# Physiological Demands of Therapeutic Horseback Riding in Children With Moderate to Severe Motor Impairments: An Exploratory Study

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**Purpose:** To examine energy expenditure at rest and during a single therapeutic horseback riding (THR) session in children with moderate to severe motor impairments. **Methods:** Heart rate (HR), oxygen uptake ($\dot{V}O_2$), and minute ventilation ($\dot{V}E$) were measured continuously during a 10-minute rest period and during a typical THR session. **Results:** Seven children (4 males, mean age 12.3 ± 3.5 years) completed the protocol. Significant increases from rest were seen for mean HR, $\dot{V}O_2$, $\dot{V}E$, and energy expenditure. Based on $\dot{V}O_2$, 43.3 ± 24.3% of the THR session consisted of sedentary, 44.4 ± 13.4% of light, and 12.3 ± 21.8% of moderate to vigorous activity intensity, with large interindividual differences. **Conclusions:** The physiological demands of THR in children with moderate to severe motor impairments are moderate. However, considering the short duration of maintaining moderate to vigorous exercise activity during THR in combination with the low training frequency, group data indicate that it is unlikely that THR will improve cardiopulmonary fitness in these children. **(Pediatr Phys Ther 2012;24:252–257)** *Key words: adolescence, child, equine-assisted therapy, movement disorders, physical fitness/physiology*

## INTRODUCTION AND PURPOSE

Most children with moderate to severe motor impairments are not sufficiently active because of loss of motor function. This is especially true for children who are nonambulatory and who often lack access to age-appropriate sports activities and physical education.[1] In addition to hypoactivity, previous assessments of physical fitness in this population have revealed significant below-average values for cardiopulmonary fitness,[2,3] anaerobic power,[4] muscle strength,[5,6] and agility,[7] all of which may have a significant effect on daily physical functioning. These low levels of activity and physical fitness may lead to a number of secondary consequences including increased fatigability, decreased participation in social events,[8] and reduced health-related quality of life.[9]

Physical therapy (PT) plays a central role in the management of motor impairments by focusing on function, movement, and optimal use of the child's potential, in order to promote, maintain, and restore physical, psychological, and social well-being.[10] Therapeutic horseback riding (THR) may represent an attractive and promising form of PT for children with a disability to increase daily energy expenditure (EE) and improve gross motor performance.[11] Therapeutic horseback riding is conducted by nontherapist riding instructors and assistants who are aware of the child's health status, disabilities, contraindications, and other limitations and educated in safely using trained therapeutic riding horses.[12] In THR, the child with a disability

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is taught to control the horse, using basic riding skills,[13] whereas in hippotherapy a licensed therapist uses the precise, smooth, rhythmic, and repetitive pattern of equine movements to improve the rider's balance, posture, gross, and fine motor skills.[14]

To date, very little evidence exists to support a THR-mediated improvement in physical fitness; however, results from previous studies[15,16] suggest that more musculature is recruited during THR compared with rest. Whereas we expect that the increase in muscle recruitment will lead to increases in EE secondary to increases in heart rate (HR) and oxygen uptake ($\dot{V}O_2$), this has not yet been investigated in the pediatric age range. In adult riders who are healthy, however, a significant increase in HR and $\dot{V}O_2$ was reported during horseback riding with $\dot{V}O_2$ ranging from 40% to 80% of cardiopulmonary fitness depending on equine gait (walk, trot, or canter).[17] Furthermore, Devienne and Guezennec[18] confirmed the results reported by Westerling[17] and highlighted the variability in rider EE according to the horse being ridden.

The aims of the present study were (1) to use measures of HR and $\dot{V}O_2$ to examine EE at rest and during a single THR session in children and adolescents with moderate to severe motor impairments and (2) to assess whether the increase in EE during THR has the potential to improve cardiopulmonary fitness in these patients. If THR EE is within an appropriate range to induce training effects, it may serve as an essential component of a PT rehabilitation program for this population.

## METHODS

### Patient Population

Children and adolescents participating in the THR program offered by the National Horseback Riding Center for the Handicapped, Arnhem, the Netherlands, were recruited from a comprehensive school for special education. Children between the ages of 8 and 18 years who were wheelchair-dependent (rated 1) for long distances (>500 m) on the functional mobility scale were eligible.[19] Participants were excluded if they presented with contraindications to exercise, were inexperienced with THR, or were unable to cooperate with the testing procedures. In total, 11 children and their parents provided assent/consent to participate in this study approved by the medical ethics committee of our hospital.

### Apparatus

During the study visit, participants were equipped with a facemask (Hans Rudolph Inc, Kansas City, Missouri) attached to a calibrated mobile respiratory gas analysis system (total weight: 0.57 kg; Cortex Metamax B,[3] Cortex Biophysik GmbH, Leipzig, Germany). Breath-by-breath gas analysis and volume were measured continuously at rest and during THR. During submaximal exercise, this metabolic test system has been proved to be a valid and accurate measure of $\dot{V}O_2$.[20] These measurements were transmitted wirelessly to a laptop for calculation of minute ventilation ($\dot{V}E$), $\dot{V}O_2$, carbon dioxide production ($\dot{V}CO_2$), and the respiratory exchange ratio using conventional equations. Values were averaged and stored over 10-second intervals along with HR data (T31 coded, Polar, Kempele, Finland) and were subsequently used to calculate EE at rest and throughout THR. Participants also wore an Actical accelerometer (MiniMitter/Respironics, Bend, Oregon) around their right wrist throughout the session.

### Procedure

Resting values were collected before the THR trial over a 10-minute period with the participants seated on chairs or in their own wheelchairs. All participants completed a single THR session that was identical to the sessions they had previously performed at the center, which are designed to teach control of the horse using basic riding skills. The participants were seated in straddle position, using a horse blanket and surcingle (no saddle) to experience the warmth and multidimensional movements of the horse during the THR session. A trained instructor, assisted by 1 additional side walker, directed the horse with a lead line attached to its halter. Over the 20-minute course, children performed exercises like leaning forward to touch the horse's neck, leaning backward to touch his rump, and twisting left and right on the horseback while the horse was led in a slow, steady walk, with the rider responding to the multidimensional movements of the horse. The children also performed 2 transitions during the session that involved taking the horse from a walk to a trot. Depending on the rider's safety and level of independence, the trotting lasted a 30- to 60-second period. An investigator took notes on horse gait and the exercises performed by the participants.

### Data Analysis

Metabolic equivalents (METs) were calculated by dividing $\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$) by basal metabolic rate, as predicted from the participant's sex, age, weight, and height.[21] Mean $\dot{V}O_2$ was converted into units of EE ($kcal \cdot kg^{-1} \cdot min^{-1}$) using the constant of 1L $O_2$ = 4.825 kcal. Activity EE (AEE) was calculated as EE during THR minus mean EE at rest and classified as either sedentary ($<0.01$ $kcal \cdot kg^{-1} \cdot min^{-1}$), light ($\geq 0.01$ and $<0.05$ $kcal \cdot kg^{-1} \cdot min^{-1}$), or moderate to vigorous ($\geq 0.05$ $kcal \cdot kg^{-1} \cdot min^{-1}$).[22] Mean Actical counts per minute were also classified by intensity as described by Puyau et al.[22] Wilcoxon signed rank tests were used to examine differences between the physiological variables measured at rest and during THR. Statistical significance was set at $\alpha < 0.05$.

## RESULTS

Seven children (4 males, mean ± SD, age 12.3 ± 3.5 years; height 1.44 ± 0.15 m; weight 41.96 ± 11.79

kg) completed the study protocol (4 participants were excluded because of invalid gas analysis, all nonambulatory, functional mobility scale score 111). The characteristics of the participants who completed the study protocol are shown in Table 1. Based on $\dot{V}O_2$, the mean breakdown of AEE intensities during THR was 43.3 ± 24.3% sedentary, 44.4 ± 13.4% light, and 12.3 ± 21.8% moderate to vigorous. To elucidate individual differences, Figure 1 represents the distribution of sedentary, light, and moderate to vigorous AEE during THR for the total group as well as for each participant, expressed as percentages, and shows large interindividual differences.

Figure 2 presents the mean effects of THR on different physiological parameters (2A) and the mean activity intensity of THR measured by accelerometry (2B) compared with the 10-minute resting period. The mean duration of a THR session was 18 minutes and 41 seconds, and significant increases from rest were seen for mean HR (105.7 ± 9.1 to 120.5 ± 11.8 beats per minute, $P = .018$), $\dot{V}O_2$ (10.4 ± 3.6 to 14.7 ± 4.7 mL·kg$^{-1}$·min$^{-1}$, $P = .018$), EE (0.0503 ± 0.0174 to 0.0709 ± 0.0226 kcal·kg$^{-1}$·min$^{-1}$, $P = .018$), and $\dot{V}E$ (11.8 ± 3.3 to 17.1 ± 6.4 L·min$^{-1}$, $P = .018$) (Figure 2A). No change was observed for mean respiratory exchange ratio (0.75 ± 0.03 to 0.70 ± 0.07, $P = .089$). Table 2 shows the individual physiological responses to THR, underlining the great variability in physiological response. For each participant, mean HR, $\dot{V}O_2$, and $\dot{V}E$ in rest and during THR are represented, as well as the measured peak HR, $\dot{V}O_2$, and $\dot{V}E$ during THR. Actical counts per minute also increased with a shift from predominantly sedentary activity at rest to light activity during THR (Figure 2B). More specifically, the proportion of sedentary activity counts decreased significantly during THR (73.1 ± 26.7% to 0.7 ± 1.9%, $P = .018$), while a trend toward an increase in the proportion of light activities was observed (26.9 ± 26.7% to 77.0 ± 20.1%, $P = .063$), as well as a significant increase in the proportion of moderate to vigorous activities (0.0 ± 0.0% to 22.3 ± 19.9%, $P = .028$).

Figure 3 shows the effects of gait transitions on HR, $\dot{V}O_2$/kg, EE, and $\dot{V}E$ in participant 7. The transitions in horse gait caused temporary increases in HR, $\dot{V}O_2$/kg, EE, and $\dot{V}E$.

## DISCUSSION

The aim of the current study was to examine EE at rest and during a single THR session in children and adolescents with moderate to severe motor impairments. Although THR significantly increased EE above resting levels, only 12% comprised the session consisted of moderate to vigorous physical activity, the intensity recommended

**TABLE 1**
Participant Characteristics

| Participant | Gender | Age, y | GMFCS (level) | FMS | Height, m | Weight, kg | Diagnosis |
|---|---|---|---|---|---|---|---|
| 1 | Male | 9 | IV | 221 | 1.56 | 45 | Cerebral palsy, quadriplegia, cognitive impairments |
| 2 | Male | 11 | V | 111 | 1.52 | 54 | Cerebral palsy, quadriplegia, cognitive impairments |
| 3 | Female | 10 | V | 111 | 1.37 | 30 | Cerebral palsy, quadriplegia, cognitive impairments |
| 4 | Female | 13 | III | 431 | 1.44 | 44 | Stickler syndrome, PDD-NOSS, cognitive impairments |
| 5 | Male | 8 | III | 431 | 1.26 | 23 | Mitochondrial disease (unknown) |
| 6 | Male | 18 | V | 111 | 1.62 | 54 | Cerebral palsy, quadriplegia |
| 7 | Female | 13 | III | 421 | 1.42 | 42 | Cerebral palsy, right-sided hemiplegia, 22q11 deletion, PA-VSD, psychomotor retardation |

Abbreviations: FMS, functional mobility scale; GMFCS, gross motor function classification system; PA-VSD, pulmonary atresia with ventricular septal defect; PDD-NOS, pervasive developmental disorder–not otherwise specified.

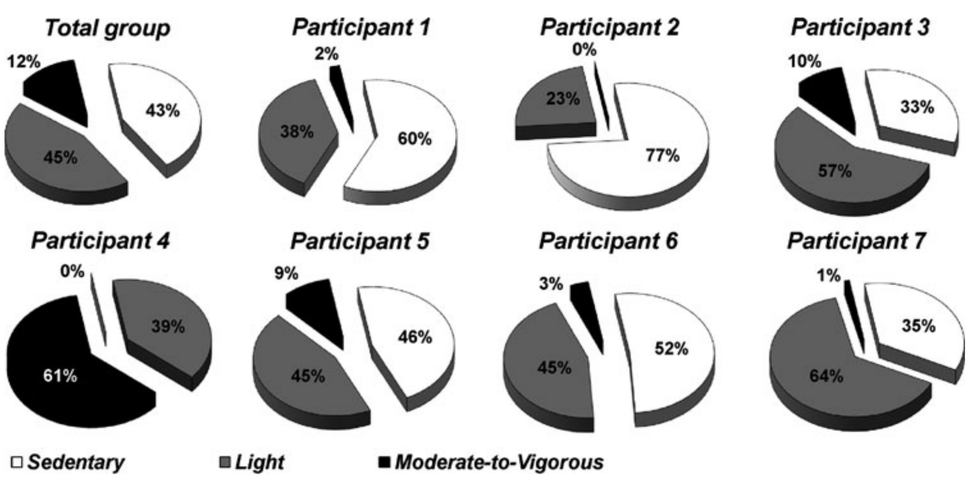


**Fig. 1.** Distribution of sedentary, light, and moderate to vigorous activity energy expenditure during therapeutic horseback riding for the total group as well as for each participant, expressed as percentages.

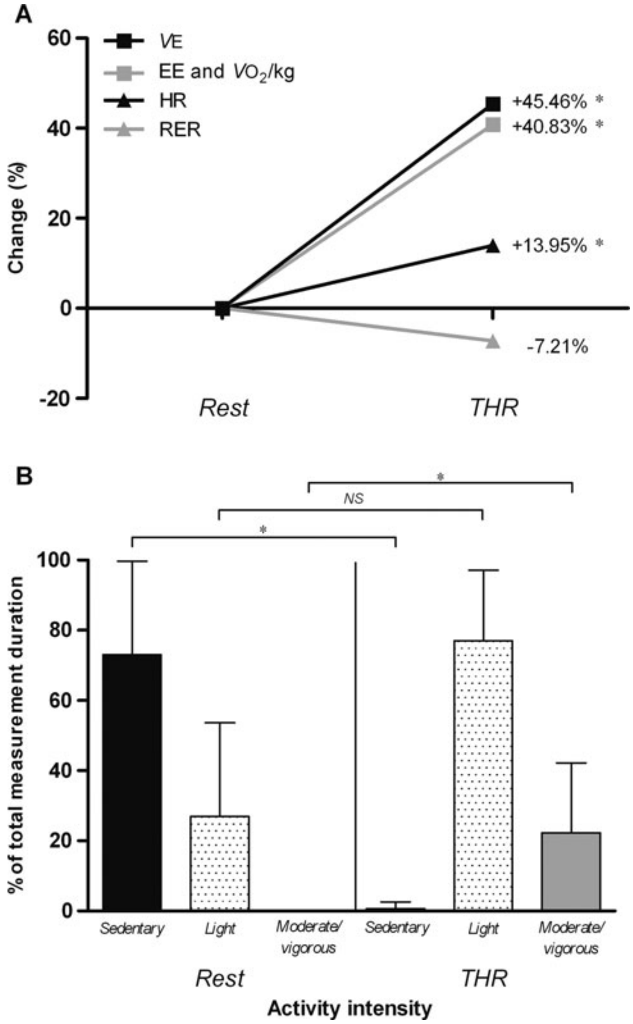


**Fig. 2.** Physiological demands of therapeutic horseback riding (THR) in children with moderate to severe motor impairments (graph A) and the mean activity intensity of THR measured by accelerometry (graph B). *$P < .05$.

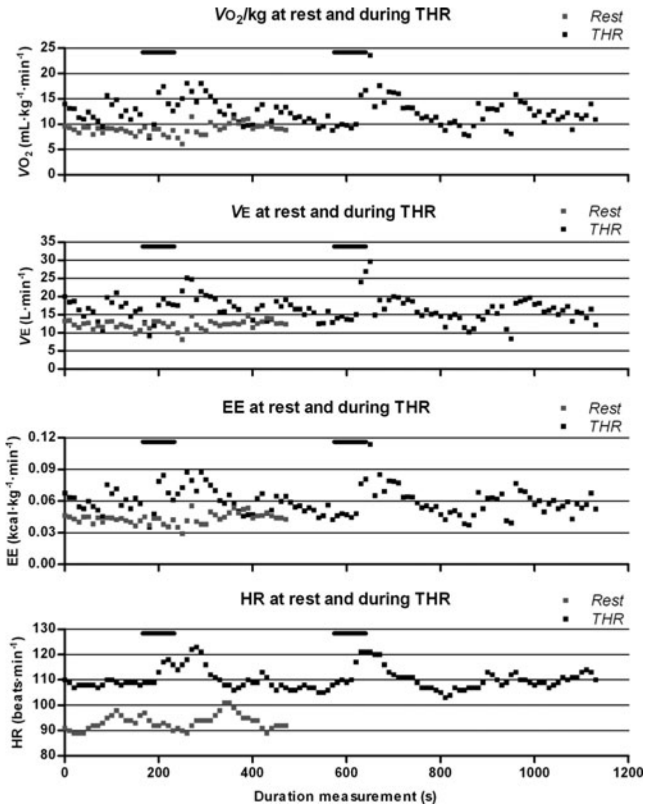


**Fig. 3.** The effects of horse gait transition (from the walk to the trot) on heart rate (HR), $\dot{V}O_2$/kg, energy expenditure, and $\dot{V}E$ (the horizontal bars depict the periods of horseback riding at a trot) in a typical participant (7). The gray dots represent the measurement at rest, and the black dots represent the measurement during therapeutic horseback riding (THR).

to maximize fitness- and health-related benefits of activity. Furthermore, there were large interindividual differences in the achieved exercise intensity, which was also reported by Devienne and Guezennec.[18] When EE was expressed in METs, the mean for the entire THR session was $3.3 \pm 1.1$, with an average peak value of $6.0 \pm 1.8$ METs during trotting. These mean values fall within the moderate-intensity range and are comparable to general horseback riding and

**TABLE 2**

Individual Physiological Response to THR

| | Rest | THR | | Rest | THR | | Rest | THR | |
|---|---|---|---|---|---|---|---|---|---|
| Participant | Mean HR, beats/min | Mean HR, beats/min | $HR_{peak}$, beats/min | Mean $\dot{V}O_2$, $mL\cdot kg^{-1}\cdot min^{-1}$ | Mean $\dot{V}O_2$, $mL\cdot kg^{-1}\cdot min^{-1}$ | $\dot{V}O_{2peak}$, $mL\cdot kg^{-1}\cdot min^{-1}$ | Mean $\dot{V}E$, $L\cdot min^{-1}$ | Mean $\dot{V}E$, $L\cdot min^{-1}$ | $\dot{V}E_{peak}$, $L\cdot min^{-1}$ |
| 1 | 110 | 116 | 160 | 8.84 | 10.92 | 24.08 | 11.49 | 13.7 | 26.6 |
| 2 | 111 | 112 | 121 | 7.98 | 9.11 | 14.85 | 12.32 | 14.4 | 20.1 |
| 3 | 101 | 112 | 140 | 9.47 | 13.37 | 32.77 | 7.79 | 11.5 | 25.9 |
| 4 | 103 | 143 | 186 | 7.43 | 21.32 | 30.86 | 9.22 | 28.3 | 45.6 |
| 5 | 121 | 123 | 143 | 17.74 | 20.61 | 36.39 | 11.15 | 11.7 | 19.2 |
| 6 | 101 | 128 | 168 | 12.57 | 15.24 | 31.89 | 18.22 | 23.7 | 45.1 |
| 7 | 93 | 110 | 123 | 9.05 | 12.36 | 23.60 | 12.26 | 16.6 | 29.7 |
| Mean | 105.71 | 120.57 | 148.71 | 10.44 | 14.70 | 27.78 | 11.78 | 17.13 | 30.31 |
| SD | 9.07 | 11.86 | 23.90 | 3.61 | 4.69 | 7.35 | 3.29 | 6.44 | 10.91 |

Abbreviations: HR, heart rate; $HR_{peak}$, peak heart rate; SD, standard deviation; THR, therapeutic horseback riding; $\dot{V}E$, minute ventilation; $\dot{V}E_{peak}$, peak minute ventilation; $\dot{V}O_2$, oxygen uptake; $\dot{V}O_{2peak}$, peak oxygen uptake.

trotting, respectively.[23] Thus, our findings imply that the overall intensity of THR may be sufficient to induce improvements in cardiopulmonary fitness. However, in combination with the relatively short duration (~20 minutes per session, of which only 12% comprised moderate- to vigorous-intensity physical activity), group data indicate that it is unlikely that THR will improve cardiopulmonary fitness.

The American College of Sports Medicine (ACSM) guidelines state that the minimal training intensity for improving cardiopulmonary fitness is approximately 55% to 65% of maximal HR, with the lower intensities most applicable to individuals who are unfit.[24] Recently, Verschuren et al[25] reported a mean $HR_{peak}$ of 194 ± 9.9 beats per minute during maximal treadmill exercise tests in children and adolescents with cerebral palsy. If one assumes a similar peak HR in our sample, the mean HR of 120.7 ± 11.8 beats per minute during THR would represent roughly 62% of maximal HR. Dirienzo et al[15] recently reported a similar increase in HR to between 66% and 100% of maximum during THR in 4 children with cerebral palsy who were nonambulatory (GMFCS level IV). The authors reasoned that this increase in HR might lead to an increase in EE and a subsequent improvement in cardiopulmonary fitness. While the HR data in the current study seemingly support this conclusion, a number of confounding factors must also be considered. First, mean HRs during THR ranged from 57% to 74% of $HR_{peak}$, with only 2 participants attaining mean HRs higher than 65% of $HR_{peak}$. During trotting however, participants reached $HR_{peak}$ values ranging from 62% to 96% of $HR_{peak}$. Second, it is important to note that HR was significantly elevated at rest in our participants, with an average of 105.7 ± 9.1 beats per minute. Third, EE derived from HR only seems to be valid for moderate- or high-intensity exercise; thus, monitoring HR alone, as in the Dirienzo study,[15] may not be optimal for the assessment of the physiological demands of THR. This is further supported by the findings of the present study, in which the increases in $\dot{V}O_2$ were significantly larger than those of HR during THR (41% vs 13%).

An interesting observation during the study was that it seemed that the achieved exercise intensity during THR increased with more independence as a rider. A possible explanation is that children with more independence engaged more actively in riding the horse, thereby recruiting more musculature to maintain their center of mass in response to the multidimensional movements of the horse, which was also suggested previously.[18] These children generally attained a longer trotting duration as well. Nevertheless, the physiological response to THR in children with mild to moderate motor impairments is still unknown.

Concerning the frequency and duration of training, the ACSM recommends 3 to 5 days per week a 20- to 60-minute bout (or multiple 10-minute bouts) of exercise that exceeds the minimum training intensity recommended for improving cardiopulmonary fitness, with lower-intensity activity to be conducted over a longer period of time.[24] The most recent ACSM recommendations state that an adult should engage in moderate-intensity exercise for 30 minutes or more on 5 or more days per week.[26] With only 12% of the approximately 20-minute THR session consisting of moderate- to vigorous-intensity physical activity, group data suggest that it is unlikely that THR induces a training effect. In the current study, 6 children attained the required moderate to vigorous exercise intensity with a summed duration ranging from only 12 seconds to almost 13 minutes during the THR session. In addition, most riders attend THR only once a week, which generally would not be sufficient to achieve a meaningful improvement in cardiopulmonary fitness over time. However, the ACSM recommendations are applicable to healthy adults and, to the best of our knowledge, it is unknown whether children who are severely deconditioned can benefit from exercise at a lower intensity, for a shorter duration, and a reduced frequency.

Although participation in the THR program seems not to make a sufficient contribution toward improved cardiopulmonary fitness, it must be noted that in agreement with a recent study,[27] primary caregivers suggest that multiple families perceived the THR program to be beneficial to their child's health-related quality of life, health, and function. Benefits reported included a growing self-confidence and self-esteem, being more happy and relaxed, feeling like anyone else on top of a horse, and improved physical function.[27]

Future studies are required to investigate the long-term effects of THR on cardiopulmonary fitness in children with disability. In children with mild to moderate motor impairments, the physiological response to THR is still unknown and future research should employ electromyography. Moreover, in addition to HR, we recommend using respiratory gas analysis as well, since $\dot{V}O_2$ provides valuable information for the assessment of the physiological demands of THR and seems more responsive compared to HR monitoring.

## CONCLUSION

The physiological demands of THR in children and adolescents with moderate to severe motor impairments are moderate, with large interindividual differences. Considering the short duration of maintaining moderate- to vigorous-intensity exercise activity during THR as well as the low training frequency, group data indicate that it is unlikely that this activity may be of a sufficient intensity to improve cardiopulmonary fitness. However, on the basis of our findings of an increased metabolic demand during transitions in horse gait, we recommend performing at least 2 sessions per week that incorporate additional gait transitions (ie, >3, given appropriate safeguards).

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