

Effects of Uphill Exercise on Digestible Energy Intake and Energy Expenditure during Exercise in Yearling Horses

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ABSTRACT : The objectives of this study were to evaluate the digestible energy intake and energy expenditure in yearling horses on different training protocols (uphill- and level-track exercise training protocols). Twenty-four thoroughbred yearlings (12 males and 12 females, aged 27.0±0.9 months) were divided into two groups based on their training on two different tracks: the uphill (with a gradient of about 3%) training group (uphill training) and the level training group (level training). The digestible energy (DE) intake and energy expenditure (EE) during exercise were measured in both the groups. It was found that the DE intake in the uphill training and the level training groups was 35.1±3.1 and 36.9±4.8 Mcal/day, respectively. The EE during exercise in the two groups was 3.05±0.51 and 2.07±0.56 Mcal, respectively. Thus, there was a significant difference in the EE ($p<0.05$), but not in the DE intake between the animals of the two training groups. The EE for a given intensity of exercise was greater in the uphill training group than in the level training group, but the DE intake was not affected by the exercise intensity. The DE intake was not generally affected by the intensity of exercise in this study, but a daily negative gain of body weight was observed in the uphill training group, particularly in the females. Thus, the energy requirement may be higher in yearlings undergoing uphill training than in those undergoing level training. (*Asian-Aust. J. Anim. Sci.* 2004, Vol 17, No. 7: 973-979)

Key Words : Digestible Energy, Energy Expenditure, Exercise, Horse

INTRODUCTION

To ensure proper feeding of yearlings during their training period, the amount of energy that must be supplied should be determined on the basis of the amount of energy expended by the animals (Pagan et al., 1981; Asai et al., 1999). The National Research Council (NRC, 1989) has published the digestible energy (DE) requirements for horses undergoing training, dividing the requirements into three levels depending on the intensity of the exercises (light, medium, and heavy). The recommended DE intake for horses undergoing light, medium and heavy exercise training are 1.25, 1.5 and 2 times that of horses not undergoing training, respectively (NRC, 1989). However, these recommended DE intakes (NRC, 1989) can only be utilized as a rough guide. In recent years, training programs for horses have diversified due to various factors, including improvements in horse training facilities. It is not uncommon for uphill training to be selected as an effective exercise training method for yearlings to improve their cardiopulmonary function. For any given velocity, the intensity of uphill exercises is than that of level-track exercises (Hiraga et al., 1995), and horses performing uphill exercises consume more energy than those performing

exercises on level track. To date, however, very little information has been published regarding the energy expenditure of horses undergoing training on uphill tracks.

The present study was undertaken to examine the differences in the DE requirements and energy expenditure between yearlings undergoing uphill training and those undergoing level-track training.

MATERIALS AND METHODS

Test horses and period of study

The study was conducted from the months of June through August, over a period of 2 years. Different yearling horses were used for each year. In total, during the entire study period, 24 thoroughbreds (12 males and 12 females), aged 27.0±0.9 months and weighing 481.0±36.1 kg were used. The 12 horses used for each year's study were divided into two groups based on the type of training: the uphill training group and the level training group; the gender ratio in both the groups was the same. Measurements of the digestible energy (DE) intake were conducted four months after the commencement of the training programs (in early July of each year). Measurements of the energy expenditure (EE) during exercise were conducted thrice every week from just before, to one month after the measurements of the DE intake (from early July to early August each year). The body weight of the horses was measured once every week throughout the study period, and the daily gain of body weight (DG) was derived from the average weight gain every week.

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Received July 31, 2003; Accepted January 26, 2004

Table 1. Training protocol in a week in uphill and level training group (Period-I was first year and II was second year)

Group	Period	n	used track	days in a week	distance (m)	speed (m/min)
Uphill training	I	6	uphill turf track	5	1,200-1,800	500-600
	II	6	uphill turf track indoor dirt track	3 2	1,600 1,600-2,400	600
Level training	I	6	turf track	5	1,200-1,800	500-600
	II	6	turf track indoor dirt track	3 2	1,600 1,600-2,400	600

Table 2. Daily feed intake (kg/day) of yearling horses. Values were mean±SD. The horses were fed timothy hay *ad libitum* during the period to adjust to experiments. The amounts of timothy hay fed to the horses were decided after this period. The horses were given free access to water.

Ingredients	Training ¹	Rest
Oats	3.1±0.3	2.0
Pelleted diet	1.2±0.2	1.0
Alfalfa cube	1.2±0.2	1.5
Salt	0.05	0.05

¹ both of uphill training and level training

Exercise

Uphill training : Table 1 shows the details of the exercise program for the horses during the first year and second year of the study. Since the exercise program differed slightly between the two years, the test period was divided into Phase I (first year) and phase II (second year).

Uphill training was conducted on an uphill turf track having a gradient of about 3%. During Phase I, the horses practiced 2-3 sessions of 800 m running (600-800 m/min) for 5 days each week. Since this exercise intensity was found to be too much for the yearlings, during Phase II, the horses performed 2 sessions of 800 m uphill running at the same speed as that in Phase I, but only on 3 days of the week. On an additional two days of the week, they performed light exercise on an indoor dirt track, and during the remaining 2 days of the week, they rested individually in their stables.

Level training : During Phase I, the horses in the level training group practiced 2-3 sessions of 800 m running (600-800 m/min) on a level turf track each day. During Phase II, they practiced a single session of 1,600 m running (600-800 m/min) on a level dirt track each day. During phase I, the horses received training on 5 days of the week and rested for 2 days of the week. During Phase II, the horses performed the same exercise as that during Phase I on 3 days of the week, but did lighter exercise on an indoor dirt track on 2 days of the week, for the same reason as that described in the section on uphill training. On the remaining 2 days of the week, the horses of both the groups rested in their stables.

Feeding

All the horses were allowed free access to hay and water (Table 2). During both the years of study, horses which

were unable to undergo training for any of various reasons, such as injury during training (rest), were given lesser amounts of oats and the pelleted feed. To prevent these horses from ingesting other feeds, their box stables were bedded with paper during the test period. After the end of each training session, the horses were individually placed in a 200 m² paddock freed of pasture for about 3 h.

Digestible energy intake

The feces were collected for 4 days after a one week adaptation period, to determine the digestible energy (DE) intakes. The amounts of hay fed to the horses were based on the observations made during the adaptation period. The daily amount of feces excreted was estimated by the acid-insoluble ash (AIA) method (Vogtmann et al., 1975; Sutton et al., 1977). A portion of the feces was collected, dried mechanically at 80°C for 48 h, and then air-dried, to yield samples for analysis. About 2 grams of each sample was boiled in 100 ml of 4 N HCl for 30 minutes and then filtered. The residue on the filter paper was placed in a crucible and burnt in an electric muffle furnace (KL-100, ADVANTEC, Tokyo, Japan) at 600°C for 4 h. The ash thus obtained was weighed to yield the amount of AIA contained in the feces. The percentage of AIA in the feces was then calculated. The amount of AIA contained in the feeds and the hay were also measured in the same way. Since AIA is not digestible, the amount of feces excreted by each horse was estimated using the following equation:

$$\text{Total amount of feces excreted} = \frac{\text{amount of AIA in the feed}}{\text{percentage of AIA in the feces}}$$

The amount of energy in the feeds and the feces was quantified using a calorie bomb meter (CA-4P, Shimadzu Corporation, Kyoto, Japan). The difference between the amount of energy in the ingested feed and that in the feces was deemed as the apparent amount of digested energy.

Energy expenditure during exercise

We estimated the energy expenditure (EE) from the heart rate during exercise (Dauncey et al., 1979; Ceesay et al., 1989; Kalkwarf et al., 1989; Li et al., 1993; Hebestreit et al., 1995; Brosh et al., 1998; Devienne et al., 2000). Preliminary tests were conducted to obtain the formulas of

Table 3. Effect of exercise on feed intake

Intake (per body weight)	Uphill training	Level training	Rest
Concentrates kg/day (kg/100 kg BW)	4.57±0.08 (0.96±0.01)	4.70±0.13 (0.96±0.02)	3.33±0.03 (0.74±0.01)
Roughage kg/day (kg/100 kg BW)	9.87±0.44 (2.08±0.10)	9.93±0.54 (2.01±0.06)	8.40±0.03 (1.86±0.03)
Total DM intake kg/day (kg/100 kg BW)	14.45±0.48 (3.04±0.10)	14.63±0.62 (2.97±0.06)	11.73±0.03 (2.58±0.03)

Values were mean±SE. Concentrates were included oats and pelleted diet, and roughage were included timothy hay and alfalfa cube

Table 4. Digestible energy intakes estimated by sampling the feces for 4 days and daily gains of the body weight

	Uphill training	Level training	Rest
Digestible energy intake, Mcal/day (Mcal/100 kg BW)	35.14±1.05 (7.38±0.24)	36.85±1.59 (7.51±0.22)	28.62±0.21 (6.36±0.11)
Digestibility (%)	57.85±1.06	60.31±0.71	58.43±0.33
Daily gain of the body weight, kg/day	-0.06±0.08	0.11±0.06	0.26±0.13

Values were mean±SE

Table 5. Energy expenditure during exercise, which was measured for three days every week through two months

	Uphill training	Level training
Energy expenditure, Mcal	3.05±0.18*	2.07±0.17
Ratio of energy consumption to DE intake, %	8.84±0.64*	5.63±0.47

* Significant different between uphill training and level training, $p < 0.05$. Values were mean±SE

regression between the heart rate and the VO_2 in every horse. Each horse performed a treadmill (Mustang, Fahrwangen, Switzerland) exercise of progressively increasing intensity. During the treadmill exercise, the heart rate was measured with a heart rate monitor (PE-3000, Polar Electro Oy, Finland) and the VO_2 was measured (Jones et al., 1989; Birks et al., 1991) by collecting the respiratory gases in a mask fitted around the nose with a tight seal, and using an O_2 analyzer (METS-900, Perma-Pure, Inc., Toms River, New Jersey, USE). During the field training, the heart rate of the individual horses was measured with a heart rate monitor (PE-3000, Polar Electro Oy, Finland) and the EE was calculated by converting the VO_2 obtained using the previous formula into energy. We found from the preliminary study that the regression that was obtained by plotting the correlation between the heart rate and the VO_2 was not linear for heart rates under 100 beats/minute. Therefore, only exercise associated with heart rates equal to or higher than 100 beats/minute was considered for estimation of the EE. During phase I, in both the uphill training and level training groups, the EE was measured on the days when the horses performed their exercises on the main tracks.

Statistical analysis

The significance of differences was tested using ANOVA with Student-Newman-Keuls' multiple-range test. The significance level for all the statistical tests was set at $p < 0.05$.

RESULTS

Feed intakes

Horses which rested for long periods of time for any of various reasons, including injury during training, were allocated to the rest group. Table 3 shows the amounts of the diet ingested; there were no differences between the uphill training group and the level training group in terms of the amounts of concentrated diet, roughage, or total dry matter ingested. In the rest group, the concentrated diet intake was small, because the amount of feeding was restricted. The roughage intake was also small in this group, even though the animals were allowed free access to roughage. Overall, in the present study, the concentrated diet intake was about 1 kg/100 kg body weight, and the roughage intake was about 2 kg/100 kg body weight in both the uphill training and the level training groups. Thus, the dry matter intake by the horses in the present study was equivalent to the amount recommended for moderate exercise by the NRC.

Digestible energy intake and daily gain of body weight

The DE intakes did not differ significantly between the uphill training and the level training groups (Table 4). The DE intakes in both the groups were equivalent to the amounts recommended for heavy exercise by the NRC. The energy digestibility tended to be lower in the uphill training group than in the level training group, although the difference between the two groups was not statistically significant. In the rest group, both the DE intake and the

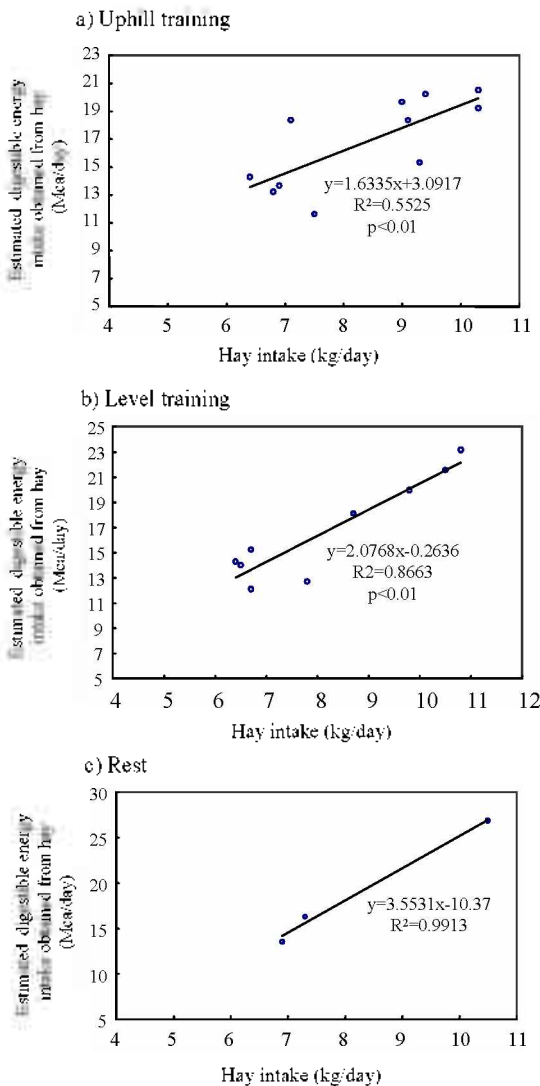


Figure 1. Relationship between the estimated the amount of digestible energy obtained from hay and the hay intake. The digestible energy (DE) intake from hay was estimated by subtracting the DE from concentrated diet from the total DE intake. The DE intake from concentrated diet was estimated by using Fennesbeck's equation (1981): $DE (Mcal/kg)=4.22-0.11 (\text{acid detergent fiber } \%) + 0.0332 (\text{crude protein } \%) + 0.00112 (\text{acid detergent fiber } \%)^2$. The acid detergent fiber was analyzed according to the method of Van Soest (1965), and the crude protein was determined by the AOAC (1999) method.

energy digestibility tended to be lower. The DG also tended to be lower in the uphill training group, but the difference between the two training groups was not statistically significant.

The influence of the type of training on the digestibility of concentrated diet was thought to be smaller than its influence on the digestibility of roughage (Katsuki et al., 1998). We estimated the amount of DE obtained from hay by using Fennesbeck's equation (Fennesbeck et al., 1981), and examined its relationship to the amount of hay intake (Figure 1). In both the uphill training and the level training groups, there was a significant positive correlation between these two parameters (uphill training: $r=0.7451$, $p<0.01$; level training: $r=0.9308$, $p<0.001$). In the rest group, however, no significant correlation was noted between these two parameters, presumably because the number of horses allocated to this group was too small. The amount of energy obtained from each kg of roughage, as estimated from this regression formula, was 1.94, 2.05 and 2.52 Mcal/kg in the uphill training, level training and the rest groups, respectively.

Energy expenditure during exercise

The heart rate during exercise varied from day to day. The mean heart rate during the measurement of EE was 167.6 ± 40.1 beats per minute in the uphill training group, and 164.3 ± 38.5 beats per minute in the level training group. The EE was significantly higher in the uphill training group than in the level training group ($p<0.05$), as shown in Table 5.

The influence of gender

We then examined the effect of gender on the DG, DE and EE in all the groups. The DG was significantly smaller in the females of the uphill training group ($p<0.01$) than in those of any other group (Figure 2a). While the mean DE intake did not differ significantly among the different training groups, there was a significant difference ($p<0.05$) between the males and females of each training group, as shown in Figure 2b. On the other hand, while the EE differed significantly between the uphill training and level training groups ($p<0.05$), it did not differ significantly between the males and females of any training group (Figure 2c). In both males and females, the amount of hay ingested per kg body weight showed a significant positive correlation with the daily gain of body weight, although the degree of correlation differed between males ($r=0.672$, $p<0.01$) and females ($r=0.655$, $p<0.01$), as shown in Figure 3. In order to achieve a 0.1 kg daily gain of body weight, it was estimated that the males and females had to ingest 1.53 and 1.98 kg of hay per 100 kg body weight, respectively, each day. The hay intake per 100 kg body weight tended to be higher in the males of the uphill training group (2.33 ± 0.17 kg) than in those of the level training group (2.17 ± 0.16 kg). In the case of the females, on the other hand, the hay intake per 100 kg body weight tended to be smaller in the females of the uphill training group (1.78 ± 0.07 kg) than in those of the level training group (1.85 ± 0.05 kg).

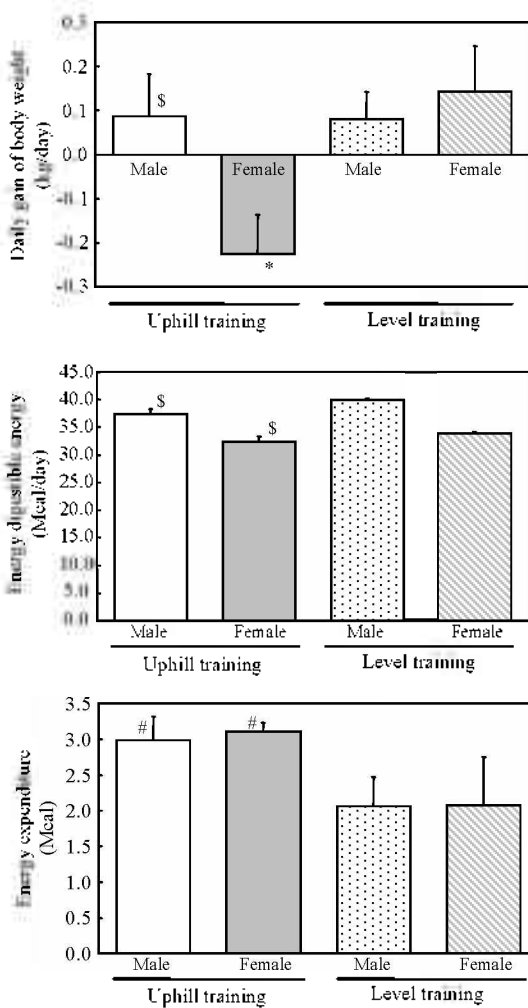


Figure 2. Daily weight gain during this study a) and digestible energy intake b) and energy expenditure during exercise c) in the males and females of the two training groups. Values shown are mean±SE. * Indicates significant differences among the 4 groups. \$ Indicates significant difference relative to the values in the females of the same training group. # Indicates significant difference relative to the values in animals of the same sex undergoing level training.

DISCUSSION

In the present study, the EE was greater in the uphill training group than in the level training group. This is probably because it takes longer for the heart rate to fall to 100 beats per minute after uphill training than after level training, as the former is associated with a greater elevation of the heart rate. This suggests that uphill training may be

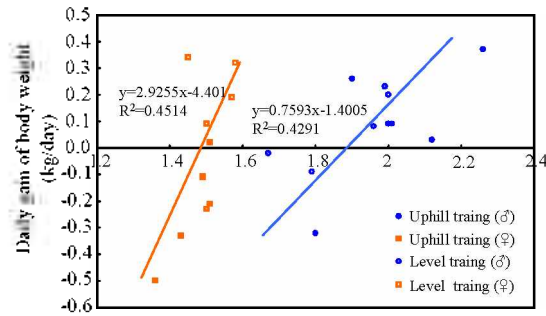


Figure 3. Relationship between the hay intake per 100 kg body weight and the daily gain of body weight during this study.

more stressful to for horses than level training (Butler et al., 1983; Thornton et al., 1987; Rose et al., 1990; Hiraga et al., 1995). Although the EE was small as compared with the DE intake, the basal metabolism after exercise might be affected by the intensity of exercise (Ishida, 1975). On the other hand, some studies in humans revealed no differences in the basal metabolism depending on the training method (Almuzaini et al., 1989; Broeder et al., 1992). The DE intake in the uphill training group did not differ significantly from that in the level training group in this study. The DG in the uphill training group also did not differ significantly from that of in the level training group, even though it tended to be smaller in the former than in the latter group. While the results did not clearly indicate whether the basal metabolism differed between the horses trained by the two methods, we concluded that there was no significant disparity in the basal metabolism between horses trained by the two different methods. Our conclusion was based on the following observations. When the EE was subtracted from the DE intake, the calculated energy intake in the animals of the uphill training group was about 3.6 Mcal smaller than that in the animals of the level training group. This amount was almost equal to the NRC-recommended energy intake for yearlings of this age group to achieve a DG of 0.17 kg/day. In this study, the disparity in the DG between the two training groups might be related to only variations of the DE intake and the EE. Moreover, a thoroughbred has a greater ability for aerobic exercise than other animals (Weber et al., 1987) and this may be the reason why the basal metabolism is not significantly affected by the exercise intensity in these animals. On the other hand, a different result of the relation between exercise intensity and the basal metabolism has been reported for the early days of the training period (Stubbs et al., 2002). When we undertook the DE intake measurements, one month had already passed since the commencement of these training protocols for the horses, but more than 8 months had already passed since the animals had begun to be trained. Fan et al. (2002) reported that the hematological

parameters of the horses adapted to exercise after more than 4 months of training.

The difference in the digestibility of hay between the two groups might have been related to the intensity of exercise. Orton et al. (1985) reported that mild exercise improved the digestibility of hay fibers. On the other hand, Katsuki et al. (1998) reported that increasing intensity was associated with improved digestibility of hay fibers. The poorer digestibility of hay in the uphill training group in the present study also seems to reflect a lower fiber digestibility in this group. Factors possibly contributing to the difference in the fiber digestion rate between the two groups include possible exercise-induced changes in the intestinal motility (peristalsis) and intestinal blood flow (Brouns et al., 1993). This suggests that uphill training may be less favorable for fiber digestibility than level training.

The females in the uphill training group consumed more energy than those in the level training group, while their DE intake was lower than that of the males of the same group. Male horses were able to meet the demands posed by the increased EE by increasing their DE intake from hay. In female horses, however, this was difficult because the amount of hay ingested by them was relatively small. Moreover, the hay ingested was less efficient at yielding a daily gain of body weight in females than in males. As a result, females showed weight loss in the face of increased EE. Although it has been reported that the DE requirements may not differ between the two genders (Ott et al., 1981), it seems likely that female horses are more susceptible to the stresses posed by heavy exercise (Harris et al., 1990). The results of this study suggest that the amount of easily digestible grains that needs to be given to horses, particularly female horses, must be carefully reviewed during heavy exercise training, such as uphill training.

The EE in the uphill training group was greater than that in the level training group, and this difference may be assumed to be equal to the excess energy requirement needed for achieving the same DG in this group as in the level training group. For a given velocity, uphill training was associated with a greater exercise load and EE than level training. Usually, horses undergoing exercise are able to ingest amounts of energy equivalent to the amounts of energy expended by them, if they were allowed free access to roughage (Frape et al., 1988). The DE intakes were not different between the animals of the uphill and level training groups in this study. The females, however, showed a negative DG which could be attributable to their not ingesting a sufficient amount of hay. We must bear in mind the possibility that sometimes the dietary intake of exercising horses may be inadequate because of appetite suppression (King et al., 1994) and a decreased digestibility of the fibers caused by heavy exercise (Orton et al., 1985; Katsuki et al., 1998). In order to achieve a consistent DG in

yearling horses, some horses undergoing uphill training have to be ingested may have to be given more digestible feed than animals undergoing level training.

삭제됨: This

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