



Oxygen cost of recreational horse-riding in females

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1 **Oxygen cost of recreational horse-riding in females**

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Abstract

Background: The purpose of this study was to characterize the physiological demands of a riding session comprising different types of recreational horse riding in females. **Methods:** Sixteen female recreational riders (aged 17-54 years) completed an incremental cycle ergometer exercise test to determine peak oxygen consumption (VO_{2peak}) and a 45 minute riding session based upon a British Horse Society Stage 2 riding lesson (including walking, trotting, cantering and work without stirrups). Oxygen consumption (VO_2), from which metabolic equivalent (MET) and energy expenditure values were derived, was measured throughout. **Results:** The mean VO_2 requirement for trotting/cantering ($18.4 \pm 5.1 \text{ ml.kg}^{-1}.\text{min}^{-1}$; $52 \pm 12\% \text{ } VO_{2peak}$; $5.3 \pm 1.1 \text{ METs}$) was similar to walking/trotting ($17.4 \pm 5.1 \text{ ml.kg}^{-1}.\text{min}^{-1}$; $48 \pm 13\% \text{ } VO_{2peak}$; $5.0 \pm 1.5 \text{ METs}$) and significantly higher than for work without stirrups ($14.2 \pm 2.9 \text{ ml.kg}^{-1}.\text{min}^{-1}$; $41 \pm 12\% \text{ } VO_{2peak}$; $4.2 \pm 0.8 \text{ METs}$) ($P = 0.001$). **Conclusions:** The oxygen cost of different activities typically performed in a recreational horse riding session meets the criteria for moderate intensity exercise (3-6 METs) in females, and trotting combined with cantering imposes the highest metabolic demand. Regular riding could contribute to the achievement of the public health recommendations for physical activity in this population.

Introduction

Physical activity guidelines for health promotion recommend that all healthy adults aged 18-65 years should aim to take part in at least 150 minutes of moderate intensity aerobic activity each week, or at least 75 minutes of vigorous-intensity aerobic activity each week, or equivalent combinations of moderate and vigorous intensity aerobic activities.¹⁻³ Exercise intensity may be expressed as an absolute measure, for example metabolic equivalents (METs) where one MET is equivalent to oxygen consumption (VO_2) at rest ($3.5 \text{ ml.O}_2.\text{kg}^{-1}.\text{min}^{-1}$), or as a relative measure such as percentage of maximal oxygen consumption ($\text{VO}_{2\text{max}}$). A perceptual scale such as Borg's Rating of Perceived Exertion (RPE)⁴ may also be used as a subjective measure of intensity. In terms of energy expenditure, one MET is also expressed as a standard resting metabolic rate of $1.0 \text{ kcal (4.184 kJ).kg}^{-1}.\text{h}^{-1}$.⁵ Moderate intensity physical activity is categorized as 3-6 METS, 40-60% $\text{VO}_{2\text{max}}$ or an RPE of 12-13.^{2,6} Vigorous intensity exercise is 6-9 METs, 60-85% $\text{VO}_{2\text{max}}$ or RPE of 14-16.

In addition to popular activities such as walking and cycling, a wide variety of leisure, household and occupational activities performed at a moderate intensity may contribute to individuals achieving the recommended amount of physical activity. However, some popular leisure activities, for example golf and some Nintendo Wii sports, may not be of a sufficient intensity to offer health benefits.^{7,8} Horse riding as a leisure pursuit offers an opportunity to increase physical activity. It has been identified as one of several "green exercises" (activities involving contact with the natural environment and green space) that promote good health by improving self-esteem and mood.⁹ Psychotherapeutic benefits from horse riding therapy have also been observed.¹⁰ In the UK, there are more than 430 riding clubs affiliated to the British Horse Society, which has over 34,000 members. In a survey of 1,248 recreational horse riders, 68% respondents said that they exercised at a moderate intensity for 30

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2 51 minutes at least 3 times per week by horse riding and/or associated activities (e.g. grooming and
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4 52 mucking-out).¹¹ Over a third indicated that horse riding was the only form of physical activity that they
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7 53 had participated in during the preceding 4 weeks. Ninety three percent of respondents were female, and
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9 54 half of these were aged 45 or above, a population group for whom physical activity levels are generally
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11 55 low.¹² Similarly a major national survey shows that the gender (90% female) and age profile (a large
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14 56 proportion of over 45 year olds) of equestrianism is not matched by any other sport in the UK.¹³
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18 58 There is at present limited and, indeed, conflicting empirical evidence to show if the physiological
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21 59 demands of recreational horse riding are likely to confer health benefits. The Compendium of Physical
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23 60 Activities^{5,14} includes MET intensity levels for specific physical activities and is used to identify
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26 61 examples of moderate and vigorous intensity activities and to evaluate the contributions of various
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28 62 types of physical activity to daily energy expenditure. The value for general horseback riding is given
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30 63 as 5.5 METs, based on data averaged from walking (3.8 METs), trotting (5.8 METs) and cantering or
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33 64 galloping (7.3 METs). These values may not represent the physiological demand of recreational horse-
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35 65 riding in females as they are derived from indirect calorimetry measurements taken several decades ago
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37 66 in a small number of young male soldiers¹⁵, Guatemalan male peasants performing agricultural
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40 67 activities¹⁶, and more recently in five experienced competitive riders of whom only three were
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42 68 female.¹⁷
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46 70 Technical innovation in the development of portable gas analysis systems has enabled the valid
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49 71 measurement of expired air and energy expenditure in the field during different physical activities.¹⁸⁻²⁰
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52 72 In addition to the aforementioned study¹⁷, two other studies have assessed the physiological demands
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54 73 of horse riding. In sixteen female equestrian athletes participating in a simulated one day event
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56 74 competition, VO_2 was equivalent to 6 METs ($20.4 \pm 4 \text{ ml.kg}^{-1}.\text{min}^{-1}$) during dressage, 8 METS ($28.1 \pm$
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2 75 4.2 ml.kg⁻¹.min⁻¹) during show jumping and 9 METS (31.2 ± 6.6 ml. kg⁻¹.min⁻¹) during cross country.²¹
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4 76 There was variability in the oxygen cost between riders performing in the same simulated competition
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7 77 but riding different horses. An earlier study of thirteen experienced and three elite horse riders reported
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9 78 that the intensity of walking, trotting and cantering ranged from 40-80% VO_{2max}, with walking and
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11 79 trotting fitting with the classification of moderate intensity, and cantering vigorous intensity (> 60%
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13 80 VO_{2max}.²²
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18 82 The above studies provide information about competitive equestrianism, but the physiological demands
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21 83 of modern-day recreational riding and its potential contribution to health-related energy expenditure is
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23 84 not well-documented. A three month training programme of moderate intensity simulated mechanical
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25 85 horse riding improved metabolic health in middle-aged and elderly individuals with type II diabetes.²³
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28 86 ²⁴ However, in younger healthy females with higher baseline fitness a 14 week horse riding training
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30 87 programme did not provide an adequate stimulus to improve health and fitness.²⁵
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35 89 The purpose of this study was to characterize the physiological demands of different types of horse
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37 90 riding in females during a recreational horse riding session. A secondary aim was to ascertain whether
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40 91 the intensity of the different riding activities was sufficient to be classed as at least 'moderate' (≥ 3
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42 92 METS) and could therefore contribute to the current physical activity for health recommendations.
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Methods

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Participants

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Oxygen cost of recreational horse-riding

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2 98 Twenty mixed-ability female recreational horse riders aged between 17 and 54 years were recruited
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4 99 from the population of students and staff on University-based Equine Studies-related courses. The
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7 100 participants were limited to volunteers with no known cardiovascular/pulmonary disease, pregnancy,
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9 101 metabolic disorders or contraindications to exercise as determined by a medical questionnaire. Nine
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11 102 participants were categorised as novice riders (< 2 years' experience) and seven as experienced riders
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13 (> 2 years' experience). Eight individuals were categorised as "very active" (> 6 hr.week⁻¹ activity ≥
14 103 moderate intensity, seven as "active" (3-6 hr.week⁻¹ activity ≥ moderate intensity) and one as
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16 104 "moderately active" (1-3 hr.week⁻¹ activity ≥ moderate intensity). Participation in recreational horse
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18 105 riding (including similar activities to those described below under "Horse Riding Session") was
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21 106 between one and seven hours per week (mean 4 ± 1 hr.week⁻¹). Prior to enrolment in the study,
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23 107 participants were provided with verbal and written explanations of the purpose, procedures, possible
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25 108 benefits, risks and discomforts associated with participation. Following this full explanation, written
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27 109 informed consent was obtained, in addition to written parental consent for volunteers aged under 18
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29 110 years. The study was granted institutional ethical approval and was conducted in accordance with the
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31 111 Declaration of Helsinki.
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40 114 Laboratory procedures took place during one visit to the University Human Performance Laboratory,
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42 115 followed 1-2 weeks later by a horse riding session in an equestrian centre.
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Anthropometry

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51 119 Participants visited the Laboratory having refrained from eating for at least two hours, and from heavy
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53 120 exercise and alcohol consumption for 24 hours. Height (m) and weight (kg) were measured using
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55 121 calibrated scales and a stadiometer (Detecto, USA). Body mass index (BMI) was calculated by
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2 122 dividing body mass by the square of the subjects' height. Skinfold thickness was measured to the
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4 123 nearest 0.2 mm at iliac crest, subscapular, triceps, and biceps skinfold sites and used to calculate body
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7 124 density.²⁶ Percentage body fat was estimated from body density values using the Siri equation.²⁷
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Laboratory cycle ergometer test

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16 128 Participants performed a maximal incremental cycling test on an SRM cycle ergometer (Schroberer
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18 129 Rad Messtechnik, Weldorf, Germany). Following a 5 minute warm-up at an intensity of 50 Watts (W),
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21 130 starting power was set to 90 W or 100 W with increments of 10 W.min⁻¹ or 13 W.min⁻¹ respectively
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23 131 for older/less active or younger/more active participants respectively.²⁸ All participants were
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26 132 encouraged to continue cycling until volitional exhaustion. Expired air was analysed using a portable
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28 133 indirect calorimetry gas-exchange system (MetaMax®3X, Cortex Biophysik, Leipzig, Germany). This
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31 134 consists of a processing unit containing oxygen and carbon dioxide analysers and a battery pack, both
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33 135 worn by participants in a harness on the chest (weight = 1.5 kg) and a facemask (Hans Rudolph,
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35 136 Kansas City, USA) containing a turbine flow meter and a sample line connected to the processing unit.
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38 137 The recommended calibration procedure was conducted prior to each laboratory test. Gas sensors were
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40 138 calibrated against known concentration gases, respiratory volumes were calibrated using a 3 L syringe,
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42 139 and ambient air measurements were conducted repeatedly. VO₂ was averaged over a 10 second
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45 140 period, and VO_{2peak} was calculated as the highest value from a 30s rolling average during the final stage
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47 141 of the test. VO_{2peak} was also expressed as a percentage of predicted value.²⁹
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Horse riding session

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Oxygen cost of recreational horse-riding

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2 145 Participants completed a standardised 45 minute horse riding session lead by a qualified instructor at an
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4 146 indoor equestrian centre. The session protocol was based on a British Horse Society Stage 2 riding
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7 147 lesson (Table 1) aimed at intermediate level recreational riders. This followed the “English” rather than
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9 148 “Western” style of riding and included the posting trot, where riders rise and sit in rhythm with the
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11 149 horse’s stride. 4 different horses were used. These were selected on the basis of similar +/- 1 inch in
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14 150 height and similar temperament. All horses were familiar with the environment, and the riders were
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16 151 familiar with riding these horses.

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21 153 RPE was recorded at 15 minute intervals without disruption to the horse riding session. Expired air
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23 154 was analysed continuously throughout the 45 minute protocol via the same MetaMax®3X portable
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26 155 metabolic measurement system used in the laboratory test, which was calibrated using ambient air prior
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28 156 to every horse riding session. Respiratory gas parameters were collected for each breath and data were
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31 157 averaged over 10s. Average values were calculated for VO_2 , carbon dioxide production (VCO_2),
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33 158 respiratory exchange ratio (RER) and minute ventilation (V_E) and energy expenditure ($kcal \cdot min^{-1}$) for
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35 159 the 45 minutes session. Average values were also calculated for the walk and trot work (5-15 min), trot
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38 160 and canter work (15-25 min), and work without stirrups (25-35 min) sections of the session.

Data Analysis

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47 164 Data were analysed using IBM SPSS Statistics for Windows, Version 20. (Armonk, NY: IBM Corp.)
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49 165 Descriptive data is reported as mean \pm standard deviation. To determine the intensity of the different
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52 166 types of horse riding, VO_2 was expressed as METs. VO_2 was also calculated as a percentage of
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54 167 individual VO_{2peak} values determined from the laboratory test, and energy expenditure ($kcal \cdot min^{-1}$) was
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56 168 estimated from VO_2 values using the energy release for VO_2 constant of 4.9 kcal per 1 L O_2 .³⁰ VO_2 and
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2 169 intensity were compared for the different riding activities and level of experience using a 3 x 2 factorial
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4 170 ANOVA with post hoc Bonferroni comparisons. Pearson's correlational analysis was used to examine
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7 171 the relationship between oxygen cost and age, body mass, % body fat, riding frequency and fitness.
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Results

Twenty participants visited the Laboratory and completed the cycle ergometer test. Four participants did not complete the study as they were unable to attend the riding session. Participant characteristics are presented in Table 2. Test termination was due to volitional exhaustion in all participants. Peak power output was 180 ± 26 W, peak RPE 19 ± 1 and peak RER 1.16 ± 0.09 . Table 3 presents the data for the different horse-riding activities performed during the session. There was a significant within-subjects effect in the comparison of oxygen cost between the walk/trot, trot/canter and work without stirrups sections of the riding session ($P = 0.034$, partial $\eta^2 = 0.265$, observed power = 0.69). Post hoc tests identified that the “trot/canter” activity was significantly higher than the “without stirrups” activity ($P = 0.001$). Similarly $\%VO_{2\text{peak}}$ and METS and energy expenditure values were all significantly higher during “trot/canter” than “without stirrups” ($P < 0.05$). There was a significant within-subjects effect for RPE between the different riding activities ($P = 0.032$), but the post hoc follow up tests were not significant. There were no differences in oxygen cost, intensity or RPE between experienced and novice riders. Figure 1 displays mean MET values averaged over each minute of riding session. Over the whole 45 minute riding session average METs were 4.6 ± 0.9 , RPE was 13 ± 2 and energy expenditure was 241 ± 73 kcal. There were no significant correlations between age, body mass, % body fat, riding frequency or fitness and oxygen cost, with the exception of BMI and % body fat which were positively related to the oxygen cost of work without stirrups ($r = 0.688$, $P = 0.009$ and $r = 0.662$, $P = 0.009$ respectively).

Discussion

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2 198 The purpose of this study was to characterize the physiological demands of different activities during a
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4 199 recreational horse-riding session, and to ascertain whether the intensity could be classed as at least
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7 200 moderate. In a group of female riders the average MET value was 5.0 for walking combined with
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9 201 trotting, 5.3 for trotting combined with cantering, and 4.2 for riding without stirrups. These
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11 202 recreational horse riding activities therefore conform to the classification for moderate intensity activity
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14 203 (3–6 METs), and may contribute to health-related physical activity benefits.^{2,6} Mean % VO_{2peak} for the
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16 204 different riding activities exceeded the 40% VO_{2max} threshold commonly used as the lower threshold to
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18 205 define moderate exercise, while perception of effort was within or higher than the associated RPE
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21 206 range of 11-13. Trotting/cantering induced a significantly higher metabolic cost than exercising
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23 207 without stirrups, but did not classify as vigorous exercise (> 6 METs), and was lower than the 5.8 and
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26 208 7.3 METs for trotting and cantering/galloping respectively reported in the updated Compendium of
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28 209 Physical Activities.^{5, 14} None of the riding activities performed by our recreational female riders
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30 210 reached the Compendium's 5.5 METs for general horse riding, derived by averaging the METs for
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33 211 walking (3.8), trotting (5.8) and cantering/galloping (7.3), based on data collected several decades ago
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35 212 from male soldiers and Guatemalan agricultural workers^{15,16}, and more recently in 5 competitive riders
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37 213 of whom 3 were female.¹⁷

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42 215 The latter study by Devienne and Guezenne (2000) measured energy expenditure during dressage and
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45 216 jumping activities, and reported METs of 3 for walking, 7 for trotting, 9 for cantering and 11 for
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47 217 jumping.¹⁷ Averaging the walking and trotting values gives 5 METs, which matches the walk/trot
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49 218 METs in our study. It is also interesting that trotting elicited an intensity of $48 \pm 14\%$ VO_{2max} in the
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51 219 competitive dressage riders, matching the $48 \pm 13\%$ VO_{2peak} for the walk/trot section in our study. The
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54 220 reason for the matching intensities in terms of % VO_{2max} despite the higher absolute energy cost in
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56 221 Devienne and Guezenne's study is that their riders were more aerobically trained, with average VO_{2max}
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values of $55 \text{ ml.kg}^{-1}.\text{min}^{-1}$ compared with $37 \text{ ml.kg}^{-1}.\text{min}^{-1}$ $\text{VO}_{2\text{peak}}$ in our riders. Nevertheless, our riders were fitter than average, with $\text{VO}_{2\text{peak}}$ values 19% higher than predicted, and all but one were categorised as active or very active. In both studies there is a high degree of variability in exercise intensity among riders for the same activity, both in terms of METS and % $\text{VO}_{2\text{max}}$. For example, the standard deviation around the mean METs was ± 1.5 for walking/trotting in our study and trotting in their study. This variability is higher than in other studies measuring the metabolic cost of household, garden and recreational activities in older individuals, for example sweeping (4.1 ± 0.7 METs), lawn-mowing (5 ± 0.7 METs) and golfing (2.8 ± 0.5 METs).^{7, 31}

Individual differences in the oxygen cost of movement can be explained by factors including age, body mass, environmental conditions, fitness or mechanical efficiency. Differences in riding experience, technique, and motivation towards the task may also contribute to the inter-individual differences for the same riding activity. In experienced and elite riders, the reported oxygen cost of trotting and cantering is approximately 70% higher than in our group of recreational riders.^{21,22} We did not detect any differences in physiological demand between novice and experienced riders, nor was age or fitness related to the oxygen cost of different activities. Higher body mass and percentage of body fat were positively related to oxygen cost, but only during work without stirrups.

Participants expended on average 241 ± 73 kcal during the 45 min session combining different riding activities, which they confirmed was representative of a typical ride for them, suggesting that they would have to repeat this 3-5 times per week to achieve the recommended 800-1200 kcal weekly energy expenditure.² Nevertheless, a 14 week intervention, during which similar horse-riding activities were performed 5 days per week, did not significantly improve health and physical fitness in similar sample of females.²⁵ The authors recommended that riding activity needs to be supplemented

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2 246 with alternative aerobic and load-bearing training in this population. The British Horse Society survey
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4 247 showed that recreational riders also participate in associated horse-care activities such as mucking out
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7 248 and grooming, which may also contribute to health-related energy expenditure and fitness
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9 249 improvements. In a recent field study, we measured ambulatory VO_2 in 8 females (18-47 yrs) during
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11 250 manure removal from a grazing paddock, mucking out a stable and grooming a horse (Beale et al,
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13 unpublished data). Physiological responses were similar for manure removal (4.9 ± 1.0 METs, $65 \pm$
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16 252 6% predicted maximal heart rate, RPE 11 ± 1) and mucking out (4.6 ± 1.2 METs, $67 \pm 5\%$ predicted
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19 253 maximal heart rate, RPE 12 ± 1), and lower for grooming (3.7 ± 0.9 METs, $65 \pm 9\%$ predicted maximal
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21 254 heart rate, RPE 9 ± 1). These data suggest that the additional activities associated with recreational
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23 255 horse riding are also of sufficient intensity to contribute to the achievement of the physical activity
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26 256 recommendations in females. However, further studies are needed to more fully characterise horse-
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28 257 riding as a recreational activity, exploring the physiological demands of habitual riding and horse-care
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31 258 activities in terms of type, frequency and duration, followed by a training study to confirm whether this
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33 259 translates into physiological health benefits. Recreational off-road vehicle riding has recently been
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35 260 examined from this perspective.^{32,33}

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40 262 The limitations of the current study are that the sample size is small and consists only of females,
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42 263 although this does reflect statistical evidence that the large majority of recreational horse-riders are
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45 264 women. However, the majority of our participants were younger than the over 45 yr old group that
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47 265 constitutes half of all recreational riders. MET values were based on the premise that 1 MET is
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49 266 equivalent to $3.5 \text{ ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in all individuals, a concept that has been challenged as
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52 267 overestimating the oxygen cost at rest.³⁴ Data collection was limited to a structured riding session in an
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54 268 indoor riding school, which may not reflect the oxygen cost and energy expenditure during typical
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56 269 recreational riding activities.

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4 271 **Conclusion**
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9 273 This study provides novel data on the physical demand of different recreational horse riding activities
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11 274 in females, and indicates that these activities meet the criteria for moderate intensity physical activity
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14 275 and may therefore contribute to public health guidelines. Future directions from this exploratory
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16 276 investigation would be to determine whether a period of regular horse-riding results in improvements in
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19 277 physical fitness, psychological well-being and quality of life indices.
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23 279 **Acknowledgements**
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26 280 We are grateful to Alex Kaley for her organisation of the data collection at the Equestrian Centre, and
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28 281 to the staff, students and horses who participated in this study.
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30 282
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References

1. World Health Organisation. Global recommendations on physical activity for health; 2010.
2. O'Donovan G, Blazeovich AJ, Boreham C, et al. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci.* 2010 28(6):573-91.
3. Department of Health. Physical Activity Guidelines in the UK: Review and Recommendations. London: Department of Health; 2010.
4. Borg G. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982;14(5):377-81.
5. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc.* 2000 Sep;32(9 Suppl):S498-504.
6. Norton K, Norton L, Sadgrove D. Position statement on physical activity and exercise intensity terminology. *J Sci Med Sport.* 2010 Sep;13(5):496-502.
7. Dear JB, Porter MM, Ready AE. Energy expenditure during golfing and lawn mowing in older adult men. *J Aging Phys Act.* 2010;18(2):185-200.
8. Willems M, Bond T. Comparison of Physiological and Metabolic Responses to Playing Nintendo Wii Sports and Brisk Treadmill Walking. *Journal of Human Kinetics.* 2009;22:43-9.
9. Pretty J, Peacock J, Hine R, Sellens M, South N, Griffin M. Green exercise in the UK countryside: Effects on health and psychological well-being, and implications for policy and planning. *Journal of Environmental Planning and Management.* 2007;50(2):211-31.
10. Burgon H. Case studies of adults receiving horse-riding therapy. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People & Animals.* 2003;16(3):263-76.
11. The British Horse Society. The health benefits of horse riding in the UK; 2011.
12. The Information Centre for Health and Social Care. Health Survey for England 2008. Leeds, UK; 2008.

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- 1
2 311 13. Sport England. Active People Survey (2010/11). 2010 [cited; Available from:
3
4 312 http://www.sportengland.org/research/active_people_survey/aps5.aspx
5
6
7 313 14. Ainsworth B, WL H, SD H, et al. Compendium of Physical Activities: a second update of codes
8
9 314 and MET values. *Med Sci Sports Exerc.* 2011;43(8):1575-81.
10
11 315 15. Passmore A, Durnin J. Human Energy Expenditure. *Phys Rev.* 1955;35(4):801-40.
12
13
14 316 16. Viteri FE, Torún B, Galicia JC, Herrera E. Determining energy costs of agricultural activities by
15
16 317 respirometer and energy balance techniques. *Am J Clin Nut.* 1971;24(12):1418-30.
17
18
19 318 17. Devienne MF, Guezennec CY. Energy expenditure of horse riding. *Eur J Appl Physiol.* 2000;82(5-
20
21 319 6):499-503.
22
23 320 18. Meyer T, Davison RCR, Kindermann W. Ambulatory gas exchange measurements - Current status
24
25
26 321 and future options. *Int J Sports Med.* 2005;26:S19-S27.
27
28 322 19. Leonard WR. Laboratory and field methods for measuring human energy expenditure. *Am J Hum*
29
30 323 *Biol.* 2012;24(3):372-84.
31
32
33 324 20. Graves LE, Ridgers ND, Stratton G. The contribution of upper limb and total body movement to
34
35 325 adolescents' energy expenditure whilst playing Nintendo Wii. *Eur J Appl Physiol.* 2008;104(4):617-23.
36
37
38 326 21. Roberts M, Shearman J, Marlin D. A comparison of the metabolic cost of the three phases of the
39
40 327 one-day event in female collegiate riders. *Comparative Exercise Physiology.* 2009;6:129-35.
41
42 328 22. Westerling D. A study of physical demands in riding. *Eur J Appl Physiol Occup Physiol.*
43
44
45 329 1983;50(3):373-82.
46
47 330 23. Kubota M, Nagasaki M, Tokudome M, Shinomiya Y, Ozawa T, Sato Y. Mechanical horseback
48
49 331 riding improves insulin sensitivity in elder diabetic patients. *Diabetes Res Clin Pract.* 2006
50
51
52 332 Feb;71(2):124-30.
53
54
55
56
57
58
59
60

- 1
2 333 24. Hosaka Y, Nagasaki M, Bajotto G, Shinomiya Y, Ozawa T, Sato Y. Effects of daily mechanical
3
4 334 horseback riding on insulin sensitivity and resting metabolism in middle-aged type 2 diabetes mellitus
5
6
7 335 patients. *J Med Sci.* 2010;72(3-4):129-37.
8
9 336 25. Meyers MC. Effect of equitation training on health and physical fitness of college females. *Eur J*
10
11 337 *Appl Physiol.* 2006;98(2):177-84.
12
13
14 338 26. Durnin JV, Womersley J. Body fat assessed from total body density and its estimation from
15
16 339 skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr.*
17
18 340 1974;32(1):77-97.
19
20
21 341 27. Siri WE. Body composition from fluid spaces and density. (1961). In: *Techniques For Measuring*
22
23 342 *Body Composition*, J. Brozek and A. Henschel (Eds.). Washington DC, USA: National Academy of
24
25 343 Sciences National Research Council.; 1961.
26
27
28 344 28. British Association of Sport and Exercise Science. Guidelines for the physiological testing of
29
30 345 athletes. Leeds, UK: BASES; 1997.
31
32
33 346 29. Jones NL, Makrides L, Hitchcock C, Chypchar T, McCartney N. Normal standards for an
34
35 347 incremental progressive cycle ergometer test. *Am Rev Respir Dis.* 1985 May;131(5):700-8.
36
37
38 348 30. McArdle W, Katch F, Katch V. *Sports & Exercise Nutrition.* Baltimore, USA. 1999.
39
40 349 31. Gunn SM, Brooks AG, Withers RT, Gore CJ, Plummer JL, Cormack J. The energy cost of
41
42 350 household and garden activities in 55-to 65-year-old males. *Eur J Appl Physiol.* 2005;94(4):476-86.
43
44
45 351 32. Burr JF, Jamnik, VK, Shaw, JA, Gledhill, N. Physiological demands of off-road vehicle riding.
46
47 352 *Med Sci Sports Exerc.* 2010 42(7): 1345-54
48
49 353 33. Burr JF, Jamnik, VK, Gledhill, N. Physiological fitness and health adaptations from purposeful
50
51 354 training using off-road vehicles. *Eur J Appl Physiol.* 2011; 111(8):1841-50
52
53
54 355 34. Byrne N, Hills A, Hunter G, Weinsier R, Schutz Y. Metabolic equivalent: one size does not fit all. *J*
55
56 356 *Appl Physiol.* 2005;99(3):1112-9.
57
58
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For Peer Review

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359 Table 1: Horse-Riding Protocol

Time	Activity
0 - 5 min	Walk warm up
5 - 15 min	Walk and trot
15- 25 min	Trot and canter work
25 - 35 min	Work without stirrups - sitting
35 - 45 min	Cool down

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Oxygen cost of recreational horse-riding

Table 2. Descriptive characteristics of participants (n = 16, female)

Variable	Mean \pm SD	Range
Age (yr)	25 \pm 11	17 - 54
Height (m)	1.63 \pm 0.05	1.51 - 1.74
Weight (kg)	66.2 \pm 17.1	45.1 - 109.0
BMI (kg.m ²)	24.7 \pm 5.4	17.6 - 37.7
Body fat (%)	30.6 \pm 6.4	20.2 - 44.8
VO _{2peak} (L.min ⁻¹)	2.407 \pm 0.519	1.741 - 3.459
VO _{2peak} (ml.kg ⁻¹ .min ⁻¹)	37.2 \pm 7.4	29.1 - 56.8
VO _{2peak} as % predicted value	119 \pm 30	79 - 182

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Table 3: Mean \pm SD values for absolute and relative oxygen consumption (VO_2), percentage of peak oxygen consumption ($\%\text{VO}_{2\text{peak}}$), metabolic equivalent (MET), energy expenditure (EE) and RPE during the different types of riding.

	walk/trot	trot/canter	no stirrups
	5-15 min	15-25 min	25-35 min
VO_2 ($\text{L}\cdot\text{min}^{-1}$)	1.122 ± 0.287	$1.240 \pm 0.430^*$	0.999 ± 0.499
VO_2 ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	17.4 ± 5.1	$18.4 \pm 3.9^*$	14.5 ± 2.9
$\%\text{VO}_{2\text{peak}}$	48 ± 13	$52 \pm 12^*$	41 ± 12
MET ^a	5.0 ± 1.5	$5.3 \pm 1.1^*$	4.2 ± 0.8
EE ($\text{kcal}\cdot\text{min}^{-1}$)	5.6 ± 1.4	$6.2 \pm 2.2^*$	5.0 ± 2.2
RPE	12 ± 2	14 ± 2	14 ± 2

^a MET = metabolic equivalent where 1 MET is equivalent to $\text{VO}_2 = 3.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
^{*} $P < 0.05$ (“trot/canter” different from “no stirrups”)

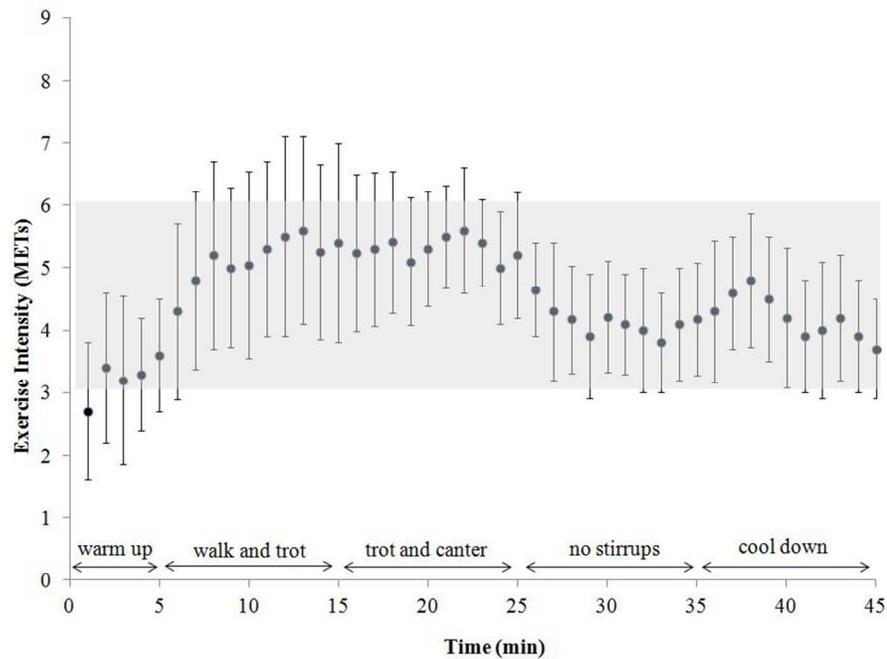


Figure 1. Mean exercise intensity expressed as metabolic equivalents (METs) averaged over each 1 minute period during the riding session. The moderate intensity exercise zone (3-6 METs) is highlighted in grey. The different activities performed are shown above the x-axis.
261x175mm (96 x 96 DPI)