scans including body fat, body mass index and lean body mass. Total energy expenditure, as well as mean and peak energy expenditure per minute, metabolic equivalents of task (MET), heart rate (HR), respiratory frequency (RF), pulmonary ventilation (VE), oxygen consumption (VO₂) and relative oxygen consumption (relVO₂) were all measured by the Cosmed K4b² system.

Because of time differences between tests, total energy expenditure of WTC was significantly higher ($P\leq 0.05$) than reining or cutting. However, the total energy expenditure observed in the WTC ride (194.7±3.84kcal) does provide insight into health benefits a 45 min ride could provide. Mean energy expenditure per minute as well as mean MET and HR data all indicated reining and cutting to be higher intensity ($P\leq 0.05$) than WTC. When WTC test was split by gait mean energy expenditure per min and MET increased as gait speed increased. Backward regression analyses were completed for total energy expenditure, energy expended per minute and MET for all subjects (n=20) and for

women subjects only (n=17). The results of this study provide insight into horseback activity and discipline differences using a portable system as well as provide novel information about riders engaged in cutting and reining in comparison with a WTC ride. The data also indicate that it is possible, if riding at more intense gaits such as long trot and canter, for longer periods of time, for health benefits to be achieved through accumulated weekly horseback riding exercise.

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NOMENCLATURE

Bpm	Beats Per minute (HR)
Db	Douglas Bag
DEXA	Dual-energy X-Ray Absorptiometry
HDL	High Density Lipoproteins
HR	Heart Rate (bpm)
Mean	Mean of all interval measurements for a test
MET	Metabolic Equivalent of Task
Pk	Peak (the highest 30 or 5 sec interval within the test)
RelVO ₂	Relative VO ₂ (VO ₂ ·kg ⁻¹ ·min ⁻¹)
RF	Respiratory frequency (breaths/min)
VE	Ventilation (l/min)
VO ₂	Oxygen Consumption
VO ₂ MAX	Maximal Oxygen Consumption

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CHAPTER I

INTRODUCTION

Excess weight gain and obesity is certainly an epidemic in the United States. More than one third of adults and almost 17% of youth were considered obese in 2009-2010 (Ogden et al., 2012) with the prevalence of obesity in the United States ranking among the highest in the world (Wolf and Colditz, 1998). While evidence indicates increases in obesity are waning (Ogden et al., 2006; Ogden et al., 2012), there are still major improvements needed to continue to support and enrich the health of American citizens.

As transportation and other technologies have advanced, the activity levels of the users has decreased tremendously, contributing to the overwhelming sedentary society in the United States and other well developed countries (Brownson et al., 2005). Health officials have produced numerous publications indicating exercise as a crucial part of disease prevention and overall health (Brown et al., 2003; Nelson et al., 2007; Garber et al., 2011). Research shows that regular exercise is associated with decreased risk of cardiovascular disease, diabetes, and cancer as well as other health concerns such as depression or anxiety (Brown, 2003). These major diseases are leading causes of mortality in the United States (Mokdad et al., 2004) and incidences of these diseases appear to be increasing despite the advances being made in the medical fields.

Recommendations for exercise from the American College of Sports Medicine (ACSM) is for moderate exercise in 30 min bouts, 4-5 d/wk. Research recommended a minimum calorie expenditure of 1000 kcal/wk to receive health benefits of exercise (Blair et al., 1989). Furthermore, duration, intensity and volume of exercise, as well as

compliance in an exercise program, all play a role in optimum health benefits for the individual (Wenger and Bell, 1986).

Horseback riding, while not a traditional form of exercise such as walking or biking, is an athletic activity that had been occurring for centuries. With an estimated 30 million people in the United States involved in some form of riding annually (American Horse Council, 1997), it could indeed be considered an effective way for a large pool of citizens to exercise, if there are beneficial effects.

Due to the nature of the sport, field testing is the only true possibility of getting valid results on a subject. With field testing comes the process of developing measurement techniques that are not only reliable, but accurate. Previous studies spanning over thirty years have utilized many different techniques and designs. Therefore, information available on horseback riding and fitness is limited and conflicting. Reasons for these differences are due to numerous factors including number of subjects, type of exercise protocol, as well as subject selection and type (Douglas et al., 2012). The equipment used and measurements taken also vary across studies. These differences in study conditions and parameters make comparison and interpretation of the data difficult.

The objective of the current study was to expand the current knowledge on traditional riding at the walk-trot-canter (WTC) gaits on energy expenditure and exercise potential, as well as provide novel information for riders participating in reining and cutting competitions, often believed to be more intense than the traditional gaits.

CHAPTER II

LITERATURE REVIEW

More than one third of adults and almost 17% of youth were considered obese in 2009-2010 (Ogden et al., 2012) with the prevalence of obesity in the United States ranking among the highest in the world (Wolf and Colditz, 1998). While evidence indicates that the increases in number of obese over the last few decades are waning (Ogden et al., 2006; Ogden et al., 2012), there is still much improvement to be made in support of and to enrich the health of American citizens.

Physical activity and health

Exercise and regular physical activity have been popular research topics in the health community for a number of years (King et al., 1988; Blair et al., 1995; Myers, 2003). Technological advances observed over the past century have likely contributed to the physical inactivity of the general public. Television, improved transportation and labor saving devices, both in the work place and at home, are all considered contributing factors to inactivity (Brownson et al., 2005). Pratt et al. (1999) established that inactivity of United States citizens was estimated to cost \$76 billion in additional medical care per year. Pate et al. (1995) attributed 12% of total deaths per year to a lack of regular exercise. These daunting numbers illustrate the impact that inactivity has had on our society and the importance that exercise and regular physical activity play in overall health.

Exercise and disease

Warburton et al. (2006) describes physical activity as a “modifiable risk factor” in many different diseases. Research has shown that regular exercise has been associated

with decreased risk of cardiovascular disease, diabetes, and cancer as well as other health concerns such as depression or anxiety (Brown, 2003). These major diseases are leading causes of mortality in the United States (Mokdad et al., 2004) and incidences of these diseases only seems to be increasing despite the advances being made in the medical fields.

Cardiovascular disease

Cardiovascular disease, a term encompassing a broad array of disorders, remains the leading cause of mortality in the United States (Kochanek, 2004). There is increasing evidence of an association between physical inactivity and risk of cardiovascular disease. Studies conducted in the late 1980's and early 1990's established an inverse relationship between regular exercise and cardiovascular disease (Arraiz, et al. 1992; Ekelund et al. 1988; Blair et al. 1989; Sandvik et al. 1993; Blair et al. 1995).

Results of one study, demonstrated that low fitness, defined as the lowest quintile of treadmill testing in an age group, is an important precursor to mortality (Blair et al., 1995). During this study, participants were evaluated on family health history, a physical examination with blood analysis as well as a standardized maximal exercise test. Participants were then monitored until date of death or December 31, 1989. The fitness levels of low, moderate and high were established by the least fit 20% being the low, middle 40% being moderately fit and the top 40% of fitness being the high fitness levels. This study not only confirmed the association between physical fitness and cardiovascular disease risk but also showed that the protective effects of exercise held true even if other risk factors were present such as smoking or high blood pressure. Other studies also showed that physical activity and fitness played major roles in combatting other risk

factors (Sesso et al., 2000). This evidence strongly suggests that exercise plays a key role in all-cause mortality and cardiovascular disease prevention.

A more recent study (Myers et al., 2004), demonstrated an association not just between physical fitness and cardiovascular disease but also in physical activity. Patient recollection and cardiovascular disease risk factor documentation were utilized to establish an association between fitness, activity level and health. Physical activity and physical fitness are often intertwined; however physical fitness is an actual measure of fitness variables like oxygen uptake (VO_2) and can be affected not only by physical activity pattern but also by genetics and environmental factors. Physical activity is virtually a measure of the amount of physical exertion a body is put through during some time period (Caspersen et al., 1985). The subjects of Myers et al. (2004), a sample group of 6,213 men, were put through a standardized exercise test to determine physical fitness status. A sub-group of 842 subjects also had an evaluation of current and past activity patterns. While the physical activity pattern correlation observed between activity and mortality reduction was weaker than that of physical fitness measured by exercise tests correlation to mortality reduction, there was still evidence of mortality reduction measuring activity levels alone (Myers et al., 2004). This study also showed that being relatively inactive was associated with higher mortality risk regardless of physical fitness level. Results were comparable to other studies that had much larger subject pools (Paffenbarger and Hyde, 1986; Blair et al., 1989). Myers et al. (2004) demonstrated that, in men, a 1000 kilocalorie (kcal) per week increase in activity conferred a 20% survival benefit, concurrent with larger cohort studies' findings (Paffenbarger and Hyde, 1984;

Blair et al., 1989). Myers et al. (2004) did acknowledge limitations, one being that women were not included in the study. However, previous data have shown that the relationship between physical fitness or activity and mortality are similar between men and women (United States health and human services, 1996; Haskell et al., 2007). The other major drawback of the Myers et al. (2004) study was that physical activity pattern data was based on subject recollection which could include bias or differences in reporting detail. Nevertheless, this study established that low energy expenditure and low physical fitness may indicate higher mortality risk even precluding other well established risk factors.

Dose-response relationship

Physical activity is a proven way to reduce risk factors of disease. In conjunction with this research on reduction of risk factors, there has been ample evidence provided of an inverse dose-response relation between volume of physical activity and all-cause mortality rates (Paffenbarger and Hyde, 1986; Ekelund and Haskell, 1988; Blair et al., 1989; Slattery et al., 1989). Evidence from studies including both men and women indicate that the risk of dying during a measured period of time decreased as physical activity increased. One of 44 similar studies (Blair et al., 1989) observed 10,244 men and 3,120 women over 19 yr of age and estimated exercise capacity by standardized exercise tests with an average follow up time of 8.1 yr (Blair et al., 1989). Results demonstrated a strong association between physical fitness and mortality due to all cause, cardiovascular disease and cancer. Similar results were observed for both men and women. The dose response relationship remained even after adjustment for age, smoking habits, family history and other risk factors. These data are supported by other studies from analysis of

physical activity (Paffenbarger and Hyde, 1984; LaCroix and Leveille, 1996) as well as cardiorespiratory fitness (Slattery and Jacobs, 1988; Blair et al., 1995). While research provided clear evidence of a need for physical activity in a healthy lifestyle, important components such as type and duration of exercise needed to elicit health benefits were not clearly addressed.

Duration, frequency and intensity of exercise and health benefits

Duration, frequency and intensity of exercise required to elicit health benefits have peaked researchers interest due to sedentary lifestyles and problems with adherence to specific exercise recommendations. Originally, it was assumed that no health benefits could be achieved without at least moderate intensity exercise for 30 min, 3 to 5 times per week as per the American College of Sports Medicine (ACSM) recommendation (Haskell et al., 2007). Moderate intensity has been defined as 3 to 6 metabolic equivalents of task (MET), greater than $31\text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and approximately 3.5 to 7 kcal/min (Warburton et al., 2006). King et al. (1995) looked at the differences between moderate and high intensity exercise and found that the moderate intensity exercise was enough to elicit a response. More recently, investigators have been looking not only at intensity but also at duration and frequency of exercise to determine the most acceptable exercise recommendation for health improvements of American citizens.

In a review article, Wenger and Bell (1986) looked at the interaction between frequency, duration and intensity and found, in most studies, that intensity was a very important component of the training effects seen on the cardiovascular system. As intensity increased, so did the improvements in $\text{VO}_2 \text{ MAX}$, a key component in measuring

cardiovascular improvement. Intensity appears to be a pivotal factor in increasing VO_2 MAX (Wenger and Bell, 1986). In the studies reviewed, frequency as low as 2 times per wk elicited improvements in participants with low beginning fitness levels but as VO_2 MAX approached $50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, 4 times/wk is needed to produce gains in cardiovascular health and strength. Duration was the third key component when observing cardiovascular response with exercise. Longer duration work elicits higher responses but improvements in VO_2 MAX are the same for 15 to 25 min durations vs. 25 to 30 min; however at 35-min duration or above, more improvements are observed. The authors concluded that improvements can be observed across all durations from 15 to 45 min but longer durations seem to elicit more benefits (Wenger and Bell, 1986).

Duration of exercise, as well as accumulation of exercise over a specific time period became a topic of interest due to low adherence to strenuous exercise protocols (King et al., 1988). Murphy and Nevill (2002) used a 6-wk brisk walking program for fitness and a cross over design with 21 sedentary men and women. One group walked for 30 min continuously and the other walked for 10 min, 3 times/d. Both groups performed at 70 to 80% of predicted maximum heart rate (HR_{MAX}), 5 d/wk. Both groups experienced health benefits and data indicated that 10-min bouts of exercise were at least as effective in increasing cardio fitness and lipid profiles as the 30 min standard. This was supported by Woolf-May (1999) who found that aerobic fitness changes were similar in three brisk walking regimens including two that were accumulated exercise vs a single session. This study was over an 18-wk period and the accumulation was always up to 30 min per exercise per day. Murtagh (2005) evaluated 20-min walking bouts vs two 10-min walking

bouts 3 times per wk in 32 subjects over a 12-wk exercise program. The subjects completed standardized exercise test on the treadmill and had other health parameters measured. They found that the brisk walking protocol of 20 min was too small to elicit proper changes in cardiovascular or other parameters in previously sedentary adults less than 60 yrs of age. Similar to a previously mentioned study, ample size in the study was limited. The authors also did not indicate if the subject's heart rate levels were controlled during the brisk walking. The intensity of exercise is a key component in the efficacy of producing health benefits (Wenger and Bell, 1986) and may be the reason for contradicting results in these walking studies. Overall, even though there is contradictory research pertaining to health benefits, there is ample evidence to show that both, continuous or accumulated exercise, produce some improvement in cardiovascular fitness (Murphy et al., 2009).

An analysis of the benefit of walking or strenuous exercise for health of 73,743 older females was done observationally through questionnaire (Manson and Greenland, 2002). Post-menopausal women in the Women's Health Initiative were asked questions on physical activity type, duration and intensity. Additionally, permission to review health records was obtained and the evidence of health incidents that happened in these women over a 5.9 yr follow-up range were requested. Data showed an inverse relation between risk of cardiovascular health issues and baseline physical activity score (presented in MET hr/wk) and similar risk reduction was observed in those walking exercise or those that completed vigorous exercise. Researchers found that women who either walked briskly or exercised vigorously for 2.5 hr or more saw an approximate risk reduction of 30%

(Manson and Greenland, 2002). Results, although observational, indicated that women at both levels of activity demonstrated health benefits and cardiovascular benefits. Results of this one study indicate that traditional exercise programs like running or cycling may not be the only way to maintain a healthy lifestyle and lays the foundation for exploring alternatives.

It is clear that intensity has an effect on the health benefits of an exercising population but the optimal intensity is controversial. Research conducted as part of the Harvard alumni health study (Lee and Paffenbarger, 2000) evaluated the activity levels of 13,485 men. They categorized activity into light (less than 4 MET), moderate (4 to 6 MET) or vigorous (greater than 6 MET). Men who completed moderate and vigorous activities had the largest reduction in cardiovascular disease risks. The men that completed light activity levels had non-significant reductions in risk of cardiovascular disease. This report supported the idea that at least moderate intensity work is needed to elicit a mortality rate reduction in an exercising population. Another investigation on relative intensity of physical activity using the Borg scale (a scale of perceived exertion) and risk of coronary heart disease also concluded that the moderate and more intense activities through perceived exertion provided lowest risk of coronary heart disease (Lee, 2003). These authors recommended that the prescription of physical activity be greater than 3 METs in order to realize significant health benefits.

National recommendations

The American College of Sports Medicine (ACSM) recommends moderate intensity exercise in order to realize health benefits. Research supports the premise of

moderate intensity exercise training to elicit fitness and health in humans. Branch et al. (2000) evaluated premenopausal women with sedentary lifestyles in a 12-wk training program and found that moderate exercise was an acceptable intensity to elicit a cardiorespiratory response. The 18 women included in this study were randomly assigned to moderate exercise at 40% $VO_{2\text{MAX}}$ or vigorous exercise at 80% $VO_{2\text{MAX}}$. The $VO_{2\text{MAX}}$ was shown to improve in both groups with no significant difference between the groups in any of the other post training values measured (Branch et al., 2000). In support of these findings Aisikainen et al. (2002) found that walking at moderate intensity of 45 to 55% of $VO_{2\text{MAX}}$ with a weekly energy expenditure between 1000 and 1500 kcal improves $VO_{2\text{MAX}}$ and body composition of previously sedentary premenopausal women. Swain et al. (2006, reviewed the cardio protective effects of vigorous exercise versus moderate exercise and found that in most cases if energy expenditure was held constant, the vigorous intensity appeared to elicit greater cardiovascular benefit. In yet another observational study, 72,488 female nurses between 40 to 65 yr of age at the beginning of the study were observed in search of an association between walking, vigorous exercise and the prevention of coronary heart disease (Manson et al., 1999). Comparable to other research there was a strong, graded inverse association between physical activity and the risk of coronary events. Manson also indicated that both walking in high quantities over a week and regular vigorous exercise induced substantial and similar reductions in coronary events. There were some limitations to these studies including small sample sizes for some (Branch et al., 2000), as well as possible reporting errors in the observational

portion; nevertheless, the ample evidence supporting moderate intensities' ability to lower disease risk and provide health benefits was strong.

Measuring energy expenditure

Recent technological advances and discoveries have provided more accurate techniques for measuring and, therefore, understanding energy expenditure. With physical activity, the idea of direct calorimetry, a direct measure of heat produced, is not practical or accurate due to changes in body mass, sweat and heat production that may not be accurately assessed (Elia and Livesy, 1992). Indirect calorimetry is the measure of oxygen consumption and has been determined to be a valid and reliable measure of metabolic rate (Brooks et al., 2000). This type of calorimetry has become the most commonly used in exercise physiology because it is easier and more reliable than the direct calorimetry. Subjects exercise by walking or running on an ergometer or treadmill, a stationary laboratory device that allows the subject to be connected to a gas analyzer and data are recorded over time at fixed power outputs. Indirect calorimetry does have its limitations. In order for the oxygen consumption to be an accurate representation of the energy expended, all ATP formed must be from aerobic processes. If ATP is produced from anaerobic processes, then the measure of aerobic function will no longer be an accurate display of the energy expended in a certain subject (Brooks et al., 2000).

Some exercise programs, like that of horseback riding, present another set of challenges. Laboratory testing is almost impossible if you want accurate information about the activity itself. Unlike biking or running, there is no laboratory machine that has been confirmed to mimic the action that a subject must make while riding a horse. There

have been attempts at creating an artificial horse for exercise purposes (Hosaka et al., 2010), but this machine only mimics the walk and trot of the horse and cannot account for all reactive movements of horse or rider that would affect energy expenditure. In order to understand the energy expenditure of horseback riders in field conditions special equipment is needed.

Another common practice for activities such as horseback riding where laboratory testing is difficult is to estimate energy expenditure through VO_2 max tests and HR analysis during activity. Essentially the subject completes a maximal effort test on a treadmill or cycle ergometer. The oxygen consumption and HRs are used to create what is called a HR- VO_2 curve to estimate how much oxygen is being consumed at a certain HR; this is referred to as the calibration procedure (Ruowei et al., 1993). The subject can then complete an activity outside the laboratory with a HR monitor on to estimate energy expenditure. There are some caveats to this technique including time use and the need for individual calibration curves for accuracy. Previous equine activity research has not used this technique directly but has used VO_2 max tests to measure physical fitness (Meyers et al., 1992; Meyers, 2006), as well as compared the VO_2 –HR calibration curve found in horse activity with actual gas collection (Westerling, 1983). The use of these two fitness tests for horseback activity and energy expenditure is called into question in a review by Ruowei et al. (1993). These authors mentioned that the HR assessment of energy expenditure favors good results when the same type of exercise is used to create the calibration HR- VO_2 curves (Ruowei et al., 1993). This note may indicate that VO_2 max

tests done on a treadmill or cycle ergometer may not provide an accurate measure of energy expenditure or physical fitness needed for riding.

The most common equipment used in the past for oxygen consumption in the field is the Douglas bag (Db) technique. The Db technique was developed in the early 1900's as a way to collect exhaled gases in field conditions and to this day is still considered a gold standard in field testing (Shephard, 1955). The Db technique while considered accurate does have some disadvantages that make it less desirable than some of the newer equipment being produced such as the K4b² (Cosmed, Italy). The most important disadvantage is that the Db only provides averages of the gas collected (Carter and Jeunkendrup, 2002). The newer systems are able to complete breath-by-breath analysis instantaneously allowing for more information to be gathered from the same exercise bout. The other major drawback is that the material of the Db could cause gas exchange that is unwanted as well as makes the whole analysis much more time consuming (Shephard, 1955; Carter and Jeunkendrup, 2002). Portable breath by breath systems increase ease as well as function for energy expenditure experiments.

The K4b² (Cosmed, Italy) is just one example of a breath-by-breath respiratory system that is being used today out in the field. The predecessor to this machine, the K2 (Cosmed, Italy), only contained an oxygen analyzer; the K4b² contains both an oxygen and carbon dioxide analyzer. A review of energy expenditure estimations has indicated that having both analyzers may make more accurate assessments of expenditure than having only the oxygen analyzer (Elia and Livesy, 1992). Both have been confirmed to be accurate in energy expenditure (Parr et al., 2001; Maiolo et al., 2003; Duffield et al., 2004).

Several studies have compared the breath-by-breath analyzers such as the K4b² to the Db method and metabolic carts. A study by Parr et al. (2001) found that the ventilation was similar, but that the K4b² significantly underestimated the FEO₂ and overestimated FECO₂ at work rates from rest to 200 W due to the special 70 ml threshold that the K4b² flow meter contains (Parr et al., 2001). The software allows the first 70 ml of each breath to escape from computing expired O₂ concentration. That being said, the software also adjusts for the volume of O₂ and the resulting VO₂ is the same as measured by the Db method. (Parr et al., 2001). Another study performed by McLaughlin et al. (2001) also compared the K4b² to the Db during cycle ergometer. This study also reported that the K4b² measurements were significantly higher at 50,100,150 and 200 W but the differences were small (McLaughlin et al., 2001).

While the Db method is still considered the gold standard for field testing in many eyes, comparisons of portable units to metabolic carts have also become more common for validation of the machines (Hauswirth et al., 1997; Duffield et al., 2004; Schrack et al., 2010). Hauswirth et al. (1997) observed 7 men during a maximal effort cycle ergometer test. This study found no significant difference in Oxygen and measurements between the Cosmed K4b² system and the CPX Medical graphics analyzer (Hauswirth et al., 1997). Duffield et al. (2004) found that when compared to a conventional metabolic cart Cosmed values for VO₂ and VCO₂ were overestimated but showed reliability in a test-retest comparison. Schrack et al. (2010) disagreed with these findings when comparing it to the medgraphics metabolic cart during steady state walking exercise. These findings supported Hauswirth in that there was no significant difference between the values

gathered by the metabolic cart (medgraphics) and that of the Cosmed K4b² system (Schrack et al., 2010). The small sample sizes, difference in types of test and methods used could all be part of the reason differences occurred. Even with these differences, studies have found the Cosmed K4b² to be a reliable and accurate measure of gas and energy expenditure (Hauswirth et al., 1997; McLaughlin et al., 2001; Parr et al., 2001; Maiolo et al., 2003).

Energy expenditure and sport

Most of the articles presented in the debate of the health benefits of fitness have used either cycle ergometer testing (Branch et al., 2000), treadmill testing (Blair et al., 1989; Asikainen et al., 2002; Murtagh et al., 2005) or personal recall of activities (Sesso et al., 2000; Manson and Greenland, 2002). Most of these reports did not comment on other sports or physical activities and the energy expenditure they can contribute to the health of an individual.

Video games have become more activity related in the past decade. With society becoming more influenced by technology and a drastic increase in sedentary lifestyle (Brownson et al., 2005), the video gaming industry has started to become a more active participant gaming experience. Researchers investigated brisk walking in a 10 min walk, 5 min rest pattern for a total of 30 min of walking compared with Nintendo Wii boxing, baseball and tennis in a similar fashion. They showed the MET values for the video games were significantly lower than in the brisk walking activity which has been shown to provide health benefits (Willems and Bond, 2009). Another study of exercise associated with video games by Sell et al. (2008) observed college age males and the video game

Dance Dance Revolution (DDR) to determine if playing DDR for 30 min a day could meet minimum exercise requirements. Experienced DDR players as well as inexperienced DDR players were observed to determine if they could meet energy expenditure requirements. This study, in contradiction with the Nintendo Wii study found that experienced DDR players exhibited exercise of a moderate intensity with mean HR of 161.2 beats per min (bpm) and mean VO_2 of $25.2\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and expended more than 150 kcal in the 30 min exercise which is the recommendation of the ACSM (Sell et al., 2008). Authors concluded that the experienced participants achieved the daily energy expenditure requirements for health benefits while inexperienced participants did not quite achieve the same benefits, most likely due to taking fewer steps/min than experienced players. The small sample sizes in both of these studies limits the true understanding of video games as a form of exercise but shows that activities once seen as sedentary lifestyle contributions can elicit an active and debatably beneficial response.

Bicycle riding or “cycling” is a more conventional form of exercise and has been shown to elicit high energy expenditure, depending on intensity of the cycling and other factors. A study conducted by the Chinese Center for Disease Control and Prevention used a K4b² (Cosmed K4, Italy) indirect calorimeter to measure energy expenditure in many daily activities and found that biking at 12 km/hr, a slow biking pace, would elicit $4.3\text{ kcal}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ also known as 4.2 MET (Liu et al., 2010). Another experiment investigating the metabolic cost of cycling found that cyclists at much higher speeds, 20 to 40km/hr were working at approximately 69% $\text{VO}_{2\text{MAX}}$ which puts them well within the moderate range of exercise. This research also indicated that mechanical power output

and pedal speed were responsible for 99% of variation in metabolic cost of cycling that did not reach lactate threshold (McDaniel et al., 2002). This article goes on to say that pedal speed has an effect on energy expenditure due to its influence over muscle shortening velocity with an ATP being required for every cross bridge cycle (McDaniel et al., 2002). An important portion of energy expenditure in all activity but clearly evident and researched in cycle ergometers is the idea of efficiency. Horowitz (1994) found that a 1.8% difference in gross efficiency could result in a 10% difference in max sustained power in an hour testing situation. This and other research has indicated that an increased efficiency in cycling may lower the energy expended. However, research into the difference in efficiency between elite and recreational cyclists found that there was little difference between recreation and world-class cyclists in metabolic efficiency and therefore would not be an appropriate indicator of success in elite cycling (Moseley and Achten, 2004).

Rowing, another non weight bearing activity, has also been studied for metabolic cost. Rowing uses large muscle groups such as the quadriceps femoris as well as many of the core muscles surrounding the spinal column and pelvic region (Hagerman et al., 1988). A study of energy expenditure in simulated rowing, also known as a rowing ergometer found that the average energy cost for 310 oarsman in a 6 min maximum effort test in simulated rowing was 221.5 kcal (Hagerman et al., 1978). These authors assumed that 70% of total energy was coming from aerobic and the remaining 30% from anaerobic. A comparison of rowing and cycling has led to some discrepancies in energy cost with some experiments indicating cycling elicits more of a metabolic cost and others indicating that

rowing elicits a higher metabolic cost. Hagerman et al (1988) found that in both untrained men and women who completed incremental cycling and rowing tests that HR, VO_2 and other expenditure variables were all higher in the rowing tests. Ventilation and heart rate ranged in cycling from 20 to 90 breaths per minute (btps) and 90 to 150 bpm. The VE and HR were higher on both counts for rowing ranging from 30 to 120 btps and 110 to 170 bpm. Due to previous research, the authors of this study indicated that the increase in energy cost was probably from greater muscle mass usage as well as unfamiliarity with the rowing movements. One of the reasons their results differ may be due to the use of inexperienced rowers indicating much like in cycling research mechanical efficiency may affect the metabolic cost of the activity.

Rugby an international sport known for its aerobic components and physical collisions, requires strength and endurance training in order to be successful. The average velocity of players was measured at 4.9-5.9 km/h the equivalent of walking for most players and the game was described as an intermittent sport with work to rest ratio ranging from 1:28-1:7 (Meir et al., 2001). Coutts et al. (2003) estimated energy expenditure of 15 rugby players the VO_2 HR curve created on a treadmill was used to predict energy expenditure. The mean overall oxygen consumption was $47.1 \pm 3.4 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ with an average relative exercise intensity of $81.1 \pm 5.8\%$ of VO_2 . The author reported energy expenditure of 7.9 MJ of energy expenditure during a rugby match. This is roughly 13.4 METs, well above what would be considered moderate exercise.

Soccer also requires strength and endurance training in order to be successful due to the long match times and distance traveled over that time. The ACSM indicates that

the range of METs for soccer varies from 7 during a casual game to 10 during a competitive one. A study by Rodriguez and Iglesias (1990) observed soccer players, both elite and amateur with a portable telemetric system and found that the relative VO_2 was 43-69% of $\text{VO}_{2\text{MAX}}$ for all players combined. This was lower than previously measured and predicted values for soccer players as was the energy expenditure of 11.5 kcal/min. Notably lower than the energy expenditure observed from rugby research. However, this decrease may be due to predictions based on HR- VO_2 regression overestimating the energy expenditure when compared to telemetric systems.

Energy expenditure and horseback activity

Horseback activity has evolved from being a necessary mode of transportation to mostly a leisure activity. Even though it is no longer a necessity, an estimated 30 million people are involved in some form of riding annually (American Horse Council, 1997). Even with this large sector of the population participating there is little information on horseback riding as a form of healthy exercise. The few experiments conducted have reported on body composition, lipids and other blood markers as well as the cardiorespiratory fitness indications such as HR and VO_2 .

Body composition

In a study looking at the exercise performance of collegiate rodeo athletes the lipid profile and body fat investigation was found to be in normal ranges. The average body fat percentage among athletes competing in rough stock, steer wrestling, roping and barrel racing was around 12%. Rough stock participants had the lowest with body fat percentage of $9.4 \pm 1.4\%$ and the male steer wrestlers had the largest of $17.7 \pm 2.6\%$ which has been

attributed to the fact that larger body mass is desirable in their discipline (Meyers et al., 1992). The body fat percentage observed in collegiate equestrian athletes was an average of $24.5 \pm 6.0\%$ with a range of 16-34% (Meyers and Sterling, 2000). These numbers were higher than reported in aerobic sports such as distance running and swimmers but similar to field hockey, softball and rodeo and still in norms for female populations (Meyers and Sterling, 2000). Roberts et al. (2009) reported a mean body fat percentage of $21.7 \pm 1.9\%$ with 16 female collegiate eventing riders. Another study of collegiate athletes during a 14-wk riding exercise program reported body composition pre and post the training regimen. At baseline, the average body fat percentage was $25.1 \pm 1.1\%$ and post the 14-wk training regimen the body fat percentage was $23.5 \pm 0.9\%$ and that Fat free mass was 47.6 ± 1.8 kg to 49 ± 1.6 kg (Meyers, 2006). Both of these changes, even though non-significant, indicate that equitation training may have an effect on body composition over time.

Blood chemistry

In the blood chemistry of the rodeo competitors reported by Meyers et al. (1992) triglyceride, cholesterol, high density lipoproteins (HDL) as well as total cholesterol to HDL ratio, an indicator of coronary heart disease risk were measured. In female barrel racers, the HDL mean of 52.0 ± 3.7 mg/dl and the total cholesterol of 154.8 ± 14.7 mg/dl were considered lower than women in distance running or weight lifting but the triglyceride concentration was higher. However, all of the numbers were considered in normal ranges for women (Meyers et al., 1992). In males, HDL ranged from 34.8 ± 6.4 mg/dl in steer wrestlers to 38.1 ± 3.7 mg/dl in rough stock riders and the total cholesterol ranged on average from 141.5 ± 25.5 mg/dl in steer wrestlers to 155.7 ± 14.7 mg/dl in

rough stock riders. Total cholesterol: HDL ratio was in the 3 to 4 range across all groups, indicating a low risk for coronary heart disease in the population (Meyers et al., 1992).

Meyers and Sterling (2000) also investigated the blood chemistry of collegiate equestrian competitors measuring triglyceride, cholesterol, HDL and total cholesterol to HDL ratio. The average triglyceride count was 102.5 ± 60.9 mg/dl with a large range of 42 to 261 mg/dl. The cholesterol mean was 187.6 ± 28.0 mg/dl with a range of 135.0 to 219.0 mg/dl. There was an indication of excessive cholesterol, and triglycerides in 21 to 46% of the participants but the total cholesterol HDL ratio ranged from 3.1 to 4.1 indicating an average to low risk of coronary heart disease (Meyers and Sterling, 2000). Another study of collegiate equestrians in a 14-wk exercise program examined the lipid profile and found triglyceride 104.4 ± 18 mg/dl pre training and 101.6 ± 10.5 mg/dl post training, cholesterol at 185.5 ± 7.6 mg/dl pre training and 191.5 ± 7.8 mg/dl post training. The total cholesterol HDL ratio average was 4.0 both pre and post training (Meyers, 2006). A study of walking as exercise over 2yrs noted that time needed for lipid profile improvement may be age dependent, specifically HDL. In the younger population like those evaluated in these studies, it may be take 6 to 12 months to see improvement and in an older population it could take even longer. It was also noted that frequency of exercise seemed to play a role in HDL improvement (King et al., 1995).

Maximal oxygen consumption

The $VO_{2\text{MAX}}$ reached during a treadmill test of rodeo athletes was similar to those of basketball, water polo and gymnastic athletes with ranges from 47 to 50 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in the men. While these are lower than athletes involved in endurance sports such as

cycling or running, they were still considered to possess above average aerobic capacity (Meyers et al., 1992). In a study of 24 collegiate equestrian females, the average $VO_{2\text{ MAX}}$ during a treadmill test was much lower at $33.9 \pm 4.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ with a range of 25.8 to $41.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Lower $VO_{2\text{ MAX}}$ are expected in females and the authors noted there was a large variation in fitness levels of the equestrian riders present in the study. The numbers were comparable to the rodeo athletes and were considered average for female standards (Meyers and Sterling, 2000).

Westerling et al. (1983) opted to a max cycle ergometer test instead of a treadmill test on 16 riders (13 experienced riders and 3 elite, national team riders). The 13 experienced riders reached $VO_{2\text{ MAX}}$ average of $43.8 \pm 4.0 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. The three elite riders had $VO_{2\text{ MAX}}$ of 48, 58 and $57 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ indicating higher fitness levels of the elite level riders. Myers et al. (2006) in a 14-wk equitation exercise program for 15 collegiate equestrian, used a Bruce protocol max treadmill test to determine maximal oxygen consumption. The equestrians were compared pre and post 14-wk exercise programs and had average $VO_{2\text{ MAX}}$ pre-training of $33.4 \pm 1.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and a post-training of $35.3 \pm 1.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ this was a non-significant change but may have indicated a possible, minimal improvement in fitness among the subjects. The authors noted that this non-significant improvement was greater than that seen in 6 months of commuter cycling (Hendriksen and Zuiderveld, 2000) but lower than other exercise regimens (McArdle et al., 2010).

Heart rate

Rincon and Turco (1992) evaluated the metabolic effort of jumping by recording HR of both the rider and the horse over a total of 12 obstacles. They found the HR of the riders during and post competition fluctuated from 150 bpm to almost 200 bpm at max and fell to around 125 bpm. It was not clear when the test actually began and ended in the charts of HR but authors did mention the actual jumping test lasted approximately 1min with 15 min of HR data taken. They observed HR greater than 90% of maximal pulse rate indicating an increased energy expenditure during jumping. Von Lewinski et al. (2013) reported on effects of dressage performances including high level dressage movements known as airs above the ground in both a rehearsal and performance with a crowd. HR was measured before, during the 7 min performance and after the performance. HR ranged from approximately 91 ± 10 bpm to 150 ± 15 bpm in the public performance which were the higher heart rates recorded. The authors concluded that some of the HR increase recorded in the public performance was due to stress response, indicated by HR variability and cortisol levels in the riders, compared with the rehearsal data.

Westerling (1983) evaluated the metabolic effort of riders at the walk, trot rising, trot sitting and canter. In the walk the mean HR of the experienced riders was 108 ± 13 bpm, the elite riders had a range of 70-110 bpm. At the trot rising the 13 experienced riders had an average of 163 ± 19 bpm. At the trot sitting the experienced riders experienced heart rates average of 170 ± 15 bpm and canter was 172 ± 18 bpm. The authors concluded the reason for higher HR in sitting trot compared to rising trot was most likely due to a larger share of static muscle contraction with this style of riding.

A study similar to the present study exploring higher intensity equine activities of show jumping and cross country in a one day event setting recorded HR and VO_2 of female collegiate riders (Roberts et al., 2009). This study demonstrated a correlation between assumed intensity level and HR, with dressage being the least intense and cross country being the most intense. Mean values for dressage, show jumping and cross country were 157 ± 15 bpm, 180 ± 11 bpm and 184 ± 11 bpm respectively. This study found that there was a significant difference between the metabolic demands of each phase of the sport of eventing and also reported that there was a large variability between riders completing the same simulated competition (Roberts et al., 2009).

Oxygen consumption

In the study of experienced and elite dressage and show jumpers (Westerling, 1983) oxygen consumption was also measured during the last 2 min of each part of the test. The average oxygen consumption for walk for the experienced riders was $9.4 \pm 1.4 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, trot rising $27.7 \pm 3.3 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, trot sitting $28 \pm 4.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and canter $30.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Each different riding style was ridden for 5 min total with rest in between each section. Oxygen consumption estimates observed in canter indicated a use of between 60-90% of maximal aerobic effort well within the range for aerobic conditioning.

Roberts et al. (2009) also explored oxygen consumption of the event riders. The trend observed with HR, increasing with each phase of the one day event, was also seen in apparent oxygen consumption data. The mean relative oxygen consumptions for dressage, showjumping and cross country were $20.4 \pm 4.0 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, $28.1 \pm 4.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$

$^1 \cdot \text{min}^{-1}$, and $31.2 \pm 6.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ respectively. The authors estimated that during the cross country phase the riders were reaching up to 90% of their VO_2max . While these are promising results for horseback riding as a sport, the VO_2 max in this case was only estimated and may not be a good estimate of relative metabolic effort. However, unlike the Westerling study, the oxygen consumption and carbon dioxide output was measured by metamax3B (MMX3B 1.0, Leipzig, Germany) which is another form of a breath by breath analyzer which may have provided more accurate gas measurements. These studies, indicate that at the exercise intensities reported, horseback riding may in fact have metabolic efforts equivalent to health benefiting exercise.

CHAPTER III

MATERIALS AND METHODS

Subjects

Twenty participants, three males and seventeen females completed riding protocols and dual-energy x-ray absorptiometry (DEXA) scans. The participants were current horseback riders with known experience in the events of reining or cutting. Riders were asked to complete a questionnaire defining their experience and exercise habits as well as submit to a DEXA scan for physiological characteristics. The DEXA scan was completed at the Texas A&M University Applied Exercise Science Laboratory (447 Tom Chandler Rd). A trained technician completed the scan and the results were analyzed for body composition.

Treatments

All subjects performed each of the three riding tests. The three tests were a walk-trot-canter ride (WTC), a reining pattern (reining) and a cow work simulation using a mechanical flag (cutting). The WTC test was completed over 45 min with walk, trot, long trot and canter completed over 18, 12, 10 and 5 min respectively. The trot portion was described as a leisurely jog for the horse and the riders sat this pace. During the long trot portion the rider was asked to push the horse into a faster, longer more impulsive trot, the rider was asked to post this pace. Reining test consisted of running National Reining Horse Association (NRHA) Pattern #5. This pattern contained fast, large and small, slow canter circles, a figure 8 with flying lead changes, roll backs both directions and a sliding stop at the end. The mean time for participants was 4.9 ± 0.68 min for this test. The Cutting test

was a simulation of a cutting class with three distinct “cows” being worked over 2 min 10 sec. The mechanical “cow” was a ProCutter Model 1801 (provided by Show Pro Industries, Springtown, TX). The cutting simulation was provided by working a pre-recorded routine designed to simulate an actual event where 3 total cows were worked with short periods of walking between the cows. The horse rider combination was asked to follow a flag along a fence line and halt between movements of the flag to simulate separating another cow from the herd.

Parameters of interest

During each of the three trials, different parameters concerning oxygen consumption and cardiovascular fitness were collected using a Cosmed K4b² (Cosmed, Italy). The parameters observed and measured in this study were heart rate (HR) in beats per minute (bpm), oxygen uptake (VO₂) in ml/m, carbon dioxide exhalation (VCO₂) in ml/min, respiratory frequency (RF) in breaths per minute, ventilation (VE) in liters/min (l/min), Ventilation in liters per minute (l/min), VO₂ per Kg (VO₂/Kg) expressed in ml·min⁻¹·kg⁻¹, and average energy expenditure per hour (EEh) expressed as kcal/hr. Energy expenditure was calculated by the Cosmed K4b² software (Cosmed, Italy) using the Weir equation (Schrack et al., 2010).

Equipment assembly

The operator arrived 1.5 hr prior to subject testing time. The K4b² was turned on and allowed a 45 min warm up time prior to calibrating and subject testing.

The mask and flow meter were assembled by plugging a sanitized turbine into the mask adapter by pushing and rotating clockwise. The optoelectronic reader was then placed

over the turbine and attached to the mask. The wind cover was applied over the flow meter and the sampling line placed in the optoelectronic reader hole designated for the sampling line. The turbine cable was then attached to the control panel of the K4b² portable unit (PU).

Calibration

Three calibration tests were completed prior to each subject test. The first calibration was for the turbine. The calibration syringe, a 3000 ml syringe is attached to the optoelectronic reader. With the PU attached to the computer the option “calibration” was chosen from the main screen and “turbine calibration” was selected. The syringe was operated by pulling and pushing the plunger, the display showed expired and inspired readings for the strokes of the syringe. When “calibration done” appeared the operator checked for inaccurate readings and the turbine was calibrated. If discrepancies were detected, sampling line and the portable unit were checked for problems and the test was run again

Room air calibration required the operator to remove the sampling plug from the flow meter. In the main menu, with the PU still linked to the computer, “calibration menu” was selected and the option “room air calibration” was selected by pressing enter. The display showed O₂ and CO₂ values for room air and a message of “Do not breathe near the sampling line” was displayed until the calibration was over. When “calibration done” appeared; the readings were checked for inaccuracies and the calibration was complete. If discrepancies were detected, sampling line and the PU were checked for problems and the test was run again.

Reference gas calibration required a gas cylinder containing a ratio of 16% O₂ to 5% CO₂. The sampling plug was again removed from the flow meter and calibration menu opened. Within the calibration menu reference gas calibration was chosen. The first part is a room air calibration similar to the Room air calibration sequence, the sampling plug remained open to room air. The display then read “sample reference gas”, the sampling line is plugged into the calibration unit which is the connection of the portable unit and the gas cylinder. At the end of the procedure “calibration done” was displayed and the numbers were checked against reference numbers for discrepancies. If discrepancies were detected, sampling line and the portable unit were checked for problems and the test was run again.

Every 2- wks the operator completed a delay calibration. The calibration menu was again opened and the O₂/CO₂ delay calibration option was selected. A room air calibration occurred first in this calibration sequence, the sampling line was removed from the flow meter until the “connect sampling line and press enter” appeared on the display. The sampling line was connected to the flow meter attached to a testing mask. The operator then pressed enter and began breathing at a constant rate in synch with the beeping the PU emitted. After some cycles the values for the delay calibration appeared and were checked for discrepancies. If discrepancies were detected the sampling line and the portable unit were checked for problems and the test was run again.

Subject preparation

Once the mask and flow meter were assembled and the K4b² unit calibrated for the protocol, the patient was prepared for carrying of the equipment. The heart rate monitor was a belt applied at the thorax region of the subject. The elastic strap of the HR belt was adjusted to fit tightly around the thorax with buckles interlocking on the sides that created a snug but comfortable fit. Once the HR belt was applied underneath the subjects clothing the harness was then put on the subject. The harness allowed both the control unit and the battery back to sit in the upper back region of the subject with the battery rested between the shoulder blades and the control system right below. The harness applied over the subjects head was buckled and tightened to fit snugly and securely. The K4b² unit was then fixed into the designated holders to ensure security of the machine during the ride. The heart rate and temperature probe cable as well as the GPS receiver were plugged into the PU, the HR and temperature probe to the HR-Temp probe on PU and the GPS cable applied to the RS232 port on the bottom of the PU. The Settings were changed in “External device” to GPS to initialize GPS for the test.

The mask and head cap were then applied to the subjects face. The subject was asked to hold the mask over the nose and mouth while the tester applied the head gear by snapping the 4 elastic bands to their holders found on either side of the mask. The mask and head gear was applied so that there was a strap above and below the ear on each side. The elastic bands of the head cap were adjusted to create a tight seal around the subjects face without causing discomfort. The subjects riding helmet was applied over top of the head gear and adjusted for safety and comfort.

Telemetric and test procedures

After calibration and subject preparation was concluded the software was prepped for telemetric data transmission. The receiver unit for telemetry was connected to the recording computer (PC) with a serial cable. In the control panel of the K4b² transmission was enabled by choosing “transmitter ON” in the “settings” menu. The asterisk was moved to “transmit on” and press enter. On the PU control panel the operator entered the patient’s data by going to the “test” menu and choosing “patient’s data”. The values were modified to match the subject’s individual data including ID, age, height, weight, sex and predicted HR max which is calculated automatically based on age. The computer software was opened on the PC and a patient data dialog box was selected. The patient data for the subject was opened in the software and “Start test” on the PC was chosen. Once the test was started on the PC, the sampling line was unplugged from the mask and “start test” was selected from the “test” menu on the PU control panel. The relative humidity from a portable weather station was entered for “humidity” and enter was pressed. A room air calibration began, the sampling line remained unplugged and away from expired air until “calibration done” appeared on screen. The sampling plug was then connected to the optoelectronic reader in the mask and enter was pressed to allow a check of parameters such as HR or VO₂. The enter key was pressed again to begin storing of data. The operator checked to confirm that all parameters of interest were displaying in the breath by breath display on the PC including GPS parameters.

The subject was then mounted on the horse. The operator selected the exercise button on the main screen of the PC software to indicate that exercise started, as well as

allow GPS speed and distance to begin being collected and displayed. The first 7 min of the test the subject was asked to walk the horse around the arena tracking left, at time 7 min the subject was asked to move their horse into a working trot. A mark was placed in the data on the PC by pressing “Marker” on the main screen”. The line of data appeared red to indicate the placement of a marker. At 13 min, (6 min working trot) the subject was asked to move their horse into a more extended or “long” trot. Another mark was placed in the data to indicate the change in pace. At 18 min, (5 min of long trot) the subject was instructed to bring the horse up to canter, a marker was placed in the data to indicate the change of pace. At 20.5 min the horse was transitioned to the walk (2.5 min canter), another marker was placed in the data to indicate the change in gait. The rider completed 2 min of walk still tracking left and then changed directions at the command of the experimenter. Two minutes of walk were completed tracking right (4 min walk) and then at 24.5 min the subject was asked to transition the horse to working trot. A marker was placed in the data. The subject was instructed to long trot at 30.5 min (6 min working trot), and a mark in the data was placed. At min 35.5 the subject was instructed to canter the horse (5 min long trot), another mark was placed. The subject was instructed to transition the horse to the walk at 38 min (2.5 min canter); a marker was placed in the data. The subject was monitored for another 7 min at walk and a mark was placed at 45 min to indicate end of working period. The test was ended by pressing cancel and then enter on the PU.

The horse and subject were rested in a walk phase for 25 min. No data were collected during this time period. The subject then proceeded on to trial B.

The same process as Trial A was followed to begin Trial B. The rider's data set was opened in the software and "Start test" on the PC is chosen. Once the test was started on the PC, the sampling line was unplugged from the mask and start test was selected from the "test menu" on the PU control panel. The relative humidity from a portable weather station (enter company) was entered for "humidity" and enter was pressed. A room air calibration began, the sampling line remained unplugged and away from expired air until "calibration done" appeared on screen. The sampling plug was then connected to the optoelectronic reader in the mask and enter was pressed to allow a check of parameters such as HR or VO₂. The enter key was pressed again to begin storing data. The operator checked to confirm that all parameters of interest were displaying in the breath by breath display on the PC including GPS latitude and altitude. The subject was then asked to complete Pattern #5 of NRHA reining pattern (Fig 1), the exercise button was pressed on the PC to indicate the beginning of the protocol as well as activate speed and distance on the GPS device. The subject began by cantering on the left lead in three complete circles (first two large and fast and the third small and slow). Markers were placed after the 2 fast circles and again after the slow circle. The subject stopped in the center of the arena and completed four spins to the left; a marker was placed after the spins were completed. The subject then began cantering on the right lead and completed three circle (two large and fast and the third small and slow) and stopped after the third circle in the middle of the

arena. Again markers were placed at the end of the two fast circles and the end of the slow small circle. The subject then completed four spins to the right; another marker was placed at the end of the spins. The horse was cantered again on the left lead and a large fast circle to the left with a lead change in the center with a large fast circle to the right with a lead change in the center. A marker was placed at the end of this maneuver. The subject then completed an unclosed circle around the end of the arena with a roll back right at least 20 ft from the wall and then another unclosed circle with a roll back left at least 20 ft from the wall. A marker was placed at the halt prior to the rollback in each direction. The subject then completed another unclosed circle, ran up the right side of the arena and performed a sliding stop, and backed the horse at least 10 ft. A marker was placed to indicate the end of the pattern. The test was then ended by pressing cancel and then enter on the PU. Another 25 min rest period followed Trial B prior to the completion of Trial C.

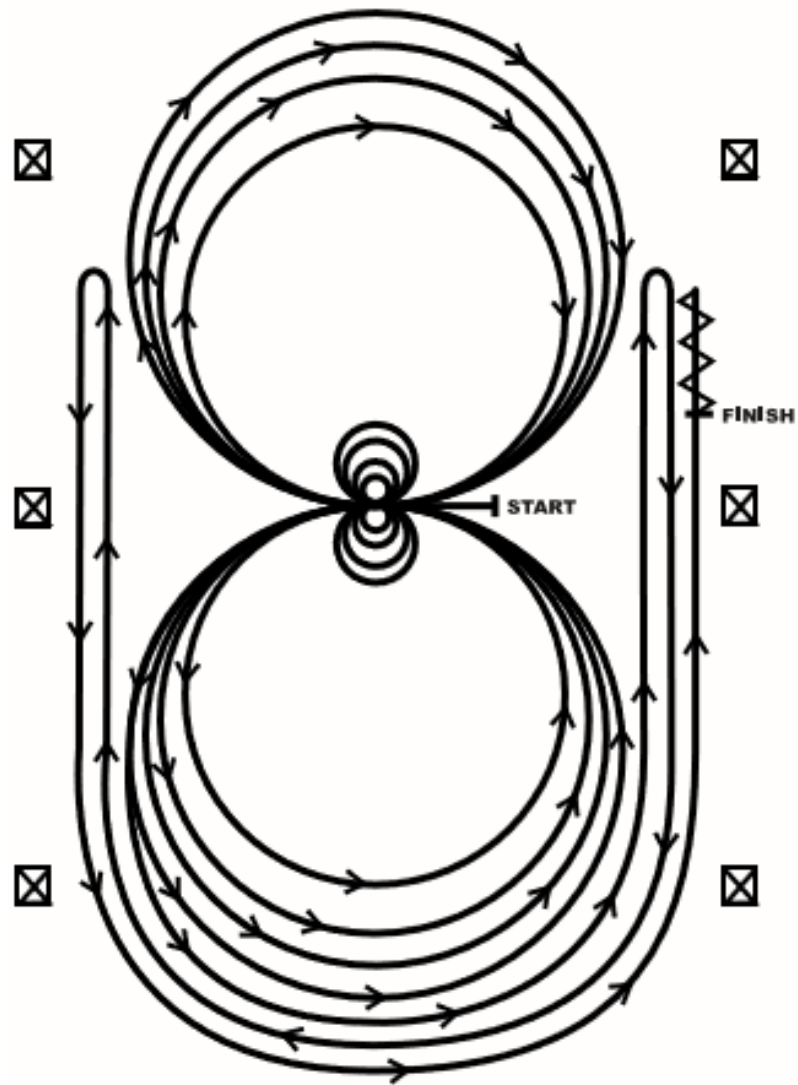


Figure 1: NRHA pattern #5. (National Reining Horse Association, 2013)

The same process as Trial A and B were followed to begin Trial C. The patient data was opened in the software and “Start test” on the PC is chosen. Once the test was started on the PC, the sampling line was unplugged from the mask and start test was selected from the “test” menu on the PU control panel. The relative humidity from a portable weather station was entered into the “humidity” and enter was pressed. A room air calibration began, the sampling line remained unplugged and away from expired air until “calibration done” appeared on screen. The sampling plug was then connected to the optoelectronic reader in the mask and enter was pressed to allow a check of parameters such as HR or VO₂. The enter key was pressed again to begin storing of data. The operator checked to confirm that all parameters of interest were displayed on the PC including GPS latitude and altitude. The subject was then instructed to complete a cow working simulation. The exercise button was pressed and a marker was pushed to indicate the start of the first “herd time” simulation. The subject was instructed to walk the horse around for 30 sec. At 15 sec the subject was instructed to walk up to the flag that was positioned in the middle of the working fence area. A marker was placed at the start of the flag movement. There were 10 changes of direction in the first cow work. Another marker was placed when the flag came back to rest in the center of the working fence. The subject was then instructed to stay facing the flag since the simulated “herd time” was too short for walking. A marker was placed when the flag began moving again, indicating the second simulated cow work. There were 11 changes of direction in the second cow work. A marker was placed when the flag came to rest in the center of the working fence area simulating the second cow was finished. The subject stayed facing the flag again until the

flag moved again to simulate the third cow. There were 8 changes of direction in the last cow simulation. Markers were placed at the beginning of the flag movement as well as the end of the final cow work. The test was ended by pressing cancel and enter on the portable unit. The total time of the cow work simulation was 2 min, 10 sec.

Once all three trials (A, B, C) were completed the subject was dismounted and all equipment removed. The riding portion of the protocol was complete.

Cleaning

After each use the equipment was cleaned and sanitized for the comfort and safety of the participants.

The head cap, Velcro, Harness and HR monitor were all soaked in hot soapy water. All except the HR monitor were soaked for 20 min. The HR monitor was dipped in hot soapy water and then dried with a towel, to prevent water damage to the sensor contained inside. The head cap, Velcro, harness and HR monitor were air dried or towel dried.

The turbine was submerged in a 10% bleach solution for a minimum of 5 min and a maximum of 20 min. The turbine was then removed from the bleach solution and completely submerged in clean water in another container, several times. The turbine was then laid out to air dry. The turbine was considered dry and ready for use when there were no water droplets on the inside.

The masks were sanitized by being submerged in water in a crock pot on low heat for 20 min. The masks were then laid out to air dry.

Statistical analyses

Data were collected by the K4b² system on a breath by breath basis. Due to the massive amount of data produced collections were averaged every 30 sec for WTC and every 5 sec for Reining and Cutting. These data were then used to calculate the total energy expenditure as well as overall peaks and means for the parameters of interest. The peak data were the largest 30 sec averaged collection for WTC and the largest 5 sec averaged collection for reining and cutting. The mean data is the mean of all the averaged sections (30 sec or 5 sec sections for WTC and reining and cutting respectively) for each test. The SAS mixed analysis of variance was used to analyze data (SAS v9.4; SAS Inst. Inc, Cary, NC). Test was considered a fixed effect and rider was random. The rider effect also encompassed the effect of horse due to each rider-horse combination being a complete block. In order to determine significant differences between tests among the parameters measured, least squares means and differences of least squares were evaluated. Statistically significant differences were reported at $P \leq 0.05$.

A second analysis of the data was performed using SAS mixed analysis of variance (SAS v9.4; SAS Inst. Inc, Cary, NC). The same 30 sec means for WTC and 5 sec means for cutting and reining were used but this time only the last 2 minutes of each gait segment were analyzed. Since walk was applied 3 times in the test, the total time analyzed of walk was 6 min with the last two minutes of each segment analyzed. The same process was used for trot, long trot and canter. These means and peaks were then analyzed along with reining and cutting to determine differences among means using least squares means and

differences of least squares means. Statistically significant differences were reported at $P \leq 0.05$.

SAS regression analysis was also used to create regression equations for the energy expenditure of each tests. A backwards regression analysis in SAS was used at $P \leq 0.15$ to determine the best predictor variables for total energy expenditure, as well as peak and average energy expenditure per min and MET. Predictor variables were considered adequate if $P \leq 0.15$. These regressions were run for all participants (n=20) as well as a separate analysis of women participants (n=17). Regression analysis was also performed using weight in kilograms as the only predictor, again for all participants (n=20) and women only (n=17). The predictor and regression equations were considered statistically significant at $P \leq 0.05$ level.

CHAPTER IV

RESULTS*

Physical characteristics

Twenty participants, three males and seventeen females completed the riding protocols and the DEXA scans. On the day of the subjects DEXA scan, anthropometric and body composition measures were made. Mean and range of these characteristics are presented in Table 1. The subjects had little variability around the mean age (22.4 ± 3.4 yrs). There was a large variation among subjects in weight (67.5 ± 15.4 kg), body mass index (BMI), body fat percentage (32.5 ± 7.0) and lean body mass (LBM) (43.2 ± 9.2). While the variability is large, the group mean for BMI (23.7 ± 4.1) is considered in the upper normal range with, normal being 18.5-24 (Manore et al., 2009). The group mean for body fat percentage ($32.5 \pm 7.0\%$) also indicates a population on the edge of healthy to overweight (Manore et al., 2009).

Table 1: Mean (\pm SEM) and range for anthropometric, body composition measurements as well as exercise habits of subjects (n=20)

Measurement	Mean Value	Range
Age, Yr	22.4 ± 3.4	19 – 31
Height, cm	168.1 ± 7.3	157.5 - 185.4
Weight, kg	67.5 ± 15.4	45.8 - 105.7
BMI ^a , wt/ht ²	23.7 ± 4.1	18.3 - 34.4
Body fat, %	32.5 ± 7.0	21.5 - 44.9
Android, % of Body fat	35.2 ± 10.1	16.9 - 52.1
Gynoid, % of Body fat	40.5 ± 6.1	31.6 - 48.7
LBM ^b , kg	43.2 ± 9.2	32.00- 66.5
Exercise Riding, hr/wk	8.1 ± 7.3	1.0 - 30.0
Exercise non-riding, hr/wk	1.6 ± 1.8	0 – 5

^aBMI, body mass index

^bLBM, lean body mass

*Parts of the data in this chapter are reprinted with permission from O'Reilly, C., Sigler, D., Fluckey, J., Vogelsang, M., and J. Sawyer. 2015. Rider energy expenditure during high intensity horse activity and the potential for health benefits. *International Journal of Exercise Science: Conference Proceedings*. Vol. 2: Iss. 7, Article 44.

<http://digitalcommons.wku.edu/ijesab/vol2/iss7/44> by Top Scholar, West Kentucky University.

Test information

Each test cutting, reining, and the walk-trot-canter (WTC) test consisted of different durations of time. WTC test was timed with a stop watch by the tester (45.0 min). The other two tests were less controlled in time elapsed with cutting being the shortest test ($2.10 \pm .15$ min) and reining being in the middle ($4.9 \pm .68$ min).

Energy expenditure

Because of a time difference between tests, there were significant differences for total energy expenditure ($P \leq 0.01$) between all three tests. Cutting (11.14 ± 3.83 Kcal) and reining (33.28 ± 3.85 Kcal) were both lower than WTC (194.72 ± 3.83 Kcal) with cutting having the least energy expenditure overall. The results for total energy expenditure are presented in fig 2.

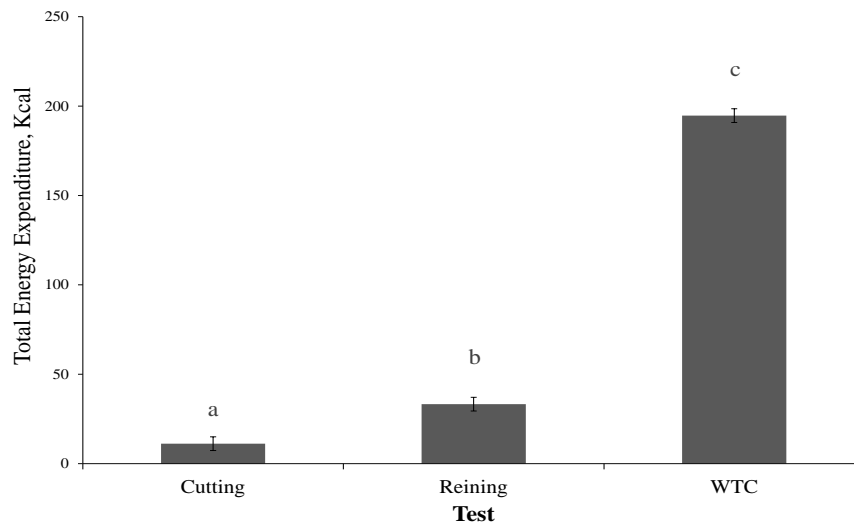


Figure 2 Total energy expenditure in kilocalories (Kcal) for cutting, reining and walk-trot-canter (WTC). ^{abc} Different superscripts indicate a difference ($P \leq 0.05$) in energy expenditure

Intensity of the tests was explored by measuring energy expended per minute and metabolic equivalents of task. Peak and mean energy expended per min are presented in fig 3. There were significant differences ($P \leq 0.05$) among all three tests for mean energy expenditure per minute. Cutting and reining had higher ($P \leq 0.05$) mean energy expended per min (4.97 ± 0.23 kcal/min and 6.96 ± 0.23 kcal/min, respectively) than WTC (4.27 ± 0.23 Kcal/min). However, at peak energy expenditure per minute there was no difference ($P = .25$) between cutting and WTC (7.58 ± 0.38 and 7.99 ± 0.38 kcal/min). Reining peak energy expenditure (10.08 ± 0.38 kcal/min) was higher ($P \leq 0.05$) than both WTC and cutting peak energy expenditure.

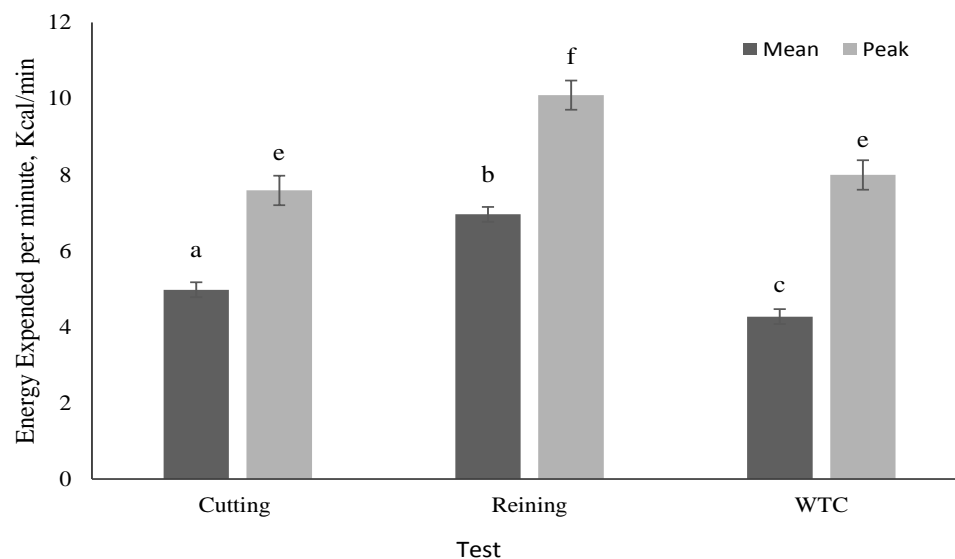


Figure 3: Mean and peak energy expenditure (Kcal/min) for cutting, reining, and walk-trot-canter ride (WTC). ^{abc}Differing subscripts indicate significant ($P \leq 0.05$) differences among mean energy expenditures. ^{ef}Differing subscripts indicate significant ($P \leq 0.05$) differences among peak energy expenditures

The WTC test was split into its various gaits (walk, trot, long trot and canter) and compared to reining and cutting (fig 4). In mean energy expended per min, walk and trot were the lowest (3.04 ± 0.21 Kcal/min and $3.46 \pm .21$ kcal/min). Cutting (4.97 ± 0.21 kcal/min) demonstrated a mean energy expended per min that was higher than walk and trot but lower than long trot (6.19 ± 0.21 kcal/min). There was no difference ($P \leq 0.76$) between the two largest mean energy expended per min, reining and canter (6.95 ± 0.21 Kcal/min and 6.90 ± 0.21 Kcal/min). The peak energy expenditure per minute was different among the measured gaits and tests. Trot and reining had the lowest and highest energy expenditure per min measured ($P \leq 0.05$) (4.20 ± 0.33 kcal/min and 10.08 ± 0.33 kcal/min respectively). There was no difference ($P \leq 0.74$) between walk peak energy expenditure per min (7.01 ± 0.33 kcal/min) and cutting and long trot peak energy expenditure per min (7.58 ± 0.33 kcal/min and 7.48 ± 0.33 kcal/min). There was also no difference ($P \leq 0.74$) between long trot, cutting and canter peak energy expenditure per min (7.79 ± 0.33 kcal/min).

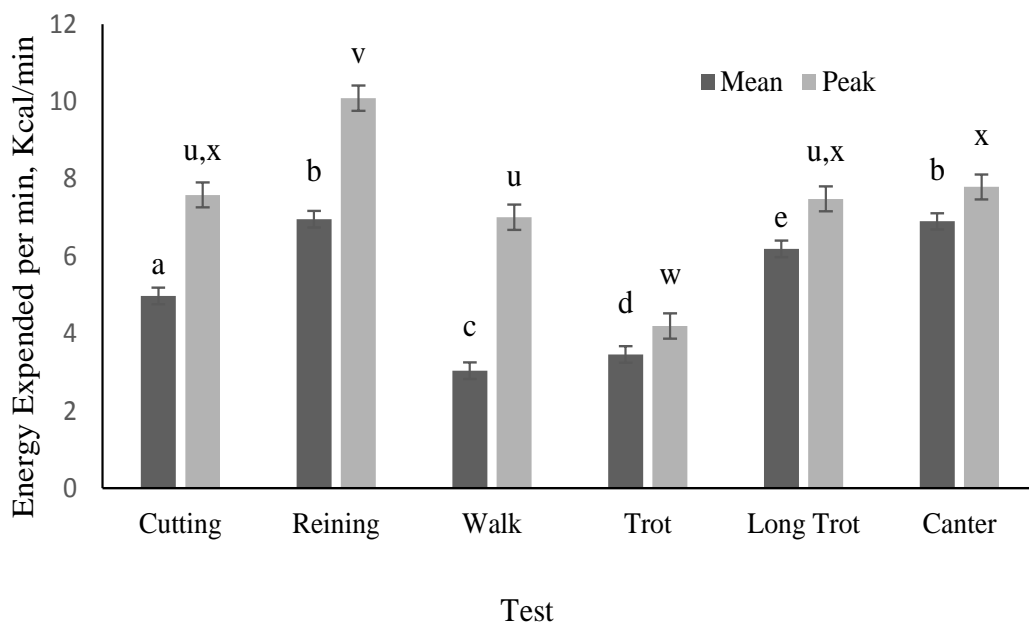


Figure 4: Mean and peak energy expended per min in kilocalories per min (Kcal/min) during cutting, reining, and the gaits walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean energy expended per min. ^{uvwxy} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak energy expended per min.

Peak and mean energy expended per minute of reining, cutting and the last 2 min of each gait were also explored (fig 5). In mean energy expended per min, walk was the lowest (2.34 ± 0.22 kcal/min) and energy expenditure got larger with increases in gaits. There was no difference between long trot, canter and reining mean energy expenditure ($P \leq 0.91$). Cutting energy expenditure per min was lower ($P \leq 0.05$) than long trot, canter and reining mean energy expenditure per min but was higher than both walk and trot. Walk also was the lowest in peak energy expended per minute (2.92 ± 0.31 kcal/min). Again intensity of the work progressed through the gaits with long trot and canter being the largest peak energy expenditure of the gaits (7.46 ± 0.31 kcal/min and 7.69 ± 0.31

kcal/min, respectively). There was no significant difference between long trot, canter and cutting peak energy expenditure ($P \leq 0.74$). Peak energy expenditure of reining remained the highest (10.08 ± 0.31 kcal/min).

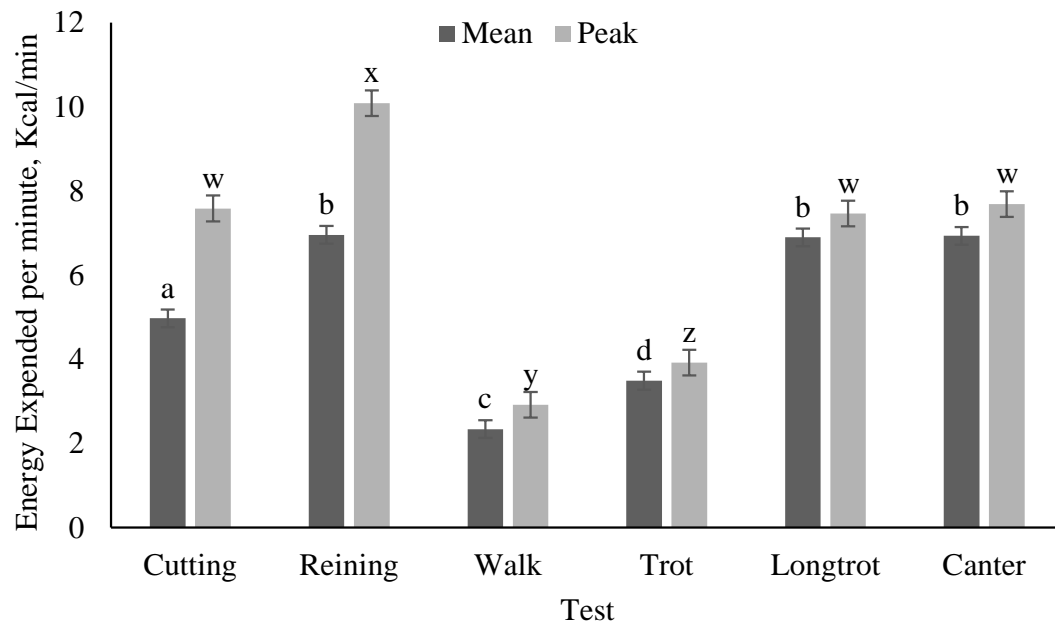


Figure 5 Mean and peak energy expenditure (kcal/min) of cutting, reining and the last 2 min of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean energy expended per min. ^{wxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak energy expended per min.

The same pattern was seen in metabolic equivalents of task (MET) (figure 6). There were significant differences among all three tests for mean MET. Cutting and reining had higher ($P \leq 0.05$) mean MET measurements (4.53 ± 0.16 MET and 6.12 ± 0.16 MET) than WTC (3.81 ± 0.16 MET). Again at peak MET there was no differences

($P=0.62$) observed between cutting and WTC (6.97 ± 0.29 MET and 7.12 ± 0.29 MET).

Reining peak MET (8.92 ± 0.29) was higher ($P \leq 0.05$) than both WTC and cutting.

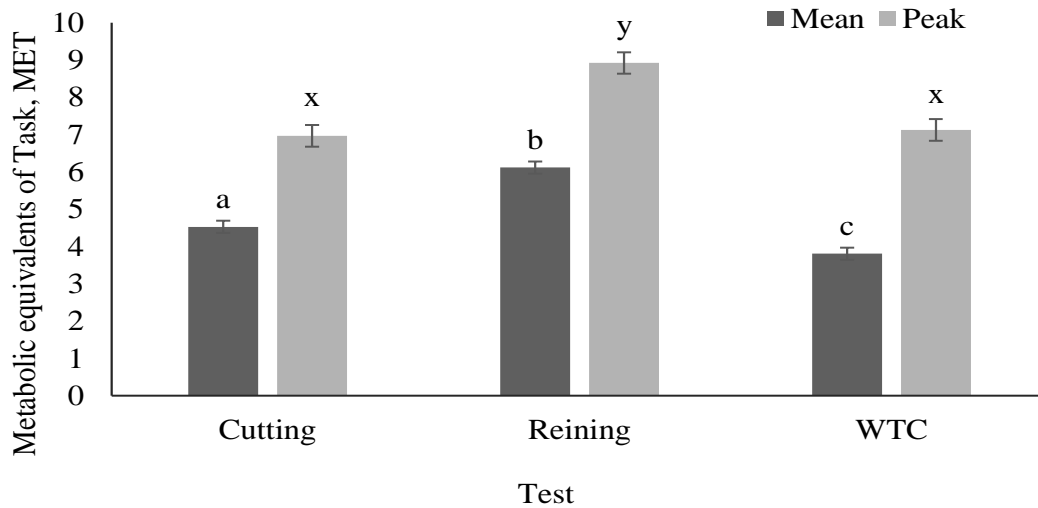


Figure 6: Mean and peak metabolic equivalents of task (MET) for cutting, reining, and walk-trot-canter ride (WTC). ^{abc}Differing subscripts indicate significant differences ($P \leq 0.05$) among mean MET. ^{xy}Differing subscripts indicate significant differences ($P \leq 0.05$) among peak MET.

Reining, cutting and the last two minutes of walk, trot, long trot and canter were analyzed for mean and peak METs (fig 7). In mean MET the same trends as energy expended per min were observed. There was no difference ($P \leq 0.76$) between reining, long trot and canter (6.12 ± 0.21 , 6.19 ± 0.21 , and 5.96 ± 0.21 MET). Mean MET of cutting (4.53 ± 0.21 MET) was lower ($P \leq 0.05$) than reining, long trot and canter but was higher than walk and trot (2.01 ± 0.21 , and 3.15 ± 0.21 MET). Walk was the lowest ($P \leq 0.05$) peak MET (2.55 ± 0.27 MET), with trot being the second lowest (3.53 ± 0.27 MET). There was no difference ($P \leq 0.05$) between cutting, canter and long trot peak MET

(6.97 ± 0.27 , 6.61 ± 0.27 , and 6.68 ± 0.27 MET respectively). Reining was the highest Peak MET (8.92 ± 0.27 MET).

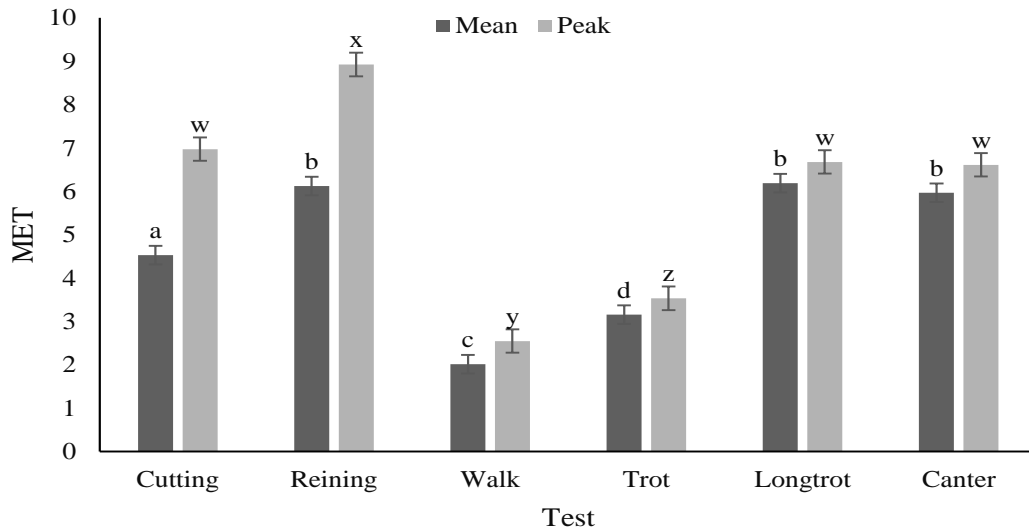


Figure 7 Mean and peak MET for cutting, reining and the last two min of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean MET. ^{wxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak MET.

Heart rate

Mean and peak HR measurements are displayed in figure 8. Mean HR was significantly different for all tests with WTC having lowest HR and reining the highest HR (131.51 ± 4.15 bpm and 163.28 ± 4.15 bpm). There was a significant difference ($P \leq 0.05$) among peak HR measurements for the three tests. However while reining peak HR was higher (179.15 ± 3.92 bpm) than the other two tests, as with the mean HR, cutting

peak HR (156.50 ± 3.92 bpm) was lower ($P < .0001$) than WTC peak HR (168.55 ± 3.92 bpm).

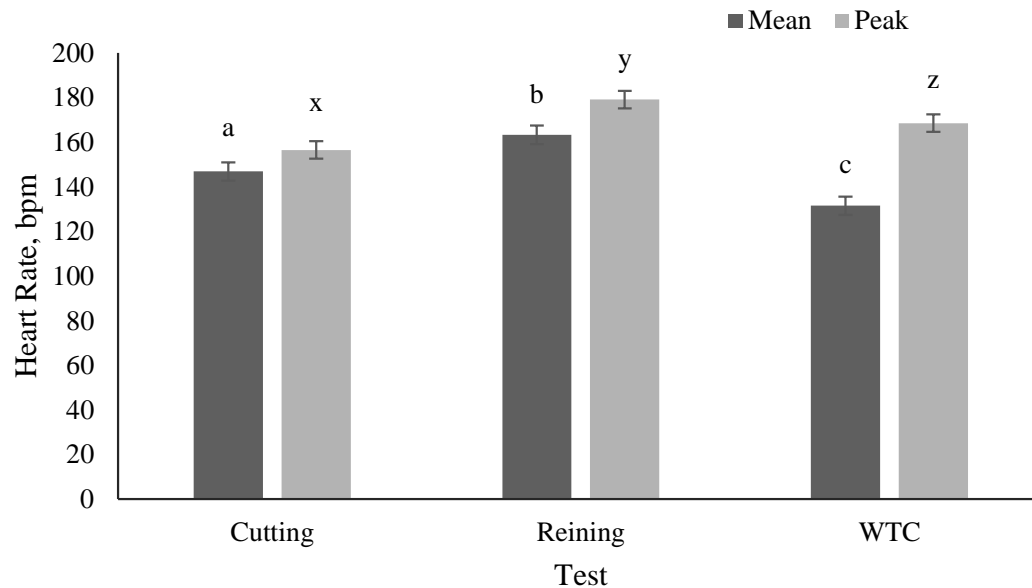


Figure 8: Mean and peak heart rate in beats per min (bpm) for cutting, reining and WTC. ^{abc}Differing superscripts indicate significance difference ($P \leq 0.05$) among mean heart rates of test. ^{xyz}Differing superscripts indicate significant differences ($P \leq 0.05$) among peak heart rates of test.

When the WTC test was split by gaits (fig 9) there was no difference ($P=0.78$) in mean HR between long trot and cutting (146.21 ± 4.29 bpm and 146.88 ± 4.29 bpm). Walk and trot mean HRs were lower than the remaining tests (120.58 ± 4.29 bpm and 125.54 ± 4.29 bpm) and reining remained the highest HR (163.28 ± 4.29 bpm). Canter was lower ($P \leq 0.05$) than reining but higher than the rest of the tests measured for average HR. Trot had the lowest observed peak HR and reining remained the highest HR (141.00

± 4.43 bpm and 179.15 ± 4.43 bpm). There was no significant difference ($P=0.92$) between walk and long trot peak HR (160.50 ± 4.43 bpm and 160.20 ± 4.43 bpm). There was also no difference of peak HRs ($P \leq 0.26$) between canter (165.60 ± 4.43 bpm), walk and long trot; or cutting (156.50 ± 4.43 bpm), walk and long trot. There was however, a difference ($P \leq 0.05$) between canter and cutting with canter having a slightly higher peak HR than cutting.

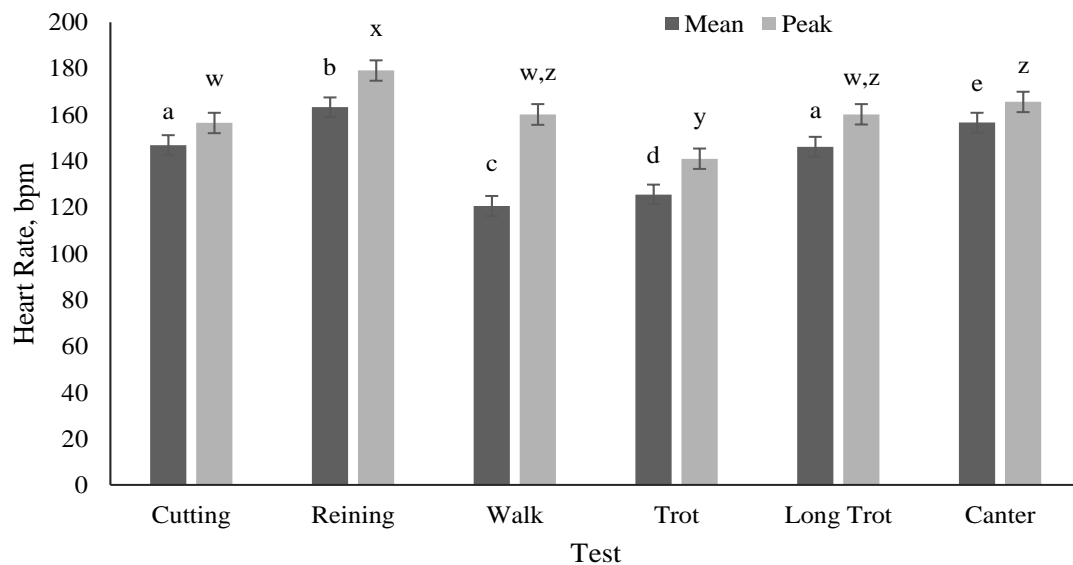


Figure 9: Mean and peak heart rate in beats per min (bpm) for cutting, reining, walk, trot, long trot and canter. ^{abcde}Differing superscripts indicate significant differences ($P \leq 0.05$) of mean heart rates. ^{wxyz}Differing superscripts indicate significant differences ($P \leq 0.05$) of peak heart rates.

Mean and peak heart rate of cutting, reining, and the last two min of walk, trot, long trot and canter are presented in figure 10. Walk was the lowest ($P \leq 0.05$) mean HR (114.95 ± 4.4 bpm). The last two minutes of each gait increased in HR as gait increased with no significant difference ($P=0.08$) detected between long trot and canter mean HR

(152.14 ± 4.4 and 156.89 ± 4.4 bpm). There was also no difference between cutting and long trot ($P=0.06$). Reining mean HR was higher ($P \leq 0.05$) than all other tests (163.28 ± 4.4 bpm).

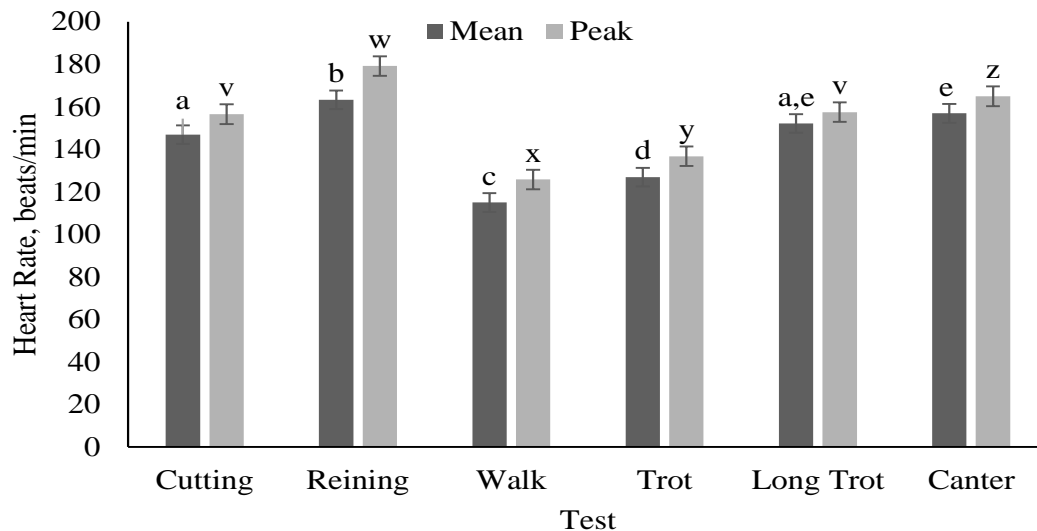


Figure 10 Mean and peak heart rate for cutting, reining and the last two minutes of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean heart rates. ^{vwxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among heart rates.

Reining also contained the largest ($P \leq 0.05$) peak HR (179.15 ± 4.63 bpm). The peak HR of the gaits increased with an increase in gait, with walk (125.75 ± 4.63 bpm) being the lowest and canter being the highest (164.95 ± 4.63 bpm). There was no difference ($P=0.78$) between long trot and cutting (157.45 ± 4.63 and 164.95 ± 4.63 bpm).

Gas analyses

Oxygen uptake, carbon dioxide production and relative oxygen uptake (relVO_2), oxygen uptake per kg ($\text{ml O}_2 \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$) were all measured on a breath by breath basis throughout the tests. Mean and peak measurements of all three were analyzed.

Peak and mean relative oxygen consumption among the three tests are presented in fig 11. There were significant differences ($P \leq 0.05$) among all three tests. Reining had the highest mean relVO_2 ($21.27 \pm 0.59 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), with cutting quite lower ($15.65 \pm 0.59 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and WTC having the lowest mean relVO_2 ($13.12 \pm 0.59 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). There was no difference ($P = .58$) found between peak relative VO_2 for cutting and WTC ($24.07 \pm 1.03 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $24.67 \pm 1.03 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). Reining had a higher peak relVO_2 ($P \leq 0.05$) than the other two tests ($30.83 \pm 1.03 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$).

With WTC split by gait (fig 12), there was no difference ($P = 0.10$) between walk and trot relVO_2 , the two lowest mean relative VO_2 ($9.23 \pm 0.72 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $10.75 \pm 0.72 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). There was also no difference ($P = 0.98$) between mean relVO_2 for reining ($21.17 \pm 0.72 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and canter ($21.19 \pm 0.72 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$).

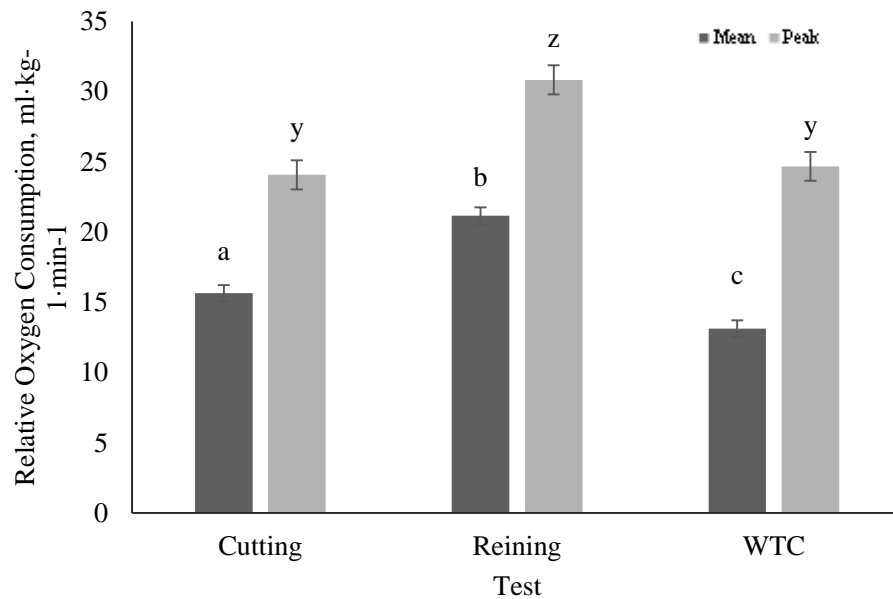


Figure 11: Mean and peak relative oxygen consumption (RelVO₂), ml·kg⁻¹·min⁻¹. ^{abc}Differing superscripts indicate significant differences (P≤0.05) among mean relVO₂. ^{yz}Differing superscripts indicate significant differences (P≤0.05) among peak relVO₂.

Cutting had a higher mean relVO₂ (7.10 ± 0.35 ml·kg⁻¹·min⁻¹) than walk and trot (P≤0.05) but was lower than the faster gaits of long trot and canter as well as reining. At peak relVO₂, there was no difference (P=0.06) between walk and long trot relVO₂ (21.38 ± 1.16 ml·kg⁻¹·min⁻¹ and 23.18 ± 1.16 ml·kg⁻¹·min⁻¹). There was also difference (P≤0.37) between peak relVO₂ for long trot, cutting and canter (24.07 ± 1.16 ml·kg⁻¹·min⁻¹ and 24.03 ± 1.16 ml·kg⁻¹·min⁻¹). Trot presented lower (P≤0.05) peak relVO₂ than all the other tests (13.15 ± 1.16 ml·kg⁻¹·min⁻¹) and reining peak relVO₂ was higher (P≤0.05) than all the rest of the tests (29.14 ± 1.16 ml·kg⁻¹·min⁻¹).

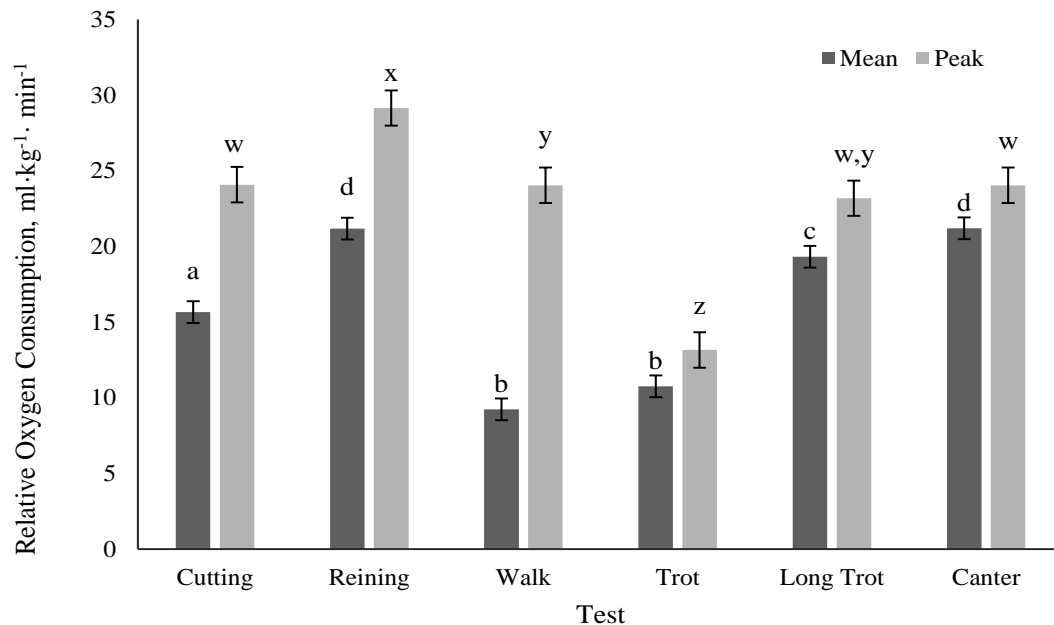


Figure 12: Mean and peak relative oxygen consumption (relVO₂) for cutting, reining, walk, trot, long trot and canter. ^{abcd} Differing superscripts indicate significant differences ($P \leq 0.05$) among mean relVO₂. ^{wxyz} Differing superscripts indicate significant differences ($P \leq 0.05$) among peak relVO₂.

Mean and Peak relVO₂ of reining, cutting, and the last two minutes of walk, trot, long trot and canter are presented in figure 13. Walk and trot were the lowest ($P \leq 0.05$) mean relVO₂ ($7.22 \pm 0.70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $10.87 \pm 0.70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) with walk being the lowest. There was no difference ($P = 0.91$) between the two faster gaits of long trot and canter mean relVO₂ ($21.38 \pm 0.70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $21.3 \pm 0.70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). There was also no difference ($P \leq 0.91$) between long trot, canter and reining mean relVO₂. Cutting mean relVO₂ ($15.65 \pm 0.70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) was larger than both walk and trot but lower than the three remaining tests ($P \leq 0.05$). Reining peak relVO₂ ($30.83 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) was higher than all other tests ($P \leq 0.05$). Walk and trot were the lowest peak relVO₂ ($8.80 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $12.22 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) with walk being lower ($P \leq 0.05$) than all

other tests. There was no significant differences ($P \leq 0.61$) amongst long trot, canter and cutting ($23.09 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, $23.60 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, and $24.07 \pm 0.89 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ respectively).

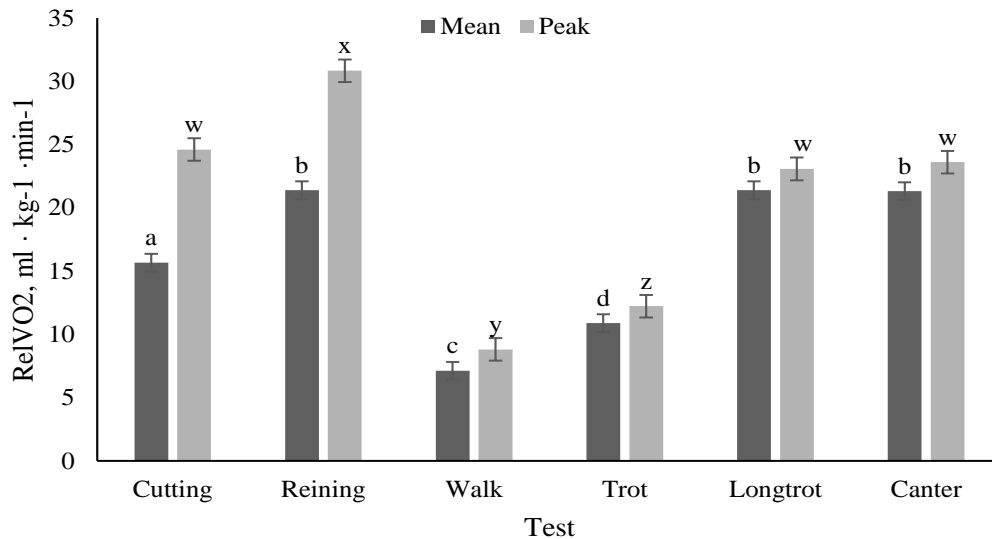


Figure 13 Mean and peak relative oxygen consumption (RelVO₂), ml · kg⁻¹ · min⁻¹ for cutting, reining, and the last two minutes of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean RelVO₂. ^{wxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak RelVO₂.

Mean and Peak oxygen consumption (VO₂) for cutting, reining and WTC are presented in figure 14. There was a significant difference ($P \leq 0.05$) among all three tests for mean VO₂, with reining having the highest mean VO₂ ($1405.68 \pm 47.52 \text{ ml/min}$), and cutting mean VO₂ ($1043.19 \pm 47.52 \text{ ml/min}$) also being higher than WTC mean VO₂ ($865.94 \pm 47.52 \text{ ml/min}$). Reining VO₂ ($2054.23 \pm 79.30 \text{ ml/min}$) remained higher ($P \leq 0.05$) than the other two tests in peak measurements of VO₂ but there was no

significant difference ($P=0.85$) between cutting and WTC peak VO_2 (1606.55 ± 79.30 ml/min and 1620.22 ± 79.30 ml/min).

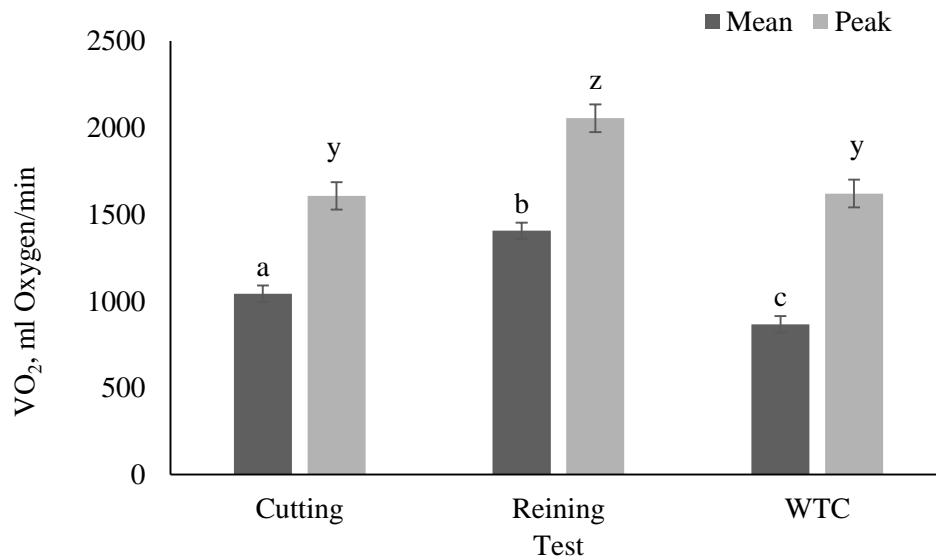


Figure 14: Oxygen uptake (VO_2), ml O_2 /min for cutting, reining and walk-trot-canter (WTC). ^{abc}Differing subscripts indicate significant differences among mean VO_2 . ^{yz}Differing subscripts indicate significant differences among Peak VO_2 .

WTC split into gaits, (Fig 15), there was no difference among mean VO_2 of walk and trot ($P=0.08$). There was no difference ($P=.24$) between mean VO_2 of reining (1335.91 ± 52.58 ml/min) and long trot (1273.81 ± 52.58 ml/min) as well as reining and canter mean VO_2 ($P=0.27$). Cutting had a higher ($P\leq 0.05$) mean VO_2 than walk and trot but was lower than both long trot and canter VO_2 . Reining had a higher peak VO_2 ($P\leq 0.05$) than all other tests (1954.4 ± 78.86 ml/min). There was no difference ($P\leq 0.57$) between cutting, canter and long trot peak VO_2 . There was also no difference ($p=0.17$)

between long trot and walk peak VO₂. Trot had the lowest peak VO₂ (859.91 ± 78.86 ml/min)

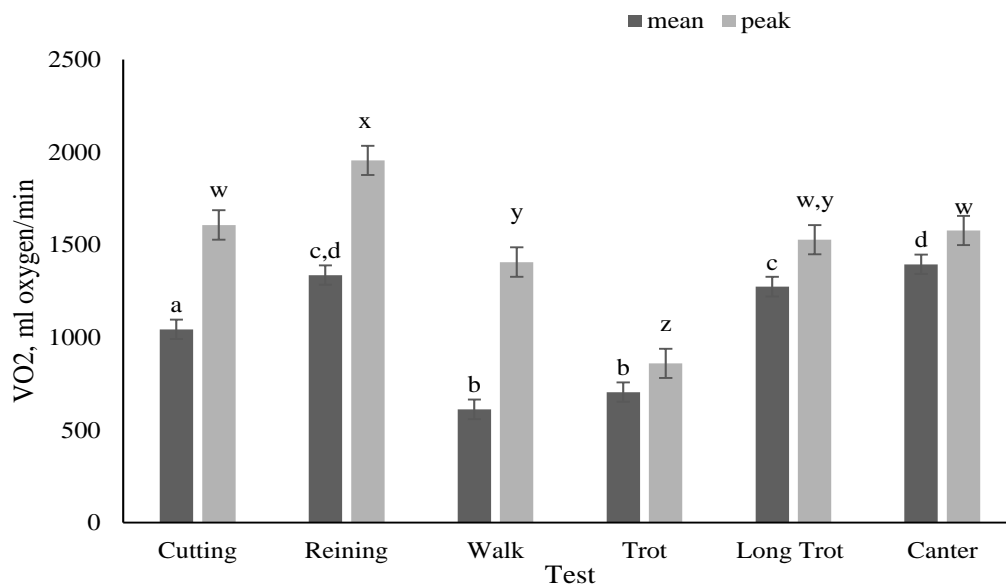


Figure 15: Mean and peak oxygen uptake (VO₂), ml O₂/min, for cutting, reining, walk, trot, long trot, and canter. ^{abcd}Differing superscripts indicates a significant difference among mean VO₂ ^{wxyz}Differing superscripts indicate a significant difference among peak VO₂

Mean and peak oxygen uptake (VO₂) of cutting, reining, and the last two minutes of walk, trot, long trot and canter are presented in figure 16. Walk and trot were again the lowest (P≤0.05) mean oxygen consumption (472.43 ± 45.54 and 712.37 ± 45.54 ml/min) with walk mean oxygen consumption being the lowest of all the tests. There was no difference (P≤0.94) between long trot, canter or reining mean VO₂. Cutting mean VO₂ (1043.19 ± 45.54 ml/min) was higher than walk and trot but lower than long trot, canter and reining mean VO₂. Reining had the highest (P≤0.05) peak VO₂ (2054.23 ± 62.68

ml/min). There was no difference ($P \leq 0.64$) between peak VO_2 of cutting, long trot and canter (1606.55 ± 62.68 , 1519.22 ± 62.68 and 1548.94 ± 62.68 ml/min respectively). Cutting, long trot and canter were all higher ($P \leq 0.05$) than the two other gaits of walk (579.92 ± 62.68 ml/min) and trot (801.81 ± 62.68 ml/min)

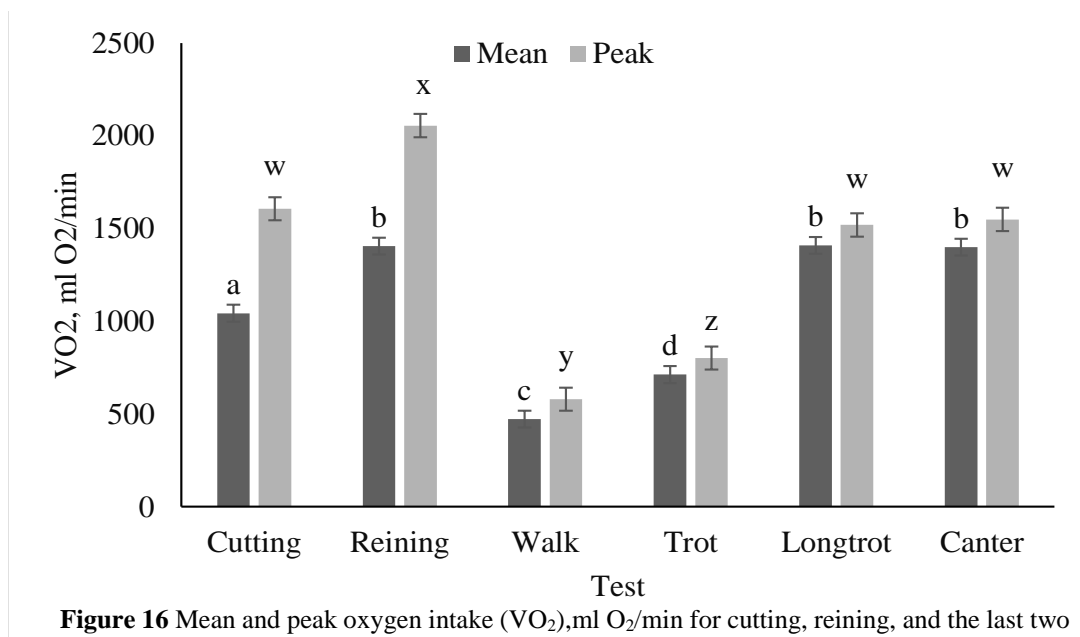


Figure 16 Mean and peak oxygen intake (VO_2), ml O₂/min for cutting, reining, and the last two min of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean VO_2 . ^{wxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak VO_2 .

The mean and peak respiratory exchange ratio (RER) for cutting, reining and WTC test are presented in figure 17. Cutting had the lowest mean RER (0.8131 ± 0.014) with no significant difference detected ($P \leq 0.05$) between reining and WTC mean RER (0.9482 ± 0.014 , and 0.9266 ± 0.014). Peak RER followed the same trend with cutting being the lowest ratio (0.9917 ± 0.028) with no significant difference ($P \leq 0.05$) detected between peak RER of reining and WTC (1.1139 ± 0.028 and 1.145 ± 0.028).

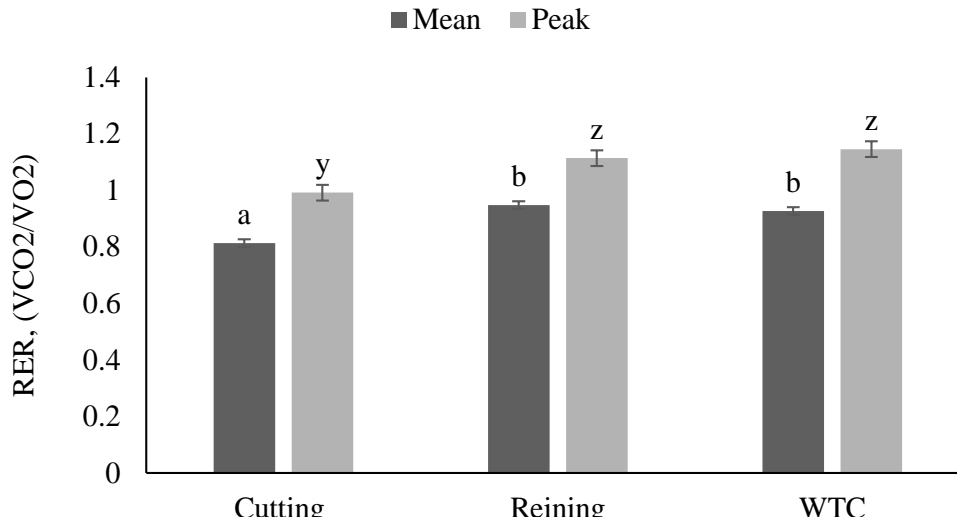


Figure 17 Mean and peak respiratory exchange ratio (RER), VCO_2/VO_2 for cutting, reining and walk-trot-canter (WTC). ^{ab}Differing superscripts indicate significant differences ($P \leq 0.05$) among mean RER. ^{yz} Differing superscripts indicate significant difference ($P \leq 0.05$) among peak RER.

Mean and peak respiratory exchange ratio (RER) for cutting, reining, and the last two minute of walk, trot, long trot and canter are featured in fig 18. Cutting had the lowest measured mean RER (0.8131 ± 0.0138). Reining, walk and canter had no significant difference ($P \leq 0.05$) and were the highest (0.9482 ± 0.014 , 0.9487 ± 0.014 , and 0.9522 ± 0.014 respectively). There was no significant difference ($P \leq 0.05$) between trot and long trot (0.8971 ± 0.014 and 0.9091 ± 0.014), which were higher than cutting but lower than the rest of the tests. There was no significant difference ($P \leq 0.05$) in the two highest peak RER measurements of reining and walk (1.1139 ± 0.022 and 1.0916 ± 0.022). There was no significant difference ($P \leq 0.05$) between trot, long trot and cutting peak RER measurements (0.9506 ± 0.022 , 0.9485 ± 0.022 and 0.9917 ± 0.022 respectively).

Reining (1.1139 ± 0.022) and cutting also had no statistical difference and were lower than that of reining and walk.

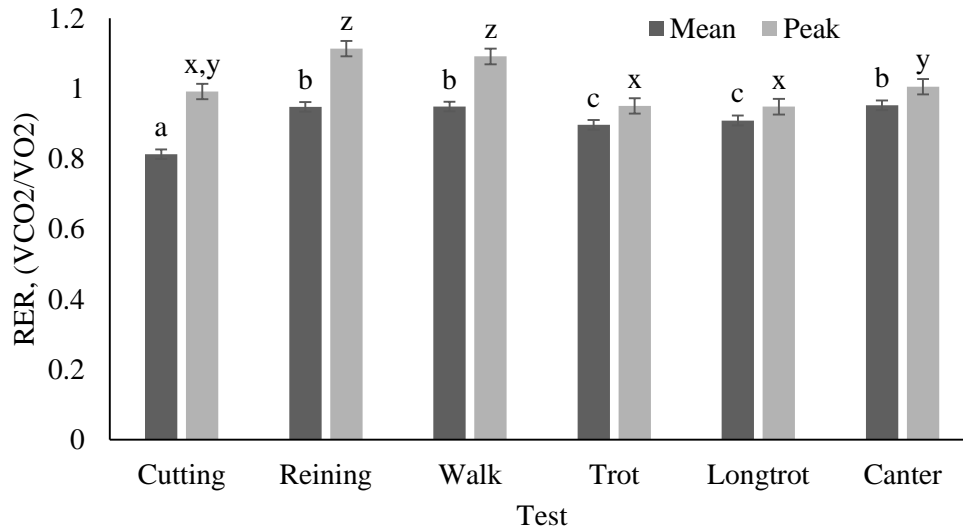


Figure 18 Mean and peak respiratory exchange ratio (RER) VCO_2/VO_2 for cutting, reining, and the last two min of walk, trot, long trot and canter. ^{abc} Differing superscripts indicate significant differences ($P \leq 0.05$) of mean RER. ^{xyz} Differing superscripts indicate significant differences ($P \leq 0.05$) of peak RER.

Pulmonary ventilation and respiratory frequency

Mean and peak respiratory frequency for cutting, reining and WTC are presented in fig 19. There was a significant difference ($P \leq 0.05$) among all three tests with mean RF. Reining had the highest mean RF (42.09 ± 1.56 breaths/min), with cutting having a slightly lower RF (38.85 ± 1.56 breaths/min), and WTC RF measuring lowest (29.66 ± 1.56 breaths/min). There was no significant difference ($P = 0.07$) between reining and cutting peak RF (59.77 ± 2.66 breaths/min and 55.52 ± 2.66 breaths/min). Peak RF of WTC remained lower ($P \leq 0.0019$) than the other two tests (47.95 ± 2.66 breaths/min).

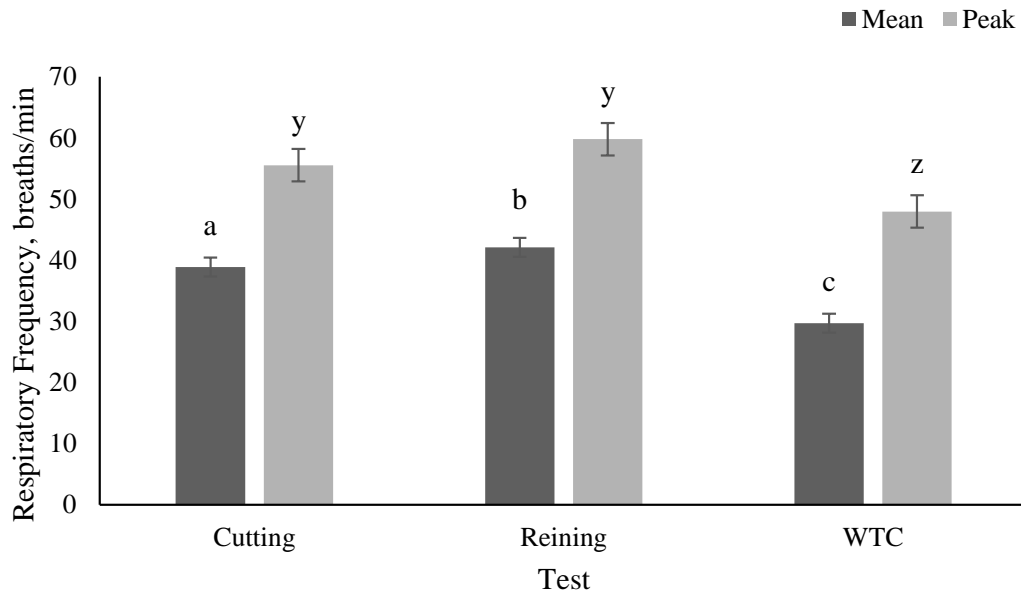


Figure 19: Mean and peak respiratory frequency (RF) in breaths per minute for cutting, reining and walk-trot-canter (WTC). ^{abc}Differing superscripts indicate significant differences ($P \leq 0.05$) among mean RF. ^{yz} Differing superscripts indicate significant difference ($P \leq 0.05$) among peak RF.

Figure 20 presents the mean and peak respiratory frequencies with WTC split by gait. Walk, trot and long trot, lowest to highest mean RF respectively, were lower than the three remaining tests (24.51 ± 1.63 breaths/min, 29.92 ± 1.63 breaths/min and 33.33 ± 1.63 breaths/min). There was no difference ($P=0.1018$) between canter mean RF (40.65 ± 1.63 breaths/min) and cutting mean RF (38.85 ± 1.63 breaths/min) or canter and reining ($P = .19$) (42.09 ± 1.63 breaths/min) mean RF. However reining did have a significantly higher ($P \leq 0.05$) mean RF than cutting. Unlike with mean RF there was no difference ($P=0.064$) between reining and cutting peak RF (59.77 ± 2.43 breaths/min and 55.53 ± 2.43 breaths/min) but were higher than the WTC gaits peak RF. There was also no difference ($P \leq 0.44$) between peak RF of walk and canter (42.29 ± 2.43 breaths/min

and 45.90 ± 2.43 breaths/min); or walk, trot and long trot peak RF (42.29 ± 2.43 breaths/min, 38.19 ± 2.43 breaths/min and 40.54 ± 2.43 breaths/min). All WTC gaits, walk, trot, long trot and canter peak RF, were different and lower ($P \leq 0.05$) than reining and cutting peak RF and only canter mean RF was not significantly lower ($P \leq 0.05$) than reining and cutting mean RF..

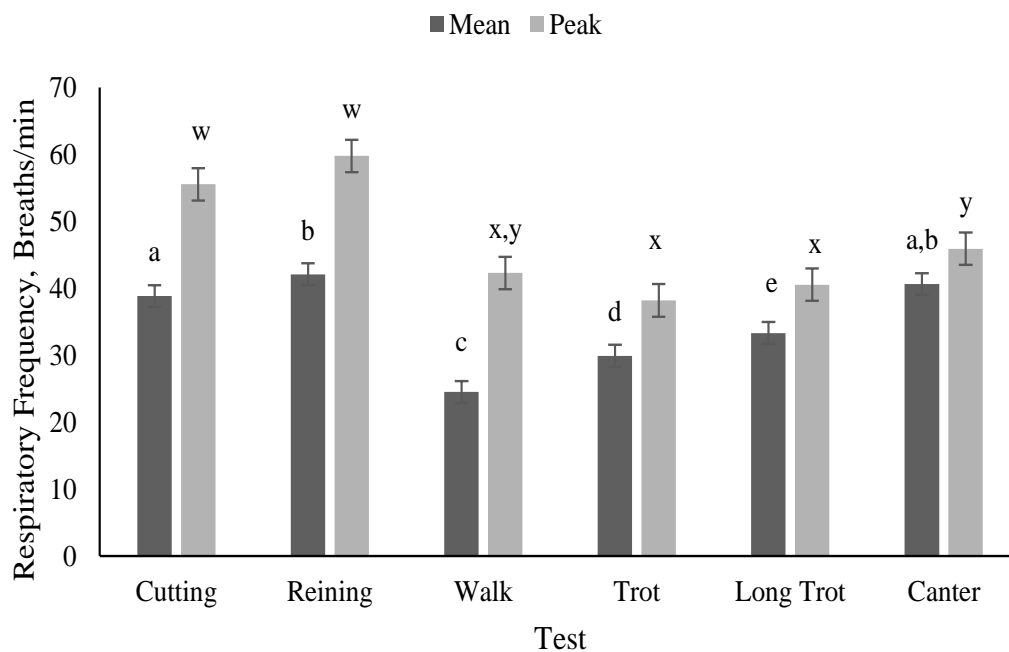


Figure 20 Mean and peak respiratory frequency, breaths/min for cutting, reining, walk, trot, long trot and canter. ^{abcd} Differing superscripts indicate significant differences ($P \leq 0.05$) of mean respiratory frequencies. ^{wxy} Differing superscripts indicate significant differences ($P \leq 0.05$) of peak respiratory frequencies.

Mean and peak respiratory frequencies (RF) of cutting, reining and the last two minutes of walk, trot, long trot and canter are presented in fig 21. Walk mean RF was the lowest of all the tests (22.9 ± 1.71 breaths/min). The mean RF of the gaits increased as

the gait increased with from walk, the lowest, trot, long trot and finally canter the highest ($P \leq 0.05$) mean RF. There was no difference ($P = 0.64$) between reining and canter mean RF (42.1 ± 1.71 breaths/min and 41.5 ± 1.71 breaths per min), which were also the highest mean RF. There was no difference ($P = 0.06$) between cutting and reining peak RF and they were higher than all the other tests peak RF. Walk had the lowest peak RF (27.32 ± 2.7 breath/min). Canter (45.76 ± 2.7 breaths/min) was the highest of the 4 gaits (walk, trot, long trot and canter) but was lower than both cutting and reining ($P \leq 0.05$). There was no difference between trot and long trot ($P = 0.62$).

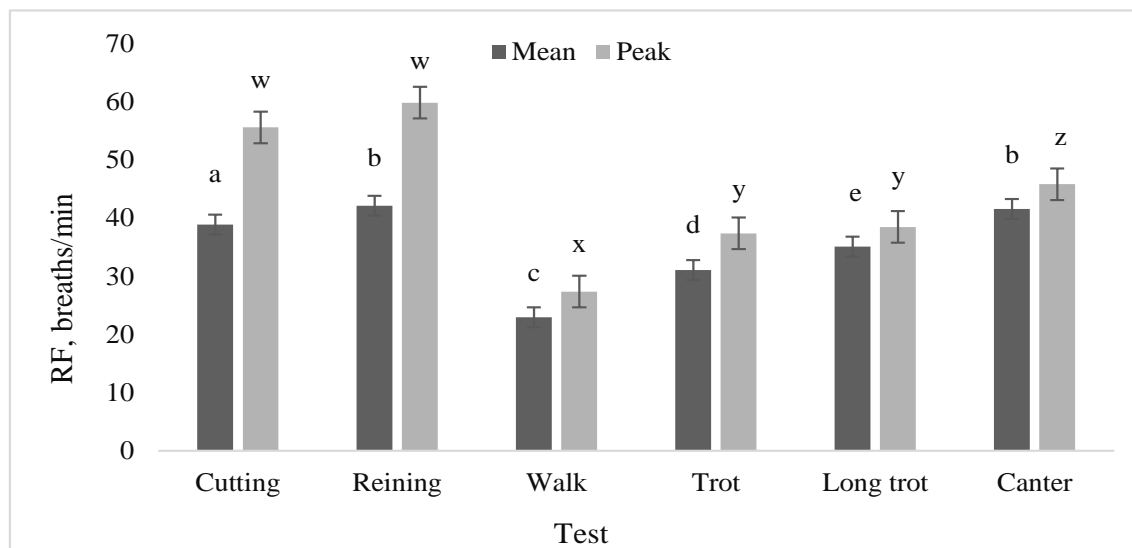


Figure 21 Mean and peak respiratory frequency (RF) in breaths/min for cutting, reining, and the last two minutes of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean RF. ^{uvwxyz} Differing subscripts indicate significant differences ($P \leq 0.05$) among peak RF.

Mean and peak pulmonary ventilation (VE) are presented in fig 22. Reining (49.14 ± 1.85 l/min) showed significantly greater mean VE than both the cutting and WTC tests

(32.11 ± 1.85 l/min and 28.69 ± 1.85 l/min). There was no difference ($P=0.06$) between the cutting and WTC mean pulmonary VE. When observing peak VE reached in each test, there were differences among all three riding tests. Reining peak pulmonary VE was larger ($P \leq 0.05$) than both the other tests (66.56 ± 2.33 l/min). WTC (52.56 ± 2.33 l/min) had larger peak VE rates than the cutting test peak pulmonary ventilation (44.04 ± 2.33 l/min).

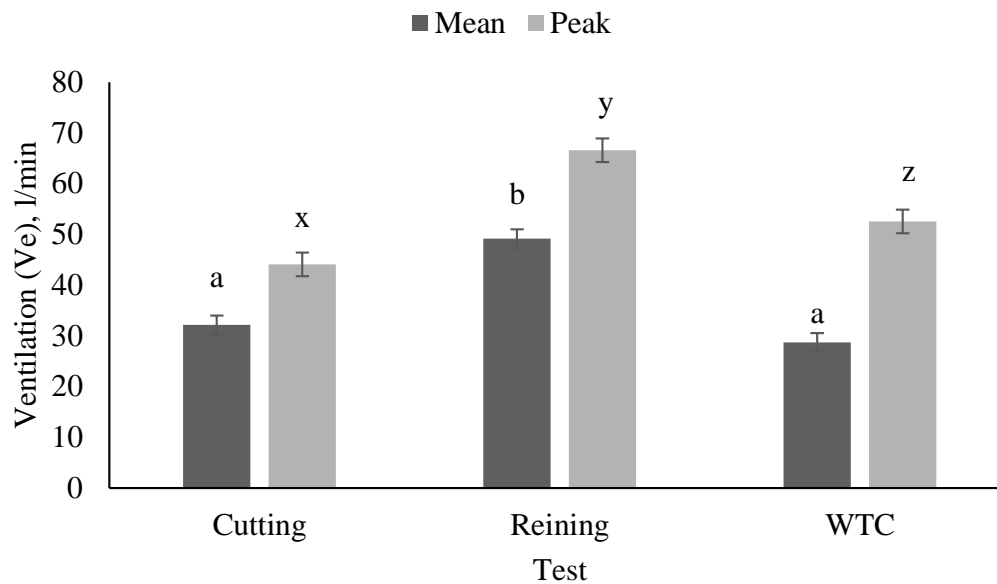


Figure 22: Mean and peak pulmonary ventilation rates, l/min for cutting reining and walk-trot-canter (WTC). ^{ab}Differing superscripts indicate a significant difference ($P \leq 0.05$) among mean ventilation. ^{xyz} Differing superscripts indicates a significant difference ($P \leq 0.05$) among peak ventilation.

With WTC split by gait (fig 23) there was no difference ($P=0.09$) between the two lowest mean pulmonary ventilations, walk and trot (21.78 ± 1.65 l/min and 24.41 ± 1.65 l/min). Reining, canter and long trot in descending order were the highest mean VE rates

across all gaits and tests (49.14 ± 1.65 l/min, 46.03 ± 1.65 l/min and 37.89 ± 1.65 l/min). Cutting mean VE (32.11 ± 1.65 l/min) was higher ($P \leq 0.05$) than walk and trot but lower than long trot, canter and reining. Reining peak VE remained pointedly higher ($P \leq 0.05$) than the rest of the tests peak ventilation (66.56 ± 2.10 l/min) with walk and canter peak VE being the second highest but were still lower ($P \leq 0.05$) than reining (48.05 ± 2.10 l/min and 51.77 ± 2.10 l/min). There was no difference ($p \leq 0.3824$) between peak ventilation of walk and canter or walk, cutting, and long trot peak VE (48.05 ± 2.10 l/min, 44.04 ± 2.10 l/min and 46.27 ± 2.10 l/min respectively). Trot peak VE was lower ($P \leq 0.05$) than all the other tests peak VE (29.01 ± 2.10 l/min).

Mean and peak ventilation (VE) were also explored for cutting, reining and the last two minutes of walk, trot, long trot and canter (Fig 24). Reining had the largest mean VE (49.14 ± 1.73 l/min) and walk had the lowest ($P \leq 0.05$) mean VE (17.62 ± 1.73 l/min). The Ventilation, went up as gait increased with no significant difference ($P=0.12$) between

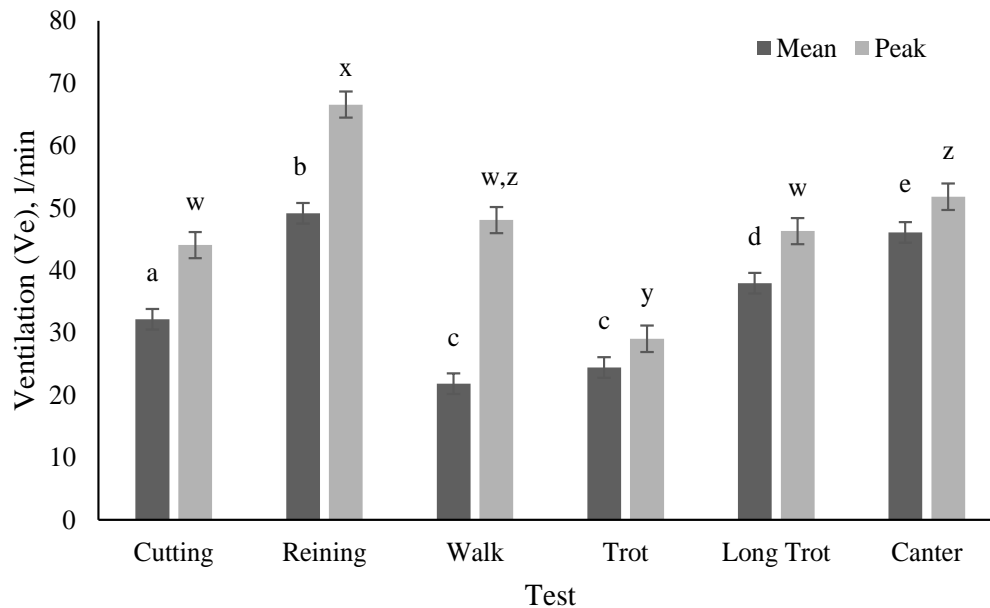


Figure 23 Mean and peak ventilation rates for cutting, reining, walk, trot, long trot and canter. ^{abcde} Differing superscripts indicate significant differences ($P \leq 0.05$) among mean ventilation rates. ^{wxyz} Differing superscripts indicate significant differences ($P \leq 0.05$) among peak ventilation rates.

mean VE of long trot and canter (42.96 ± 1.73 l/min and 45.63 ± 1.73 l/min). Cutting mean VE (32.11 ± 1.73 l/min) was higher ($P \leq 0.05$) than walk and trot mean VE but lower than long trot, canter and reining mean VE. The same increase in ventilation as gait was increased was seen in peak VE with differences ($P \leq 0.05$) among all four of the gaits (walk, trot, long trot and canter) with walk being the lowest peak VE (22.78 ± 1.94 l/min) and canter being the highest of the gaits peak VE (51.11 ± 1.94 l/min). Reining was the highest ($P \leq 0.05$) peak VE (66.56 ± 1.94 l/min). There was no difference ($P = 0.29$) between cutting and long trot peak VE (44.04 ± 1.94 l/min and 46.17 ± 1.94 l/min).

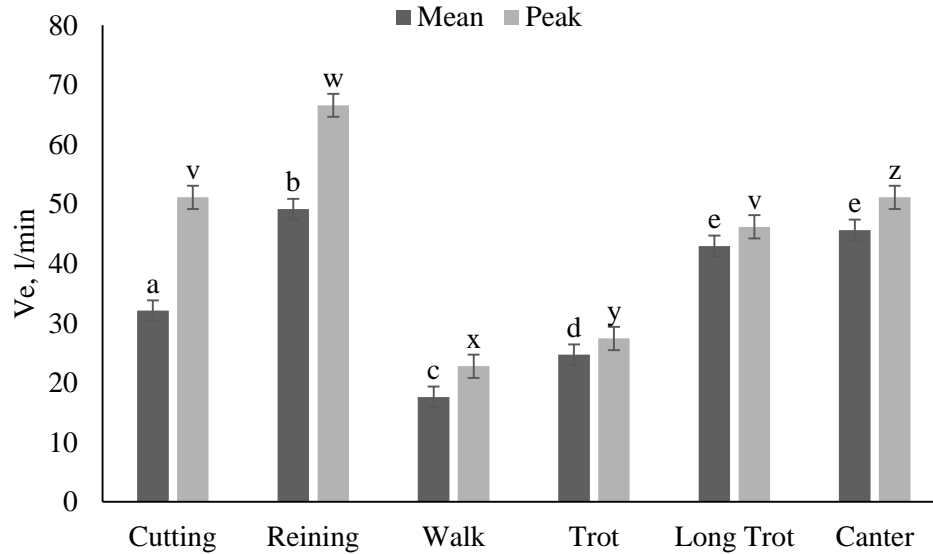


Figure 24 Mean and peak ventilation (VE), liters/min (l/min) for cutting, reining and the last two minutes of walk, trot, long trot and canter. ^{abcde}Differing subscripts indicate significant difference ($P \leq 0.05$) among mean VE. ^{wxyz}Differing subscripts indicate significant differences ($P \leq 0.05$) among peak VE.

Regression

A backward regression analysis and an alpha level of 0.15 was conducted to evaluate how well the rider characteristics of weight, age, BMI, height, body fat percentage, lean body mass, hours ridden per week and hours exercised per week predicted total energy expenditure, mean energy expended per minute and mean MET for each of the riding tests.

In table 2 the regression equations for total energy expenditure of cutting, reining and WTC are presented. Each of the three tests had a different combination of predictor variables that created a statistically significant ($P \leq 0.009$) prediction of total energy expenditure and adjusted R^2 ranging from .46 to .69. Cutting retained the most predictor variables with weight, age, BMI, body fat percentage and LBM all being statistically

significant ($P \leq 0.05$). Cutting also contained a predictor variable of hours ridden that was statistically significant ($P \leq 0.10$). Reining also contained Weight, age, body fat percentage and LBM, all significant ($P \leq 0.05$) but failed to retain BMI or hours ridden. WTC had the weakest adjusted R^2 (0.46) with only a predictor of weight ($P \leq 0.05$).

In table 3 the regression equation coefficient estimates and standard errors for mean energy expenditure per minute for cutting, reining, WTC, and the split gaits of the WTC test of walk, trot, long trot and canter are presented. All regression equations were statistically significant ($P \leq 0.05$) with R^2 ranging from 0.16 at trot to 0.76 with cutting. Weight was a statistically significant ($P \leq 0.05$) predictor variable in all 7 equations. BMI was present in all equations except that of trot and long trot, but was only a statistically significant predictor ($P \leq 0.05$) for cutting and canter. BMI was also present in reining ($P \leq 0.10$) WTC, and walk ($P \leq 0.15$).

Table 2 Regression equations for total energy expenditure (n=20) for cutting, reining and walk-trot-canter(WTC).

Test	Intercept	Weight, kg	Age, yrs	BMI	Body Fat, %	LBM, kg	Riding, Hrs	P-Value ¹	Adj. R ²
Cutting	11.14 ± 5.99**	0.73 ± 0.22*	0.63 ± 0.17*	-0.79 ± 0.34*	-0.42 ± 0.17*	-0.74 ± .29*	0.11 ± 0.07**	0.0009	0.6901
Reining	45.77 ± 17.38*	1.79 ± 0.47*	0.85 ± 0.39*	---	-1.16 ± 0.51*	-2.65 ± 0.73*	----	0.0008	0.6199
WTC	107.99 ± 21.41*	1.28 ± 0.31*	---	---	---	---	---	0.0006	0.4606

BMI, body mass index; LBM, lean body mass ¹Model P-value * indicates P≤0.05 **indicates P≤0.10

Table 3 Regression equations for mean energy expenditure per minute (n=20) for cutting, reining and walk-trot-canter (WTC), walk, trot, long trot and canter.

Test	Intercept	Weight, kg	Age, yrs	BMI	P-value ¹	Adj R ²
Cutting	0.53 ± 0.96	0.09 ± 0.02*	0.11 ± 0.04*	-0.18 ± 0.08*	<0.0001	0.7586
Reining	4.36 ± 1.29*	0.11 ± 0.04*	---	-0.21 ± 0.13 **	0.0006	0.5361
WTC	3.10 ± 0.61*	0.05 ± 0.02*	---	-0.11 ± 0.06***	0.0006	0.5353
Walk	2.10 ± 0.61*	0.05 ± 0.02*	---	-0.11 ± 0.06***	0.0015	0.4804
Trot	2.38 ± 0.51*	0.02 ± 0.01*	---	---	0.043	0.1645
Long Trot	3.27 ± 0.75*	0.04 ± 0.01*	---	---	0.0008	0.4423
Canter	6.39 ± 1.12*	0.12 ± 0.03*	---	-0.32 ± 0.12*	0.0013	0.4886

¹Model P-value *indicates P≤0.05 **indicates P≤0.10

Age was the only other statistically significant ($P \leq 0.05$) predictor variable for mean energy expended per minute but was only present in the cutting equation.

The same backward regression process was run again, with only female subjects ($n=17$) present in the model. The total energy expenditure regressions for female participants are presented in table 4. All regression equations were statistically significant ($P \leq 0.01$) with R^2 ranging from 0.48 with WTC to 0.84 with reining. Weight was again a significant predictor ($P \leq 0.05$) in all 3 equations. Age was also present in all three occasions; it was statistically significant ($P \leq 0.05$) in cutting and reining but was non-significant ($P \leq 0.10$) in WTC. Cutting retained the most predictor variables with Body fat percentage, LBM, and hours ridden also being statistically significant predictors as well as BMI being non-significant ($P \leq 0.10$). BMI was also present in WTC but was a non-significant predictor ($P \leq 0.10$). Hours ridden was also present as a non-significant ($P \leq 0.10$) predictor in reining.

Table 4 Regression equations for mean metabolic equivalents of task (MET) (n=20) for cutting, reining walk-trot-canter(WTC), walk, trot, long trot and canter.

Test	Intercept	Weight,kg	Age, yrs	BMI	Body Fat, %	LBM, kg	P-value ¹	Adj. R ²
Cutting	7.88 ± 1.85*	0.09 ± 0.05**	0.10 ± 0.04*	---	-0.14 ± 0.05*	-0.16 ± 0.08**	0.0158	0.4123
Reining	8.58 ± 1.04*	---	---	-0.10 ± 0.04*	---	---	0.0272	0.2011
WTC	6.64 ± 0.67*	---	---	---	-0.04 ± 0.01*	-0.04 ± 0.01*	0.002	0.4606
Walk	3.95 ± 0.50*	---	---	-0.05 ± 0.02*	---	---	0.0184	0.2312
Trot	6.04 ± 0.79*	---	---	---	-0.04 ± 0.02*	-0.04 ± 0.01*	0.0061	0.3864
Long Trot	9.66 ± 1.21*	---	---	---	-0.06 ± 0.03*	-0.05 ± 0.02*	0.0119	0.3365
Canter	15.52 ± 3.04*	0.15 ± 0.10***	---	-0.24 ± 0.15***	-0.15 ± 0.08**	-0.20 ± 0.12**	0.0078	0.4694

BMI, body mass index; LBM, lean body mass

¹Model P-value

*indicates P≤0.05 **indicates P≤0.10

In table 5 the regression equations, coefficient estimates and standard errors for mean MET for cutting, reining, WTC, walk, trot, long trot and canter are presented. All regression equations were statistically significant ($P \leq 0.05$) with adjusted R^2 ranging from 0.20, reining and 0.47, Canter. There was not one predictor that was present in all seven regression equations. Both body fat percentage and LBM were present in five of the regressions cutting, WTC, trot, long trot and canter. Body fat was significant ($P \leq 0.05$) in all analyses except canter, LBM was significant ($P \leq 0.05$) in WTC, trot and long trot but was non-significant ($P \leq 0.15$) in cutting and canter. Weight was only present in two tests but was non-significant in both cutting ($P \leq 0.10$) and canter ($P \leq 0.15$). BMI was also present in reining, walk and Canter but was only a significant predictor ($P \leq 0.05$) in reining and walk. Cutting had an additional significant predictor of age and also contained the most predictor along with canter.

The regression equations for mean energy expended per minute for female participants are presented in table 6. All regression equations were statistically significant

Table 5 Regression equations for total energy expenditure of female participants (n=17) for cutting, reining and walk-trot-canter(WTC).

Test	Intercept	Weight, kg	Age, yrs	BMI	Body Fat, %	LBM, kg	Riding, Hrs	P-Value ¹	Adj. R ²
Cutting	22.71 ± 10.51**	1.05 ± 0.31*	0.74 ± 0.21*	-0.75 ± 0.38**	-0.71 ± 0.26*	-1.40 ± 0.54*	0.20 ± 0.09*	0.0173	0.5727
Reining	-11.86 ± 7.07**	0.42 ± 0.05*	0.89 ± 0.26*	---	---	---	-0.71 ± 0.46**	<0.0001	0.8476
WTC	69.42 ± 43.91**	3.62 ± 1.25*	3.89 ± 1.94**	-8.44 ± 4.31**	---	---	---	0.008	0.4894

BMI, body mass index; LBM, lean body mass ¹Model P-value

*indicates P ≤ 0.05 **indicates P ≤ 0.10

($P \leq 0.05$) except for trot ($P = 0.1725$), with R^2 ranging from 0.43 to 0.66 in the statistically significant equations. Weight was present in all equations, and was statistically significant in all but trot ($P \leq 0.10$). BMI was present in all equations except for long trot and was statistically significant ($P \leq 0.05$) in cutting, WTC, walk and Canter and was a non-significant predictor in BMI ($P \leq 0.10$) and Trot ($P \leq 0.15$). Age was present and statistically significant ($P \leq 0.05$) in cutting and long trot equations, but was also a non-significant predictor in WTC, walk ($P \leq 0.10$) and Trot ($P \leq 0.15$). Cutting also exhibited hours exercised as a non-significant predictor variable ($P \leq 0.15$). Long trot contained two other significant predictor variables ($P \leq 0.05$) of body fat percentage and hours ridden and also had LBM as a non-significant predictor variable ($P \leq 0.10$).

The regression equations for mean MET for female participants ($n = 17$) are presented in table 7. All regression equations were statistically significant ($P \leq 0.05$) except

Table 6 Regression equations for energy expenditure per min of female s (n=17) for cutting, reining walk-trot-canter(WTC),, walk, trot, long trot and canter.

Test	Intercept	Weight,kg	Age,yrs	BMI	Body Fat, %	LBM, kg	Exercise, Hrs	Riding, Hrs	P-value ¹	Adj. R ²
Cutting	1.03 ± 1.32	0.14 ± 0.03*	0.14 ± 0.05*	-0.34 ± 0.12*	---	---	-0.14 ± 0.09***	---	0.0014	0.6627
Reining	3.80 ± 1.30*	0.16 ± 0.05*	---	-0.31 ± 0.16**	---	---	---	---	0.0005	0.6097
WTC	1.74 ± 0.93**	0.08 ± 0.03*	0.08 ± 0.04**	-0.20 ± 0.09*	---	---	---	---	0.0061	0.5103
Walk	0.96 ± 0.79	0.08 ± 0.02*	0.07 ± 0.03**	-0.20 ± 0.078	---	---	---	---	0.0036	0.5502
Trot	1.83 ± 1.11***	0.06 ± 0.03**	0.08 ± 0.05***	-0.18 ± 0.11***	---	---	---	---	0.1725	0.1503
Long Trot	9.50 ± 4.60**	0.31 ± 0.12*	0.20 ± 0.08*	---	-0.26 ± 0.12*	-0.49 ± 0.24**	---	0.08 ± 0.04*	0.0279	0.4758
Canter	6.33 ± 1.26*	0.15 ± 0.05*	---	-0.41 ± 0.16*	---	---	---	---	0.0073	0.4336

BMI, body mass index; LBM, lean body mass ¹Model P-value *indicates P≤0.05 **indicates P≤0.10

for reining with the remaining 6 adjusted R^2 ranging from 0.38 to 0.47. Age was the most frequently observed predictor variable being present in all but canter. Age was only a significant predictor ($P \leq 0.05$) in the cutting, walk, and long trot equations but it was also a non-significant predictor in Trot ($P \leq 0.10$) and WTC ($P \leq 0.15$). BMI was only a predictor in walk, trot and canter but was a significant predictor ($P \leq 0.05$) in all of them. Body fat was also a significant predictor ($P \leq 0.05$) in cutting, WTC and long trot. Long trot also contained three other significant predictors ($P \leq 0.05$) with weight, LBM and hours ridden. Hours exercised was present in walk and canter but was a non-significant predictor variable ($P \leq 0.15$) in both. Weight was also present in walk but was non-significant ($P \leq 0.15$).

One more regression analysis was run in an attempt to control co-linearity issues as well as make a user friendly equation. Due to the correlations between the predictor variables, weight in kg was chosen as a sole predictor variable in these regression

Table 7 Regression equations for mean MET of female participants (n=17) for cutting, reining and walk-trot-canter(WTC). walk, trot, long trot and canter.

Test	Intercept	Weight,kg	Age, yrs	BMI	Body Fat, %	LBM, kg	Riding, Hrs	Exercise, Hrs	P-value ¹	Adj. R ²
Cutting	3.75 ± 1.33*	---	0.13 ± 0.05*	---	-0.06 ± 0.02*	---	---	---	0.0075	0.4315
Reining	---	---	---	---	---	---	---	---	---	---
WTC	4.02 ± 1.02*	---	0.06 ± 0.04***	---	-0.05 ± 0.02*	---	---	---	0.0139	0.3796
Walk	3.17 ± 0.78*	0.03 ± 0.02***	0.07 ± 0.03*	-0.17 ± 0.07*	---	---	---	-0.09 ± 0.05***	0.0318	0.4128
Trot	3.61 ± 1.17*	---	0.09 ± 0.05**	-0.10 ± 0.03*	---	---	---	---	0.0163	0.3854
Long Trot	16.43 ± 4.55*	0.30 ± 0.12*	0.22 ± 0.08*	---	-0.03 ± 0.12*	-0.60 ± 0.23*	0.08 ± 0.04*	---	0.028	0.4754
Canter	11.17 ± 1.39*	---	---	-0.20 ± 0.55*	---	---	-0.21 ± 0.13***	---	0.0105	0.404

BMI, body mass index; LBM, lean body mass ¹Model P-value * indicates P ≤ 0.05 ** indicates P ≤ 0.10

equations for total energy, mean energy expended per minute and mean METs. These regressions were run with all subjects (n=20) as well as just with the women (n=17).

The regression analysis for total energy expended for the three tests of cutting, reining and WTC are presented in table 8. All three equations were significant with R² of 0.46, 0.21, and 0.46 for cutting, reining and WTC respectively. The influence that weight had also known as the parameter estimate of weight varied for each of the tests with cutting having the smallest influence to WTC having the largest. All coefficients were found to be statistically significant (P≤0.05).

Table 8 Regression equations for total energy expenditure of cutting, reining and walk-trot-canter (WTC) with weight (wt) in kg as the only predictor variable.

Test	Intercept	Wt, Kg	P-value	Adj R²
Cut	2.78 ± 2.06***	0.12 ± 0.03*	0.0006	0.4625
Reining	15.12 ± 7.59**	0.27 ± 0.11*	0.0248	0.2084
WTC	108.00 ± 21.40*	1.28 ± 0.31*	0.0006	0.4606

*indicates significant predictor variable P≤0.05. **P≤0.10 ***P≥0.20.

The regression analysis for average energy expended per minute for cutting, reining, WTC as well as walk, trot, long trot and canter are all presented in table 9. All equations were found to be statistically significant (P≤0.05) with R² ranging from 0.16 to 0.6. The influence of weight for these regression equations were all statistically significant (P≤0.05) and also were very similar ranging from 0.02±0.01 to 0.06±0.01.

Table 9 Regression equations (n=20) for mean energy expenditure per min of cutting, reining, walk-trot-canter (WTC), walk, trot, long trot, and canter with weight (Wt) as only predictor.

Test	Intercept	Wt, Kg	P-Value	Adj R²
Cut	1.17 ± 0.66 **	0.06 ± 0.01*	<0.0001	0.6
Reining	2.89 ± 0.94*	0.06 ± 0.01*	0.0003	0.4962
WTC	2.36 ± 0.45*	0.03 ± 0.01*	0.004	0.4859
Walk	1.35 ± 0.45*	0.03 ± 0.01*	0.0011	0.4229
Trot	2.38 ± 0.51*	0.02 ± 0.01*	0.0430	0.1645
Long Trot	3.27 ± 0.75*	0.04 ± 0.01*	0.0008	0.44
Canter	4.19 ± 0.92	0.04 ± 0.01	0.0071	0.3024

*significance P<0.05 **P≤0.10.

The regression analysis for mean MET for cutting, reining, WTC as well as walk, trot, long trot and canter are presented in table 10. All equations were found to be statistically significant (P≤0.05) except for cutting (P=0.1880). With these prediction equations the influence of weight was negative but was again very similar among equations ranging from -0.01±0.01 to -0.04±0.01. The statistically significant equations contained statistically significant coefficients for weight (P≤0.05).

Table 10 Regression equations for mean MET (n=20) of cutting, reining, walk-trot-canter (WTC) walk, trot, long trot and canter with weight (wt) in kg as the only predictor.

Test	Intercept	Wt, Kg	P-value	Adjusted R²
Cut	5.48 ± 0.72*	-0.01 ± 0.01***	0.1880	0.04
Reining	7.87 ± 0.82*	-0.03 ± 0.01*	0.0411	0.1681
WTC	5.49 ± 0.46*	-0.03 ± 0.01*	0.0014	0.4098
Walk	3.59 ± 0.39	-0.01 ± 0.01*	0.0269	0.2017
Trot	4.88 ± 0.52*	-0.03 ± 0.01*	0.0029	0.3646
Long Trot	7.93 ± 0.82*	-0.04 ± 0.01*	0.0088	0.2867
Canter	9.04 ± 0.88*	-0.04 ± 0.01*	0.0031	0.3589

*i indicates significant predictor $P \leq 0.05$. ** $P \leq 0.10$ *** $P \geq 0.20$

The regression analysis for total energy expenditure of female participants (n=17) is presented in table 11. The regression equations for both reining and WTC were found to be significant but the equation for cutting was found to be non-significant (P=0.238). The two significant equations had varied influences from weight with reining having less (0.45 ± 0.07 kg) than WTC (1.26 ± 0.39 kg). The intercepts also had very large standard errors.

Table 11 Regression equations for total energy expenditure of cutting, reining and walk-trot-canter for females (n=17) (WTC) with weight (Wt) in kg as the only predictor variable.

Test	Intercept	Wt, Kg	P-value	Adj R ²
Cutting	4.43±2.48**	0.10 ± 0.04*	0.238	0.2496
Reining	4.64 ± 4.81***	0.45±0.07*	<0.001	0.6959
WTC	108.78± 25.50*	1.26±0.39*	0.0054	0.3735

*indicates significant predictor variable $P \leq 0.05$. ** $P \leq 0.10$ *** $P \geq 0.20$.

The regression analysis for mean energy expended per minute for female (n=17) subjects is presented in table 12. The regression equations were all significantly significant except for trot ($P=0.1750$). The coefficients of weight in these regressions were fairly similar ranging from 0.03 ± 0.01 to 0.07 ± 0.02 . All of the weight coefficients were found to be statistically significant ($P \leq 0.05$).

Table 12 Regression equations for energy expended per minute of cutting, reining walk-trot-canter (WTC) walk, trot, long trot and canter of females (n=17) with weight (Wt) in kg as only predictor.

Test	Intercept	Weight, kg	p-value	Adj. R ²
Cutting	1.77±0.79*	0.05 ± 0.01*	0.0018	0.4561
Reining	2.16 ± 1.06**	0.07 ± 0.02*	0.0005	0.5403
WTC	2.39 ± 0.55*	0.03±0.02*	0.0047	0.3844
Walk	1.36 ± 0.48	0.03±0.01*	0.0041	0.3946
Trot	2.53±0.614*	0.01±0.01***	0.1750	0.0603
Long Trot	3.20 ± 0.92*	0.04±0.01*	0.0069	0.3543
Canter	4.17 ± 1.12*	0.04 ± 0.02*	0.0336	0.2184

*indicates significant predictor variable $P \leq 0.05$. ** $P \leq 0.10$ *** $p \geq 0.20$.

The regression analysis for mean MET for female subjects (n=17) is presented in table 13. The cutting, reining, walk, and long trot equations were all found to be non-significant. The remaining tests were all significant with Adj R² ranging from 0.25 to 0.29. Again the influence of weight didn't vary much (-0.02 ±0.01 to -0.04±0.02).

Table 13 Regression equations for mean MET for females in cutting, reining, WTC, walk, trot, long trot and canter with weight (Wt) in kg as the only predictor.

Test	Intercept	Weight, kg	p-value	Adj. R²
Cutting	5.80±0.90*	-0.02±0.01***	0.1750	0.06
Reining	7.34±0.98*	-0.02±0.02***	0.2741	0.01
WTC	5.45±0.57*	-0.02±0.01*	0.0145	0.2933
Walk	3.54±0.45*	-0.01±0.01**	0.0842	0.1314
Trot	4.90±0.66*	-0.03±0.01*	0.0184	0.2726
Long Trot	7.81±-1.04*	-0.03±0.02**	0.0562	0.1702
Canter	9.00± 1.11*	-0.04±0.02*	0.0230	0.2528

. *indicates significant predictor variable P≤0.05. **P≤0.10 ***p≥0.20.

CHAPTER V

DISCUSSION

The findings suggest that reining and cutting, two competitive sports in the western discipline, are more metabolically demanding than that of the traditional light walk-trot-canter ride. Previous studies have documented an increase in certain parameters, such as VO_2 , HR, and V_e , as speed of gait increased. These previous studies indicated that as gait increased so did the intensity of the exercise (Westerling, 1983; Devienne and Guezennec, 2000; Roberts et al., 2009). One plausible cause, presented by Douglas et al. (2012) is that faster gaits and those adopting a forward seat, like jumping or cross country, may require more leg and trunk control. This requirement in turn determines a higher recruitment of musculature leading to higher intensities and more energy expenditure. This was further supported by kinematic studies (Lovett et al. 2005) indicating a change of posture in riders completing rising trot as well as a theory that the rising trot required more thigh activation and more corrections to maintain center of balance. Douglas et al. (2012) went on to indicate that canter requires more muscle to maintain posture due to the differences in ground reaction forces and change of orientation of the trunk with the movement of the canter. The present study corroborated this theory through most of the parameters measured (energy expended per minute, MET, HR, V_e , RF, $relVO_2$). With means of most parameters for the WTC gaits of walk, trot, and long trot and canter increasing sequentially.

Intensity changes were further supported by the novel introduction of reining and cutting, both often, considered to be more intense than general riding. The same theories

Douglas used for trot and canter, could also be used to explain the intensities presented by reining and cutting. In reining there is not only the influence of gait used, a (considerable duration of most reining tests use canter) but reining also has maneuvers like rollbacks, stops, and lead changes, all of which require maintaining center of gravity while orientation of the trunk is changing. The quick and challenging changes of direction and pace in cutting and flag simulations most likely lead to a need for more trunk control to maintain correct center over the horse. Both sports in their specific maneuvers may recruit more muscle than normal riding due to the unique physiologic stresses it places on both horse and rider

While the present study supports the theory of increasing intensity with progression through the gaits (especially with measurement of the last two min of each gait), the current data does seem to be a little lower overall for many measured parameters with peak measurements being more consistent with previous data than the means. This may be due to the population chosen, including both sexes and various experience and estimated fitness levels as well as type of test and machines used during testing. The breed and primary disciplines of riding of the horses might also provide explanation for some of the differences. Devienne and Guzenec (2000) proposed that the nature of the horse being ridden could have an effect on energy expenditure. Their data indicated that the horse that had to be pushed forward would increase energy expenditure but the only significant results were in the canter. Kinematic studies indicate that much of the muscle activity seen in horseback riders is for posture control through the core and hip area (Terada et al., 2004; Lovett et al., 2005), maintaining center of balance and posture could be affected by

horses with naturally different ways of going as seen in desirable traits for English riding horses versus western riding horses. While horses were not compared within the present study innate differences between the western horses used for the present project and the jumper and eventing breeds most likely used in previous data may also have an effect on the energy expenditure and other intensity measurements taken.

There is a trend among peaks within the present study with walk being significantly higher than the mean as well as higher than previous data has observed. This disagrees with previous studies that report intensity that observed oxygen consumption going up as the horse and rider pair progresses through the gaits (Westerling, 1983; Devienne and Guezennec, 2000). This is most likely due to the design of the WTC test with walk following canter on two separate occasions within the test. This would lead to high rates of most parameters at the walk in the moments immediately following canter due to the influence of canter on the walk portions. This is further confirmed by the analyses using just the last two minutes of each gait. With these measurements, the walk data is much lower at both mean and peak. Cutting may also be affected by test design due to the periods of complete stillness within the test. The duration of the test is already very short, the reduction of movement, averaged into the tests parameters may have caused a lowering of the mean measurements. During actual cow work, the horse and rider pair would probably never be completely still and during those simulated herd times would be moving through a herd of cows.

Body composition

The mean body fat percentage of this subject pool ($32.5 \pm 7.05\%$) was found to be higher than that of previous studies on horseback activity (Meyers et al., 1992; Meyers and Sterling, 2000; Meyers, 2006; Roberts et al., 2009). Reported body fats of previous studies are presented in table 14. Our study was the only reported study to use dual X-ray Absorptiometry (DEXA) which could have led to some of the differences in body fat measurement. However, 32.5% fat is classified as overweight (Jeukendrup and Gleeson, 2010) and is a higher mean body fat percentage than most other female and male athletes (Pollock et al., 1980; Meyers et al., 1992). These differences in comparison to other riding studies as well as other athlete's exacerbates the currently presented idea that horseback riding may not provide a fitness level needed for health benefits. Other considerations like hours ridden per week and type of riding done would affect the fitness level seen and may have caused the fitness level of the subject pool to be lower.

Table 14 Body fat percentages (\pm SD) from previous equestrian activity studies.

Body Fat Percentage Comparisons		
Rider Type	Mean Body fat (%)	SD
Rough Stock (male n= 20) ¹	9.4	1.4
Roping (male n= 20) ¹	13.1	1.7
Steer Wrestling (male n=20) ¹	17.7	2.6
Barrel Racing (Female n= 10) ¹	24.2	1.4
Female Equestrians (n=24) ²	24.5	6
Females after 14Wk Riding Program (n=15) ³	23.5	0.9
Eventers (Female n=16) ⁴	23.4	5.3

¹Meyers et al. 1998

² Meyers and Sterling 2000

³ Meyers 2006

⁴ Roberts et al. 2010

BMI another common and easy measurement, a weighted ratio of weight and height was also measured in all participants. The mean value (23.71 ± 4.12) is on the high end of normal. This mean was very similar to the mean BMI found by Meyers in 2000 (24.8 ± 1.7). Meyers reported that this mean fell within norms for athletic females (Meyers and Sterling, 2000).

These two measurements are used as gauges of physical fitness and may indicate physical conditioning of equine athletes may not be as productive as other sports. However the riding habits per week of the riders in the present study varied widely (mean 8.15 ± 7.27 hrs/wk range 1.0-30.0 hrs/wk) as did the exercise per week (mean 1.58 ± 1.79 hrs/wk). There is also a documented trend of increased population BMI from 1959 to 2010 (Lee et al., 2011). Lee et al. (2011) found that BMI sharply increased in the adolescent ages and the increases have become larger since the beginning of the 1990's. This was further confirmed by Flegal and associates (2012) who found BMI distribution as well as the prevalence of obesity had increased in the United States from 1980 to 1999 but found that it has since leveled out with no significant difference between 20010 and 2003-2008. These variations may provide insight into some of the differences seen in the body fat percentage and subsequently estimated fitness levels.

Energy expenditure

Energy expenditure in this study was collected by the Cosmed K4B2 machine. The machine automatically calculates total energy expenditure and energy expenditure rates using an equation in its program. This equation is based off of the Weir equation

(Schrack et al., 2010) and uses oxygen consumption and carbon dioxide production (exhalation) to determine the amount of energy used.

Total energy expenditure was a slightly misleading statistic due to the differences in times spent in each riding activity. With cutting being the shortest test it is no surprise that it is also significantly lower ($P \leq 0.05$) in total energy expenditure (11.1384 ± 3.8328 Kcal), same can be said for WTC having the longest test and the largest energy expenditure (194.72 ± 3.8328 Kcal). However when energy expenditure was examined on an intensity basis of energy expenditure per minute or METs there were some significant differences that lead to the conclusion of cutting and reining being more metabolically demanding. The WTC data, while containing energetically intense gaits like long trot and canter, had a lower mean energy expenditure overall due to the large influence of the two less intense segments, walk and trot, which also happened to be the two largest segments of the test (18 min and 12 min). This was confirmed by the differentiation of the WTC test into its gaits with walk and trot being the smallest in the mean measurements of energy expenditure per min ($3.0371 \pm .2144$ Kcal/min and $3.4567 \pm .2144$ Kcal/min). The cutting test may also be affected by the length of the activity, but with breath by breath analysis it is hoped that there is some validity in the energy expenditure of the 2min 10sec riding activity. This being noted in mean energy expended per minute reining had the largest Kcal/min ($6.9557 \pm .2302$ Kcal/min), cutting being significantly lower than reining ($4.9754 \pm .2302$ Kcal/min) but also significantly higher than WTC. These mean measurements across complete tests, cutting and reining have higher energy expenditures per minute than WTC which is indicative of higher intensities for those two rides.

While there is currently no data specifically on cutting and reining, there is data on other equestrian activities that are considered to be more intense than the traditional WTC ride. Roberts et al. (2009) found in a study of 16 eventers show jumping and cross country jumping, considered extremely intense had rates of 8.2 ± 1.1 kcal/min and 8.5 ± 1.1 kcal/min respectively. This is higher than that found for mean energy expenditure of both reining and cutting but is similar to the peaks reached for both ($7.6 \pm .38$ kcal/min and 10.09 ± 0.38 kcal/min). The energy expenditure for dressage (5.9 ± 1.0 kcal/min), a shorter version of a walk-trot-canter ride, was similar to the mean energy expenditures found for both reining and cutting and was higher than the mean found for the WTC ride completed in this study. The duration of the sports as well as the gaits ridden in the sports could both have contributed to these differences. Another major factor that could be playing a role in these differences is the difference in machines and calculations used for energy expenditure. There are several validated equations for energy expenditure (Elia and Livesy, 1992) and there will be slight differences depending on the equation and oxygen consumption equipment used.

When comparing reining and cutting to the separated gaits of walk, trot, long trot and canter there were some interesting findings. In mean energy expenditure per minute there was no significant difference between the intensity of reining long trot and canter. This similarity is expected due to the amount of canter work found in the reining pattern. While cutting mean energy expended per minute is significantly lower than both long trot and canter the design of the riding test may be causing that lower average. During an actual cutting competition involving live cattle, the time that the present study participants

stood still would be used to choose and separate another cow from the herd. When comparing these gaits to the peak energy expended per minute reining is well above any other intensity most likely due to the faster pace of canter required for roll backs and sliding stops. Interestingly enough, cutting long trot and canter all had similar peak value. This is again reflective of the nature of the sport of cutting, with intense bursts of energy expenditure seeming to be a signature of the sport.

MET

Metabolic equivalents of task (MET) are a common way in the health and sport industries to report intensity of an activity. One MET is defined as the energy required to sit quietly equivalent to $3.5 \text{ mlO}_2 \cdot \text{kg} \cdot \text{min}$. National health publications have reported that a moderate intensity MET (3-6MET) is required for adequate health benefits to be acquired from activities. MET is also used to compare activities that would otherwise be incompatible (Pate et al., 1995; Warburton et al., 2006; Haskell et al., 2007; Garber et al., 2011). Since MET and energy expended per minute are both calculated from gas analysis the issues seen in the data of energy expended per minute is also present in the MET data for this study.

No other equine activity study has reported METs as part of their data. All 3 tests, cutting reining and WTC were within what is considered the moderate range of MET (source, health) with reining's average METs being on the higher end of moderate and WTC being on the cusp of light and moderate intensity. A compendium of METs, as a reference guide for the health conscious and health providers, has helped classify different activities into the different categories. A sample of these activities is presented in table

15. In the compendium horseback riding, general is listed at an MET of 4, which is comparable to the results found in this study with the light WTC ride (mean of $3.8 \pm .16$). But the results of cutting and reining are similar to that of golf, and bicycling respectively and are higher than the compendiums estimation of horseback activity.

Table 15: Activities and the estimated METs produced ¹.

Activity	METs
Golf, walking and carrying clubs	4.5
walking, 2.0 mph, level surface, slow pace	2
Walking, 5.0 mph	8
Bicycling, 10-11.9mph, leisure, slow, light effort	6
Sitting quietly	1
jogging, general	7
horseback riding general	4
Soccer, casual	7
Rugby	10

¹Adapted from Ainsworth, W. Haskell, et al., 2000

The peaks of all three activities WTC, cutting and reining were well above that estimate and the peak MET reached were similar to activities like jogging, playing soccer and rugby according to the compendium. This indicates that previous publications may have underestimated the intensity of horseback riding, or at the very least underrepresented the variation that can be present in horseback riding activity. However, there are some caveats to MET energy expenditure estimations. METs assume that a larger persons will have larger resting metabolic rates but people of the same mass with different percent body fat and lean mass percentages will have different metabolic rates

(Jette et al., 1990). It also doesn't take into account skill level which has been documented to be a significant factor in horseback riding muscle recruitment (Terada, 2000).

Heart rate

Heart rate was continuously measured throughout all three tests. It is often used as a gauge of intensity as well as a way of estimating energy expenditure in other activities (Astrand and Rodahl, 1977; Ruowei et al., 1993). As with the energy expenditure data, the mean heart rate data was higher for reining and cutting than it was for WTC. WTC and cutting peak HR showed no significant differences ($P \leq 0.05$) indicating that the peak HR of WTC, most likely from long trot or canter were similar to the heart rates reached in the short but intense bout of cutting simulation. This idea was further confirmed when the WTC test was displayed by gait, cutting and long trot had similar peak heart rates.

Table 16: Heart rates (HR) in beats/min for previously studied equestrian activities.

Activity	HR (bpm)
Walk¹	108 ± 13
Trot (rising)¹	163 ± 19
Trot (sitting)¹	170 ± 15
Canter¹	172 ± 18
Dressage²	157 ± 15
Show Jumping²	180 ± 11
Cross Country²	184 ± 11

¹Westerling et al. (1983)

²Roberts et al. (2009)

Heart rate data has been measured over several different equestrian activities, this information is presented in table 16. The data observed for dressage (Roberts et al. 2009) was similar to the mean heart rates found for reining. Cutting was slightly lower than the averages found for the dressage test. While dressage was reported to be the least intense of the three phases of the event (Roberts et al., 2009), it is speculated that cutting may have higher HR in reality, due to the averaging in of rested periods where herd time was being accounted for. The peaks reached in these trials are more closely matched to other studies except for walk of the present study. Walk was considerably higher in both the mean and the peak but when taking only the last two minutes of each walk gait segment, the walk HR became more in agreement with other studies (mean 114.95 ± 4.40 bpm peak 125.75 ± 4.63 bpm). The trot mean and peak was also lower than previous studies trot work. This could be due to several things including the nature of the trot, size of horse as well as fitness and experience levels of the riders (Westerling, 1983; Terada, 2000). The quarter horses used in the present study completed a trot also known as a jog which is characterized by slow and smooth movement across the ground, the most comparable study used larger jumping and dressage horses that have larger strides with more suspension that may have caused the differences seen. The long trot, peak completed in a rising trot by the subjects, was comparable to the rising trot HR seen in previous study. The peak in canter was somewhat lower than that of previously reported canter HR but the reining peak was similar to previously reported HRs for show jumping and cross country. The previous study that examined riding by different gaits, looked at each gait individually with rest (or washout periods) in between each gait. This allowed there to be

less influence from the gait previously ridden on the gait being tested. This fact along with the differences in breeds and discipline requirements may have led to some of the discrepancies between studies. Even though the measurements of HR were consistently lower in the present study, the pattern of heart rate increasing as gait intensity increased was seen in the mean HR analysis especially in the analyses of the last two minutes of each gait.

Ranges for other sports like cycling, rowing, and rugby have also been within comparable ranges. These heart rates are shown in table 17. The heart rates observed in reining are similar to those of averages for rugby and also HR present during an advanced videogame version of Dance Dance revolution (DDR). Both of these activities have been reported to reach intensities to produce health benefits when completed for long enough periods of time. (Coutts et al., 2003; Sell et al., 2008). Rowing and cycling ranges are provided and the average range for cycling encompasses many of the different gaits of horseback riding, as does rowing which are both considered exercises that could increase health benefits (Hagerman et al., 1988; Warburton et al., 2006).

Table 17: Heart rates of previously studied non-equestrian activities.

Activity	Heart Rate (bpm)
Dance Dance Revolution ¹	161.2 [†]
Rugby ²	166 [†]
Rowing ³	110-170 *
Cycling ³	90-150*

¹ Sell et al. 2008

² Coutts et al. 2003

³ Hagerman et al. 1988

[†] Averages * Ranges

Gas analysis

The K4b² contains both an oxygen analyzer as well as a carbon dioxide analyzer, this is for accuracy purposes of energy expenditure data. One way to display oxygen consumption is to make it relative to the subject (by kg). This allows for comparisons among sports that are weight bearing versus not weight bearing and comparison among subjects of different builds. Again, the trend of subjects riding in reining having the highest measurements and WTC having the lowest relative oxygen consumption was apparent. The peak $relVO_2$, also had a similar trend with cutting and WTC peaks having no significant differences. When comparing the individual gaits, the typical trend of increasing as gait increased was present, with no significant difference between long trot and canter. The influence of canter on the walk was lessened by taking the last two minutes of each gait and therefore a significant difference was seen between walk and trot. Reining was not significantly different from long trot or canter mean $RelVO_2$. This is to be expected due to the amount of canter that was performed in the reining test. Cutting on the other hand was slightly lower than expected in the mean, being lower than both long trot and canter. This may be due to the periods of stillness experienced during herd time, as well as the length of time the cutting test took versus the amount of time spent in each gait.

In mean and peak $relVO_2$ reining was again similar to that of Dressage (mean $20.4 \pm 4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, peak $28.6 \pm 6.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). The means and peaks for show jumping and cross country were higher but had larger standard deviations and reining was not far from values seen in show jumping. Cross country involves galloping, which requires a

forward seat as well as terrain changes like uphill and downhill that could also affect the effort of the rider. The fact that cross country has a larger relative VO_2 seems to agree with both metabolic and kinematic riding data (Westerling, 1983; Schils et al., 1993; Roberts et al., 2009).

The relative VO_2 observed in Westerling et al. (1983), were similar to findings of the present study at the walk ($9.4 \pm 1.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and were even high compared to the last two min walk data ($7.12 \pm 0.70 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). However the values found for trot and canter were higher than even the peak values for the trot and canter. The Douglas bag technique was used during this study and air was only collected for the last 2 minutes of each gait. The testing procedure was also very different with rest in between each gait. While the cause for these significant differences among values is unknown, having such differences in experimental design could lead to variation.

RER

The respiratory exchange ratio (RER) did not produce the expected results, especially with the sport of cutting. Cutting mean RER (0.8131 ± 0.014) indicated that cutting never moved out of fat metabolism. Cutting was considered a more intense sport with short but intense bursts of speed and energy. The low RER may be due to the small working sections within the test, with the working time being too short for the machine to take accurate recordings that reflect the cellular work being done. Mean RER of trot and long trot (0.8971 ± 0.014 , and 0.9091 ± 0.014) indicate that they are the most oxidative of the gaits and are the gaits that will produce the most fat metabolism.

VE

The same trend as before is seen in ventilation, with reining and cutting being significantly higher than WTC. The peak differed slightly from the other trends with WTC being significantly different and higher than cutting. When split by gaits, the same pattern of increasing ventilation with gait was seen as was the similarity between cutting, long trot and walk. The similarity of walk to cutting and long trot was not seen in the analyses of the last two min of each gait. Long trot also became larger than cutting in mean V_e with the last two min analyses. Ventilation was observed in an equine activity study for walk, trot rising, trot sitting and canter (Westerling, 1983). The canter and reining mean V_e (46.03 ± 1.65 l/min and 49.14 ± 1.65 l/min) were similar to that of canter and trot sitting (49.4 ± 7.1 l/min and 55.4 ± 9.4 l/min) in the Westerling study. Walk (21.78 ± 1.65 l/min) was also comparable to that seen in the Westerling study (21.2 ± 5.9 l/min) as was the long trot (37.89 ± 1.65 l/min) with the trot rising data (44.3 ± 6.6 l/min).

Health and equine activity

While the anthropometric data suggest a less fit subject pool, the data collected supports the idea that horseback riding may in fact be a viable health benefiting exercise. Like most forms of exercise, this would be under the premise of using the right intensity exercise for an adequate amount of time. Health publications indicate that an intensity of 4-6 MET or a moderate intensity activity for 30 min, and in some cases less time if accumulated over a day, can provide benefits in lowering the risk of diseases (DeBusk et al., 1990; Murphy and Nevill, 2002; Warburton et al., 2006; Haskell et al., 2007). This data showed that the mean MET in what is considered a light WTC ride was right on the

border of being a moderate MET level (3.81 ± 0.16 MET). This along with the evidence that sports that are considered more intense, cutting (mean, 4.53 ± 0.16 MET) and reining (mean, 6.12 ± 0.16 MET) having MET levels that definitely fit in the range indicate that the amateur horse owner could include horseback riding as part or all of an exercise regimen.

Blair et al. (1989) indicated that the burning of 1000 kcal per wk would provide health benefits to the average male subject. With total energy expenditure of the 45 min WTC test averaging 194.72 ± 3.8 Kcal it is possible to achieve that goal of 1000kcal per week with a reasonable amount of effort. It would be important for the person attempting this to understand that the intensity of gait and discipline they choose will greatly influence the outcome of their calorie burning exercise with canter having the most beneficial intensity (6.93 ± 0.21 kcal/min) and walk having the least beneficial (2.34 ± 0.21 kcal/min).

Heart rate is often used as a measure of intensity and energy expenditure in sports and activities due to ease of data collection and use. The data collected in this study indicates that HR would be an adequate estimator of intensity for the traditional WTC gaits since the increases in HR, VO_2 and therefore energy expenditure all appear to be very similar. However HR may not be an accurate indicator of intensity or energy expenditure for reining or cutting due to the major differences between HR and VO_2 in these two tests. The HR appears to be higher than what would be indicated for the energy expenditure elicited. This is probably due to anticipatory influence and stress caused by the test itself.

Regression

The regression equations that were created using the data from the present study provide insight for future research but may be misleading for general estimations of energy expenditure and intensity. The subject pool was small and the variation between subjects was limited with a few outliers. These general characteristics could pull the regression coefficients one way or the other making it hard to know if the influences seen from certain predictors are accurate.

Another caveat to the regression equations is the concept of co-linearity. Many of the predictors used in the first backwards regressions were related to one another and may have influenced effects of one another. This again, may lead to results that are less than accurate. The second set of regressions run were to try to eliminate this problem as well as make a simpler equation for users by only using weight. While weight may not be the best predictor for a whole population, since body composition can vary so widely and body composition effects energy expenditure, it was significantly correlated for this data.

While the accuracy of the regression data may not be applicable for the total population, it does give some insight for future regression analysis of larger data sets. Co-linearity should be a consideration of measurements taken that may be used for energy expenditure regression analysis and predictors should be chosen carefully to eliminate these problems. The current data provides some insight into predictors that may or may not be affective in future regression analysis.

CHAPTER VI

SUMMARY

The objective of this study was to measure and compare energy expenditure markers for WTC, reining and cutting. Energy expenditure of reining and cutting, two sports commonly believed to be more intense than the traditional gaits, had never been measured prior to this study. This study also attempted to provide information on the relationship between horseback riding and health benefits of exercise. The present study confirms the popular belief that reining and cutting are more physically intense (rates) than WTC and that health benefits could be obtained through riding as long as the correct intensities were upheld.

Previous studies indicate that intensity of the exercise increases as gait increases was supported by the current study (Westerling, 1983; Douglas et al., 2012). An increase in energy expenditure above that of WTC was observed when reining or cutting was measured. The energy expenditure per minute and METs (means) all increased as gait increased, but were considerably lower than those reported in previous studies measurements. This could be due to many factors including subject pool and variability as well as horse breed choice and other parameters. The differences across previous and the current studies makes it impossible to pinpoint a cause for inconsistencies.

The regression analysis of the data was another novel addition to previous information on horseback riding. However, the efficacy of the information provided by the analyses may be less than desired. The small sample size and limited variability amongst the predictors indicates that the results may be skewed by outliers or other

circumstances. Research with much larger subject pools would be needed to make useful and accurate predictors and equations for horseback riding and its numerous disciplines.

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APPENDIX A

Peak and Mean for all parameters for cutting, reining, walk, trot, long trot, and canter.

Measure	Treatment (Test)						Anova	
	Cutting	Reining	Walk	Trot	Long Trot	Canter	F Value	P Value
Total EE, Kcal	11.1384 ± 1.9094 ^a	33.2853 ± 1.9094 ^b	59.9619 ± 1.9094 ^c	41.0369 ± 1.9094 ^d	59.7746 ± 1.9094 ^c	34.3433 ± 1.9094 ^b	156.03	<0001
EE per min, Kcal/min								
Peak EE per min, Kcal/min	7.5841 ± 3.258 ^{ae}	10.0853 ± 3.258 ^b	7.0074 ± 3.258 ^c	4.1973 ± 3.258 ^d	7.4820 ± 3.258 ^{ae}	7.7910 ± 3.258 ^e	70.62	<0001
Mean EE per min, Kcal/min	4.9754 ± 2.144 ^a	6.9557 ± 2.144 ^b	3.0371 ± 2.144 ^c	3.4567 ± 2.144 ^d	6.1978 ± 2.144 ^e	6.9002 ± 2.144 ^b	172.99	<0001
MET								
Peak MET	6.9717 ± 2.739 ^a	8.9227 ± 2.739 ^b	6.1663 ± 2.739 ^c	3.8016 ± 2.739 ^d	6.7048 ± 2.739 ^a	6.9370 ± 2.739 ^a	74.94	<0001
Mean MET	4.5295 ± 1.798 ^a	6.1193 ± 1.798 ^b	2.6684 ± 1.798 ^c	3.1081 ± 1.798 ^d	5.5876 ± 1.798 ^e	6.1207 ± 1.798 ^b	176.85	<0001
HR, beats/min								
Peak Hr, beats/min	156.50 ± 4.4289 ^a	179.15 ± 4.4289 ^b	160.50 ± 4.4289 ^{abd}	141.00 ± 4.4289 ^c	160.20 ± 4.4289 ^{ad}	165.60 ± 4.4289 ^d	29.46	<0001
Mean HR, beats/min	146.88 ± 4.2926 ^a	163.28 ± 4.2926 ^b	120.58 ± 4.2926 ^c	125.54 ± 4.2926 ^d	146.21 ± 4.2926 ^a	156.64 ± 4.2926 ^e	100.01	<0001
Ve, l/min								
Peak Ve, l/min	44.0420 ± 2.1034 ^a	66.5605 ± 2.1034 ^b	48.0538 ± 2.1034 ^{abd}	29.0051 ± 2.1034 ^c	46.2679 ± 2.1034 ^a	51.7754 ± 2.1034 ^d	71.22	<0001
Mean Ve, l/min	32.1073 ± 1.6510 ^a	49.1413 ± 1.6510 ^b	21.7790 ± 1.6510 ^c	24.4099 ± 1.6510 ^c	37.8929 ± 1.6510 ^d	46.0325 ± 1.6510 ^e	108.86	<0001
Rf, Breaths/min								
Peak Rf, breaths/min	55.5282 ± 2.4267 ^a	59.7717 ± 2.4267 ^a	42.2947 ± 2.4267 ^{bc}	38.1857 ± 2.4267 ^b	40.5434 ± 2.4267 ^b	45.8995 ± 2.4267 ^c	29.35	<0001
Mean Rf, breaths/min	38.8525 ± 1.6282 ^a	42.0954 ± 1.6282 ^b	24.511 ± 1.6282 ^c	29.9157 ± 1.6282 ^d	33.3265 ± 1.6282 ^e	40.6495 ± 1.6282 ^{ab}	79.69	<0001
VO ₂ , ml/min								
Peak VO ₂ , ml/min	1606.55 ± 78.8598 ^a	1954.42 ± 78.8598 ^b	1406.15 ± 78.8598 ^c	859.91 ± 78.8598 ^d	1526.98 ± 78.8598 ^{ac}	1576.10 ± 78.8598 ^a	33.85	<0001
Mean VO ₂ , ml/min	1043.19 ± 52.58 ^a	1335.91 ± 52.58 ^{cd}	611.25 ± 52.58 ^b	703.94 ± 52.58 ^b	1273.81 ± 52.58 ^c	1394.09 ± 52.58 ^d	80.74	<0001
VCO ₂ , ml/min								
Peak VCO ₂ , ml/min	1220.51 ± 62.7513 ^a	1911.70 ± 62.7513 ^b	1369.71 ± 62.7513 ^c	780.27 ± 62.7513 ^d	1396.10 ± 62.7513 ^{ce}	1504.22 ± 62.7513 ^e	67.42	<0001
Mean VCO ₂ , ml/min	833.56 ± 40.3479 ^a	1326.45 ± 40.3479 ^b	586.89 ± 40.3479 ^c	642.78 ± 40.3479 ^c		1316.98 ± 40.3479 ^b	159.18	<0001
RelVO ₂ , ml · kg ⁻¹ · min ⁻¹								
Peak RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	24.0743 ± 1.1655 ^a	29.1401 ± 1.1655 ^b	21.3805 ± 1.1655 ^c	13.1499 ± 1.1655 ^d	23.1799 ± 1.1655 ^{ac}	24.0326 ± 1.1655 ^a	31.2	<0001
Mean RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	15.6458 ± 0.7184 ^a	21.1666 ± 0.7184 ^b	9.2305 ± 0.7184 ^c	10.75 ± 0.7184 ^c	19.3084 ± 0.7184 ^d	21.1945 ± 0.7184 ^b	67.11	<0001

abcdef Differing subscripts indicate significant differences

Peak and mean for all parameters for cutting, reining, and 45 min walk-trot-canter (WTC).

Measure	Treatment (Test)			Anova	
	Cutting	Reining	WTC	F Value	P Value
Total EE, Kcal	11.1384 ± 3.8328 ^a	33.2853 ± 3.8328 ^b	194.72 ± 3.8328 ^c	807.52	<.0001
EE per min, Kcal/min					
Peak EE per min, Kcal/min	7.5841 ± .3846 ^a	10.0853 ± .3846 ^b	7.9907 ± .3846 ^a	29.53	<.0001
Mean EE per min, Kcal/min	4.9754 ± .2302 ^a	6.9557 ± .2302 ^b	4.2689 ± .2302 ^c	100.32	<.0001
MET					
Peak MET	6.9717 ± .2899 ^a	8.9227 ± .2899 ^b	7.1248 ± .2899 ^a	24.61	<.0001
Mean MET	4.5295 ± .1631 ^a	6.1193 ± .1631 ^b	3.8088 ± .1631 ^c	115.68	<.0001
HR, beats/min					
Peak Hr, beats/min	156.50 ± 3.9167 ^a	179.15 ± 3.9167 ^b	168.55 ± 3.9167 ^c	41.16	<.0001
Mean HR, beats/min	146.88 ± 4.1531 ^a	163.28 ± 4.1531 ^b	131.51 ± 4.1531 ^c	97.53	<.0001
Ve, Breaths/min					
Peak Ve, l/min	44.0420 ± 2.3326 ^a	66.5605 ± 2.3326 ^b	52.5562 ± 2.3326 ^c	49.73	<.0001
Mean Ve, l/min	32.1073 ± 1.8465 ^a	49.1413 ± 1.8465 ^b	28.6871 ± 1.8465 ^a	75.89	<.0001
Rf, Breaths/min					
Peak Rf, breaths/min	55.5282 ± 2.6606 ^a	59.7717 ± 2.6606 ^a	47.9501 ± 2.6606 ^b	13.91	<.0001
Mean Rf, breaths/min	38.8525 ± 1.5570 ^a	42.0954 ± 1.5570 ^b	29.6639 ± 1.5570 ^c	97.02	<.0001
VO ₂ , ml/min					
Peak VO ₂ , ml/min	1606.55 ± 79.3042 ^a	2054.23 ± 79.3042 ^b	1620.22 ± 79.3042 ^a	25.45	<.0001
Mean VO ₂ , ml/min	1043.19 ± 47.5247 ^a	1405.68 ± 47.5247 ^b	865.94 ± 47.5247 ^c	95.84	<.0001
VCO ₂ , ml/min					
Peak VCO ₂ , ml/min	1220.51 ± 72.0231 ^a	1911.70 ± 72.0231 ^b	1545.01 ± 72.0231 ^c	48.4	<.0001
Mean VCO ₂ , ml/min	833.56 ± 43.1540 ^a	1326.45 ± 43.1540 ^b	797.76 ± 43.1540 ^a	106.65	<.0001
RelVO ₂ , ml · kg ⁻¹ · min ⁻¹					
Peak RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	24.0743 ± 1.0304 ^a	30.8327 ± 1.0304 ^b	24.6725 ± 1.0304 ^a	24.24	<.0001
Mean RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	15.6458 ± .5857 ^a	21.1666 ± .5857 ^b	13.1248 ± .5857 ^c	110.28	<.0001

^{a,b,c,d}Differing subscripts indicate significant differences

Peak and Mean for all parameters for cutting, reining, and the last two min of walk, trot, long trot and canter.

Measure	Cutting	Reining	Walk	Trot	Long Trot	Canter
EE per min, Kcal/min						
Peak EE per min, Kcal/min	7.5841 ± 0.3052 ^a	10.0853 ± 0.3052 ^b	2.9184 ± 0.3052 ^c	3.9206 ± 0.3052 ^d	7.4628 ± 0.3052 ^a	7.6903 ± 0.3052 ^a
Mean EE per min, Kcal/min	4.9754 ± 0.2113 ^a	6.9557 ± 2.113 ^b	2.3427 ± 0.2113 ^c	3.4926 ± 0.2113 ^d	6.8978 ± 0.2113 ^b	6.9334 ± 0.2113 ^b
MET						
Peak MET	6.9717 ± 0.27 ^a	8.9227 ± 0.279 ^b	2.5461 ± 0.27 ^c	3.5319 ± 0.27 ^d	6.6772 ± 0.27 ^a	6.6099 ± 0.27 ^a
Mean MET	4.5295 ± 0.2141 ^a	6.1193 ± 0.2141 ^b	2.0103 ± 0.2141 ^c	3.1525 ± 0.2141 ^d	6.1854 ± 0.2141 ^b	5.9635 ± 0.2141 ^b
HR, beats/min						
Peak HR, beats/min	156.50 ± 4.6312 ^a	179.15 ± 4.6312 ^b	125.75 ± 4.6312 ^c	136.7 ± 4.6312 ^d	157.45 ± 4.6312 ^a	164.95 ± 4.6312 ^e
Mean HR, beats/min	146.88 ± 4.4033 ^a	163.28 ± 4.4033 ^b	114.95 ± 4.4033 ^c	126.86 ± 4.4033 ^d	152.14 ± 4.4033 ^{a,e}	156.89 ± 4.4033 ^e
Ve, l/min						
Peak Ve, l/min	44.0420 ± 21.945 ^a	66.5605 ± 1.945 ^b	22.7759 ± 1.945 ^c	27.4441 ± 1.945 ^d	46.1668 ± 1.945 ^a	51.112 ± 1.945 ^e
Mean Ve, l/min	32.1073 ± 1.73 ^a	49.1413 ± 1.73 ^b	17.62 ± 1.648 ^c	24.73 ± 1.73 ^d	42.96 ± 1.73 ^e	45.63 ± 1.73 ^e
RF, breaths/min						
Peak RF, breaths/min	55.5282 ± 2.722 ^a	59.7717 ± 2.722 ^a	27.3222 ± 2.722 ^b	37.3271 ± 2.722 ^c	38.4339 ± 2.722 ^c	45.7632 ± 2.722 ^d
Mean RF, breaths/min	38.8525 ± 1.7086 ^a	42.0954 ± 1.7086 ^b	22.8999 ± 1.7086 ^c	31.0069 ± 1.7086 ^d	35.0461 ± 1.7086 ^e	41.5106 ± 1.7086 ^b
VO ₂ , ml/min						
Peak VO ₂ , ml/min	1606.55 ± 62.6808 ^a	2054.23 ± 62.6808 ^b	579.92 ± 62.6808 ^c	801.81 ± 62.6808 ^d	1519.22 ± 62.6808 ^a	1548.94 ± 62.6808 ^a
Mean VO ₂ , ml/min	1043.19 ± 45.5434 ^a	1405.68 ± 45.5434 ^b	472.43 ± 45.5434 ^c	712.37 ± 45.5434 ^d	1408.67 ± 45.5434 ^b	1399.33 ± 45.5434 ^b
VCO ₂ , ml/min						
Peak VCO ₂ , ml/min	1220.51 ± 58.3519 ^a	1911.70 ± 58.3519 ^b	596.08 ± 58.3519 ^c	730.68 ± 58.3519 ^d	1395.78 ± 58.3519 ^e	1494.11 ± 58.3519 ^e
Mean VCO ₂ , ml/min	833.56 ± 41.7919 ^a	1326.45 ± 41.7919 ^b	449.82 ± 41.7919 ^c	640.35 ± 41.7919 ^d	1280.55 ± 41.7919 ^b	1329.01 ± 41.7919 ^b
RelVO ₂ , ml · kg ⁻¹ · min ⁻¹						
Peak RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	24.5987 ± 0.8931 ^a	30.8327 ± 0.8931 ^b	8.8021 ± 0.8931 ^c	12.2169 ± 0.8931 ^d	23.0674 ± 0.8931 ^a	23.5987 ± 0.8931 ^a
Mean RelVO ₂ , ml · kg ⁻¹ · min ⁻¹	15.6458 ± 0.6986 ^a	21.3774 ± 0.6986 ^b	7.1174 ± 0.6986 ^c	10.8744 ± 0.6986 ^d	21.3774 ± 0.6986 ^b	21.304 ± 0.6986 ^b

^{abcd}Differing subscripts indicate significant differences