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Time budgets differ in horses during continuous and space-restricted rotational grazing

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ABSTRACT

Horses can become obese and develop related health issues such as laminitis from excessive grazing on high-quality pasture grass; limiting pasture intake can allow weight loss to occur. The objective of this study was to determine the effect of space-restricted rotational grazing on body weight (BW) and time budgets in horses. Eight mature geldings and mares with maintenance-only requirements were randomly assigned to either a space-restricted rotational grazing group (SRG; BW 512 ± 6 kg; $n = 4$) or a continuous grazing group (CG; BW 517 ± 49 kg; $n = 4$) for 42 d SRG horses grazed an area with dimensions to provide 80–90 % of mean digestible energy requirement for the 4 horses over a 7-d grazing period; whereas, the CG horses continuously grazed similar non-toxic endophyte-infected tall fescue pasture providing greater than maintenance requirements for the 42 d Horses in the SRG group were moved to a new area every 7 d for 6 weeks. On d 7 at 1600 h of each week, horses were brought inside, and feed was withheld overnight. At 0700 h the next day, BWs were recorded prior to turnout. Observers recorded behaviors simultaneously on SRG and CG horses every six minutes throughout the day three days per week according to an ethogram. This included 30 s scans of all horses. Proportion of grazing and standing had an inverse relationship. Proportion of grazing was affected by the treatment by time interaction, which grazing was displayed more in SRG than CG during weeks 2 and 3, and then reversed weeks 4, 5 and 6.

1. Introduction

Between 24 to 51 percent of horses (*Equus caballus*) in developed countries could be classified as overweight or obese (Wyse et al., 2008; Thatcher et al., 2012; Giles et al., 2014). Excess weight can predispose horses to diseases and conditions such as laminitis, equine metabolic syndrome (EMS), insulin resistance, and pituitary pars intermedia dysfunction (PPID) (Johnson et al., 2009; Morgan et al., 2015). These conditions cause a decrease in lifespan of horses, reduce quality of life, cause significant discomfort, and result in considerable expense to the owner (Johnson et al., 2009; Morgan et al., 2015). Proper diet and exercise are useful in preventing these symptoms (Harris et al., 2006; Borer et al., 2012). Horses fed less concentrated feeds and prevented from over grazing were less likely to develop laminitis and may maintain a healthier body condition score, namely 4–6 on a 9-point scale (Harris et al., 2006).

Obesity in the modern domestic horse can be caused by excessive caloric intake of high energy pasture grass and long periods spent grazing relative to the amount of energy expended in daily activities (Johnson et al., 2009). Ancestors of the domestic horse evolved to efficiently digest grasses with very low levels of nonstructural carbohydrates (NSC); however, modern day pasture grass has been selected to be high in NSC to allow for weight gain of livestock (Johnson et al., 2009; Martinson et al., 2017). Limiting the intake of forage while at pasture could control bodyweight in horses (Johnson et al., 2009; Glunk & Siciliano, 2011; Gill et al., 2016). In addition to being able to efficiently utilize the nutrients contained in lower NSC forages, nondomestic equid species such as plains zebra (*Equus burchelli*) and Przewalskii wild horses (*Equus ferus przewalskii*) graze for about 50 % of their day to meet their nutrient requirements (Boyd, 1998; Neuhaus & Ruckstuhl, 2002). Domesticated horses have not lost this behavior, and thus, they will graze for a similar percentage of time given the opportunity (Sweeting et al., 1985). Therefore, limiting time in pasture would be another means to control bodyweight.

Several accepted methods of achieving weight loss in horses have been established. Previously established methods include restricting

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time for grazing, or time and space allotted for consuming pasture forage, with the intention to reduce the number of calories consumed in a single day, instead of allowing horses to continuously graze without restrictions (Glunk & Siciliano, 2011; Gill et al., 2016). The most common practice is to remove horses from pasture to reduce caloric intake of grasses that are high in NSC (Martinson et al., 2017; Glunk & Siciliano, 2011; Gill et al., 2016; Glunk et al., 2013). Restricting grazing time from nine hours to three hours can reduce the amount of digestible energy (DE) from pasture from 67 % to 40 % of daily requirements consumed (Glunk & Siciliano, 2011). In Glunk and Siciliano (Glunk & Siciliano, 2011), behavior was influenced by restricted grazing through an increased intake rate in shorter periods of time in an unsuccessful attempt to consume the calories faster. Allowing only 8 h of grazing in a restricted space that contains fewer available calories can cause an average loss of 6 % of bodyweight (BW) after 35 days (Gill et al., 2016). No studies have evaluated the impact of reducing space to limit available daily calories without also reducing time available to graze on weight loss in the horse.

This study was intended to determine if weight loss can still be achieved if horses are placed in space-restricted grazing without removing them from the field as was done by Gill et al. (Gill et al., 2016). The objectives of the present study were to determine the effect of space-restricted rotational grazing without restricting time at pasture compared to continuous grazing on bodyweight in mature idle horses and the effect on time budgets.

2. Methods

2.1. Animals

This experiment was approved by the Western Kentucky University (WKU) International Care and Use Committee (Animal Welfare Assurance #A3558–01), designation #17–14.

The study was conducted from April 1 to May 12, 2018 at the WKU Agricultural Research and Education Complex at 406 Elrod Rd. in Bowling Green, KY. This 3.23 km^2 research and teaching facility houses the animals used by Western Kentucky University's Agriculture program. The Equine Unit includes multiple large pastures and a 40-stall barn with a classroom and laboratory. Eight mature idle stock type geldings and mares between the ages of 6 to 12 years old, with maintenance only requirements, were randomly assigned to either a space-restricted rotational grazing group (SRG; two mares and two geldings; initial BW 512 ± 6 kg; $n = 4$) or a continuous grazing group (CG; two mares and two geldings; initial BW 518 ± 49 kg; $n = 4$) for 42 days. Horses were current on dental care, farrier care, and vaccinations. All horses resided on the farm for at least two years prior to use in this study.

2.2. Forage requirement

The SRG horses were turned out into a single grazing cell calculated to contain enough pasture forage to provide 80–90 % of their average maintenance digestible energy (DE) requirements for six and a half days based on the work of Gill et al. (Gill et al., 2016) and National Research Council recommendations for target DE levels and the herbage mass required (National Research Council, 2007). All horses were stabled during the second half of the seventh day with feed withheld for the SRG group to facilitate weighing. Target DE levels and herbage mass required were calculated using the following equations.

(1) Target DE˙ level (Mcal) = 0.80 or 0.90 (mean BW† x 0.033 × 4 horses x 6.5 d)

(2) $Herbagemassrequired(kgDM) = \frac{TargetDErestrictionlevel(Mcaltotal)}{PastureDE(Mcal/kgDM)}$

˙DE = digestible energy; †BW = bodyweight (kg)

Dry matter (DM) was calculated according to a regression equation for compressed canopy height (cm) regressed with the weight of clipped forage in a 0.25- m^2 area on a dry matter basis (Rayburn & Rayburn, 1998). Compressed canopy height measurements were taken using a falling plate meter made from a 0.25- m^2 piece of plexiglass (1.85 kg) with a PVC sheath and a metal pole (Martinson et al., 2017). The sheath was raised to 51 cm and then dropped along the pole to canopy height below for each measurement (Rayburn & Rayburn, 1998). The initial falling plate meter measurements were taken Sunday mornings prior to horse introduction to a new SRG grazing cell to determine the mean initial compressed canopy height (x). The area of the new 6.5-d grazing cell was calculated by entering the mean initial height into a calibration equation for herbage mass contained within the field. Approximately 20–30 falling plate meter measurements were taken in a serpentine pattern with 2–3 m between each collection from each SRG cell. For the CG cell, 40–60 falling plate meter measurements were taken with 6–8 m between each measurement with adjustments made when nearing a mowed fence line.

To create the herbage mass calibration equation, 20 independent falling plate meter measurements were taken, representing 6 short, 8 medium, and 6 tall compressed canopy heights from the entire pasture area and used to calibrate the falling plate meter. Calibration was accomplished by recording the compressed canopy heights and then harvesting the foliage within the compressed canopy's boundaries to as to close to the ground as possible. The forage was harvested within a 0.25 m^2 polyvinyl chloride frame using electric grass clippers (7.2 V cordless grass shear, Black & Decker, Baltimore, MD, USA). The harvested calibration samples were dried in a Caster grass kiln and the percentage DM was calculated. Grams of DM harvested within the 0.25 m^2 area under the plate meter were regressed against the compressed canopy height (cm) to determine pasture forage density. Digestible energy of the forage was determined weekly via laboratory analysis by Dairy One Forage Labs (NIR and wet chemistry methods, Ithaca, NY) of samples collected for herbage mass calibration. The dimensions of each new grazing cell for the SRG treatment was calculated the morning prior to grazing by dividing the herbage mass required determined in Eq. 2 (above) using the DE measured during the previous week by herbage mass per square meter as determined using the rising plate meter (Table 1). Horses were moved on day 7 of each week for six weeks.

The CG horses were turned out in a single 9308 m^2 cell adjacent to the SRG group with approximately 160 % of their daily maintenance requirements for 42 days. Grazing cells for both groups were fenced using temporary electric tape (1″ polytape American Farm Works, Lititz, PA). Both groups were provided water and a trace mineral block (Champion's Choice Trace Mineral Salt Block, Cargill Salt Division, Wayzata, MN) *ad libitum*. Both SRG and CG grazing cells contained predominantly nontoxic endophyte infected tall fescue (*Festuca arundinacea*) and were similar in nutrient content.

2.3. Determination of bodyweight

Beginning April 1 and at 1600 h on day seven of each week, SRG and CG horses were brought inside overnight with feed withheld, and at 0700 h the next morning, they were weighed on a digital livestock scale (Model: PS3000, Brecknell Scales, Fairmont, MN) followed by turnout for a total of seven weight measurements per horse for the duration of the study.

2.4. Behavior observation

Beginning in week two, animal behavior was recorded on the second, third, and fifth day of each week. Six observers were randomly assigned one hour long sessions in which they would observe the behavior of all horses in both treatment groups during 30 s scans completed every six minutes. Behaviors were recorded based upon a standard ethogram as described by McDonnell (McDonnell, 2003). Observations were limited to daylight hours and ranged from nine to 12 h depending on day length,

Table 1
Space-restricted grazing cell restriction level for 4 horses at the equine unit of the WKU Agriculture and Research Education Center. Space-restricted grazing cell areas were determined by regression analysis of dry matter and compressed canopy height in combination with National Research Council daily energy requirements for 6.5 days. Calibration equation for herbage mass used each week was calculated by regressing dry matter to compressed canopy height of a rising plate meter. An unrestricted control group used for comparison had a cell size of 9308 m^2, much larger than required based upon the initial digestible energy measured of 2.28 Mcal kg^{-1}.

SRG Cell[1]	Cell Size (m^2)	iHM (kg DM)	Compressed canopy height (cm)	Approximate restriction level (%)	DE (Mcal kg^{-1})	CP (%)	NDF (%)
Cell 1	1260	172	10.2	90	2.28	27.4	44.3
Cell 2	825	141	12.7	85	2.61	25.6	49.7
Cell 3	780	145	13.2	80	2.46	27.1	40.0
Cell 4 (initial)	560	140	17.8	80	2.37	22.1	45.8
Cell 4 (final) *rain	720	132	17.8	85			
Cell 5	405	132	23.4	80	2.61	27.9	46.1
Cell 6	297	140	29.2	80	2.55	24.7	39.5

[1] SRG=space-restricted grazing; iHM=initial herbage mass; NRC=National Research Council; DE=digestible energy; CP=crude protein; NDF=neutral detergent fiber.

weather, and observer availability. At the completion of the study, 1660 animal behavior observations were recorded.

2.5. Statistical analysis

Results were analyzed using Microsoft Excel (Microsoft Corporation, Redmond, WA) and SAS version 9.4 (SAS Institute, Cary, NC). Data were grouped by entering recorded observations into Microsoft Excel and sorting into pivot tables. Frequencies of behavior were grouped by number of observations per day by behavior for each horse individually. Horses were sorted by treatment into either space-restricted grazing (SRG) or continuous grazing (CG). Bodyweight (BW) in kg was entered by week. Data was analyzed as a mixed-model with repeated measures and nesting for main effects of BW and graze frequency. Collection weeks were considered repeated measures as effects to BW and graze frequency was expected to change over time. Horses were nested within their respective treatments to determine if individual horses had a significant effect on overall treatment means. When significance was determined ($p \leq 0.05$), means were separated using Fisher's Protected Least Significant Difference (α=0.05). Pearson correlations were calculated for BW and graze frequency, using the BW measurement from the Sunday prior to the behavioral observations. Only the five weeks of behavior data were figured into the behavior collection.

3. Results

3.1. Bodyweight

A treatment by time interaction ($p < 0.0001$; $df = 6, 17.6$; $F = 20.46$) for the change in bodyweight occurred between the SRG and CG groups (Fig. 1). The CG horses (initial average BW 518 ± 49.0 kg) gained 42 kg in bodyweight (final average BW 562 ± 45.6 kg) as the weeks progressed, with a steady gain in the first few weeks and a plateau after Week 4. The SRG horses (initial average BW 512 ± 6.1 kg) lost an average of 6 kg in bodyweight (final average BW 506 ± 6.6 kg). Individual variation occurred between horses in each group, with two horses in the group weighing more at the completion of the study than at the start. SRG horses gained an average of 9 kg in BW from initial to Week 2, and 2 kg from Week 4 to 5, but had an overall minor decline in bodyweight (6.1 ± 8.7 kg).

3.2. Behavior

The behaviors most commonly displayed by both groups were graze (G; 60–83 % of behavioral observations per week) and stand (S; 14–30 % of behavioral observations per week). The remaining behaviors, such as drinking and walking accounted for less than 4 % of the time budgets. A significant interaction was detected between week and treatment ($p < 0.0001$; $df = 4, 28.8$; $F = 12.70$) for frequency of time horses spent grazing (Fig. 2). Grazing initially accounted for 83.5 % of behavior for the SRG horses but decreased to 70.1 % in the final week of the study. The CG horses increased in proportion from 69.5 % of accounted behavior spent grazing to 86.7 % in the final week of study. The SRG group had a 3.4 % increase in grazing behavior from Week 4 to Week 5, and the CG group had a 10.5 % decrease from Week 2 to Week 3. The interaction occurred between Week 2 and Week 3 where the SRG horses began to dedicate less time to grazing than the CG horses. A moderate correlation ($r = 0.63$) was evident between BW and grazing for the CG group for the five weeks that behavior was collected, and a mild correlation ($r = 0.41$) existed between BW and G for the SRG group (Figs. 3 and 4).

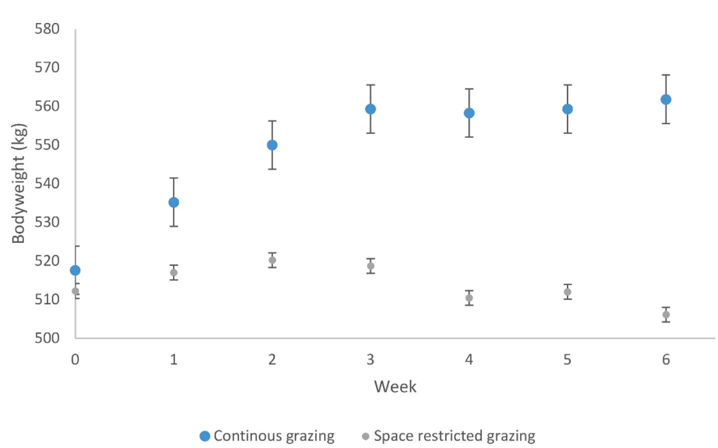

Fig. 1. Space-restricted grazing to reduce digestible energy availability by 10–20 % resulted in a significant treatment by time interaction when compared to unrestricted, continuous grazing for body weight in equine. Error bars represent standard error from the mean.

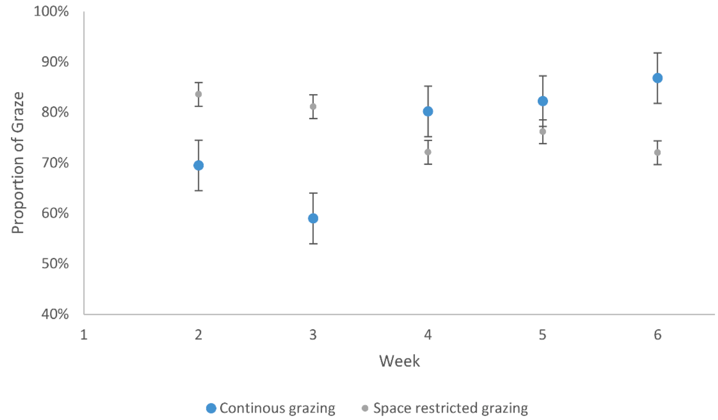

Fig. 2. Average proportion of graze behavior by continuous grazing and space-restricted grazing horses changed over time. Error bars represent standard error from the mean. ($n = 4$ per treatment).

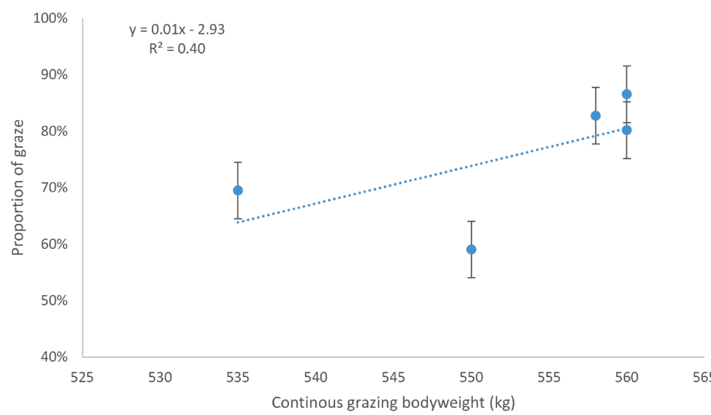

Fig. 3. Average proportion of graze behavior correlated with average bodyweight in kg for horses exposed to continuous grazing for the five weeks in which behavior was collected, as behavior was not recorded week 1, with trendline for best fit (error bars represent one standard error).

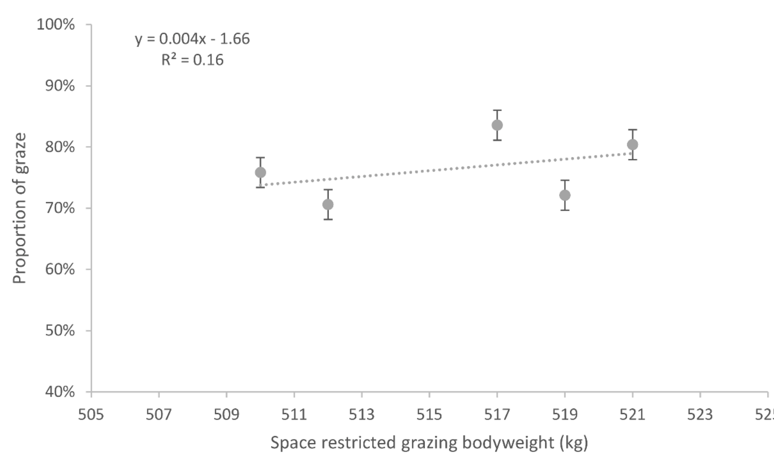

Fig. 4. Average proportion of graze behavior correlated to average bodyweight in kg for horses in space-restricted grazing for the five weeks in which behavior was collected, as behavior was not recorded week 1, with trendline for best fit (error bars represent one standard error).

4. Discussion

Bodyweight (BW) was impacted by space-restricted grazing over time, though weight loss was not as dramatic as expected. Time at pasture was not restricted. The restricted pasture space contained 80–90 % of National Research Council (NRC) daily digestible energy requirements for each week. The space restriction resulted in a marginal reduction from the initial BW in 6 weeks, effective in preventing horses from gaining significant weight as was seen in the continuous grazing group. A longer duration at the 80–90 % restriction level may have resulted in more substantial weight loss, such as the findings of Dugdale et al. (Dugdale et al., 2010), Argo et al. (Argo et al., 2012), and Gill et al. (Gill et al., 2016) that led to 11.4 %, 7.4 %, and 8 % reduction from initial BW in 12, 12, and 26 weeks respectively. A key difference between this space-restricted study and the one conducted by Gill et al. (Gill et al., 2016) was the restriction in the Gill et al. study included limiting time at pasture in addition to space. This difference in time allotted for horses to graze was likely a significant factor in the weight loss between this space-restricted study and previous studies.

In conditions where space was restricted to reduce the available calories, horses did not lose as much weight as expected. Horses in the SRG group may have increased bite rate during the 24-hour turnout to consume more grass than expected and reduce the amount of weight lost. Horses in time restricted grazing increased their dry matter intake rate when restricted to three hours of time at pasture, though the amount of total DM intake they were able to consume was still reduced compared to horses with unrestricted access (Glunk & Siciliano, 2011). A later study by Glunk et al. (Glunk et al., 2013) found that when horses undergoing restricted grazing conditions are given hay *ad libitum*, they will make up for the reduced DE intake in pasture grass by consuming more DE in hay. The compensation for restriction seen in the previous studies likely occurred in the current study as well. Additionally, individual variation in BW trajectories within the SRG group suggests that herd dynamics involved with the significant restriction of space may have influenced the average weight loss of the group. To maintain the desired restriction level of 80–90 % of NRC recommended digestible energy requirements, grazing cell sizes for SRG horses were decreased week-to-week in the current study. The pasture grass grew faster over time, likely from additional nitrogen availability and the favorable spring weather. During the final two weeks of the study, cell size was quite small, only measuring 405 and 297 m^2 respectively. Dominant horses tend to have longer grazing opportunities when forage is limited, particularly in smaller herds (Houpt et al., 1978). Although no aggressive behaviors were noted and dominance could not be confirmed with data available, dominance could explain why two of the horses in the SRG treatment gained weight over the course of the study and two lost weight.

The 80–90 % restriction led to SRG horses grazing less over time while the CG horses grazed more. There may have been multiple contributing factors to why SRG grazing decreased and CG increased. Glunk and Siciliano (Glunk & Siciliano, 2011) found that restricting the duration horses spent in the pasture resulted in these horses increasing their dry matter intake rate. During week 2, SRG horses may have increased their proportion of grazing to compensate for the restriction level. Changing conditions provided to the SRG horses may have caused them to graze less over time. Bott et al. (Bott et al., 2013) described horses as selective grazers that prefer to graze in roughs and lawns, eating the more palatable patches first and leaving taller more mature patches as places to defecate, and preferring to graze less on mature grass. In space-restricted grazing, the horses are forced to graze more uniformly. The grass was not mowed prior to moving to new grazing cells. Therefore, older, less palatable grass accumulated over time. Horses may have located the younger grass initially, but as the week progressed, they would forage less and stand more often. Meanwhile, the CG horses were able to naturally graze their cell and avoid the roughs of more mature grass, being more selective, and focusing on patches of fresher growth. A significant dip in grazing occurred during Week 4 when heavy rainfall and mud from trampling wet ground required the SRG grazing cell to be adjusted to preserve the pasture. The CG horses were not impacted significantly due to the greater amount of space, but SRG horses likely had less appealing grass due to the consequences of the ground being muddier in a more compact space. Additionally, Dugdale et al. (Dugdale et al., 2010) found that ponies in box stalls increased play behavior (40 %) and resting behavior (95 %) when hay was restricted compared to hay fed *ad libitum*. Prezwalski horses in captivity also spent less time pacing and performing other behaviors when hay was available *ad libitum,* meaning intake was unrestricted similar to conditions for the CG group (Boyd, 1988). Horses of SRG in the current study may have experienced a similar trend in increasing standing behavior as a form of resting due to having feed restricted and being unable to graze as much as CG horses. The increase in proportion of time spent grazing seen by CG may have been due to being able to graze without limits.

Of interest is that both groups of horses grazed for 60–85 % of the behaviors observed each week. Studies by Duncan (Duncan, 1980), Boyd et al. (Boyd et al., 1988), and Popp and Scheibe (Popp & Scheibe, 2014) reported that domestic and feral equids with 24-hour ability to graze foraged for 50–64 %, 49 %, and 51 % of recorded behaviors, respectively. Both groups in the current study grazed for higher percentages than most of the previous studies, perhaps due to having less area to explore and roam as the past studies allotted more than 2.2 acres per horse. Alternatively, stabled ponies given hay *ad libitum* dedicated 70 % of their time budget to consuming hay when they could see other stabled horses compared to 60 % of their time when view of other horses was constricted because of the comfort of socialization (Sweeting et al., 1985). The current study may reflect that both the CG and SRG horses felt safe to graze more than horses in larger spaces. Horses in domestic conditions may develop stereotypical behavior such as pacing and weaving when natural conditions are interrupted (Sweeting et al., 1985; Dugdale et al., 2010). The increase in grazing behavior among both the CG and SRG horses could be desirable for owners that want to limit these stereotypical behaviors.

A general relationship was evident in both groups of horses between BW and grazing behavior, with a slightly stronger relationship among the CG horses. Increasing bodyweight may have led to higher maintenance energy requirements, similar to a relationship in humans where maintenance calorie requirements increase with bodyweight (Hall et al., 2015). Week 3 for the CG horses did not follow the same relationship as closely as all horses grazed 10 % less than other weeks despite gaining 10 kg in bodyweight. An external event may have caused the horses to stand more vigilant, such as other farm activities being visible from the grazing cell that the other horses could not see. The weather during Week 3 was around 15.5 °C and sunny, but as the SRG horses did not behave differently, there does not seem to be cause for the difference.

The limiting assumptions of this study included low animal numbers for each treatment group, random assignment of horses to treatment groups created greater bodyweight variance in one the CG group compared to SRG, and growth rate of grass as a result of weather leading to increased forage height. Each treatment group was limited to four horses due to a lack of resources which reduces the overall robustness of the results. Significant rainfall during week 4 resulted in adjustments to the grazing cell of the SRG treatment to include additional area for pasture preservation, and the larger area available to the SRG horses resulted in weight gain identified in week 5. As the study neared its end, the intense growth in height (19 cm) of the pasture grass prompted the grazing cell area to be reduced (963 m^2) for the SRG horses to maintain the restriction level. This change in area may have had an influence on behavior and may have affected their physical activity and energy output. However, these natural conditions are likely to occur in practical application of the results and thus do not invalidate findings.

This study was unique in that restriction of pasture intake was attempted without limiting time allotted for horses to graze in the pasture. The restriction of space for grazing to limit horses to 80–90 % of DE requirements did affect both weight and behavior of horses over time. Weight loss in SRG was gradual but significantly different from the weight gain seen in the CG horses. More substantial weight loss may be achievable by creating grazing cells with dry matter herbage mass to contain digestible energy requirements for only a couple days at a time. To further this research, studies should be conducted using grazing cells that contain only two horses to reduce the social influence on weight loss in horses with intent to rotate locations every three days.

Assuming an easy method to estimate forage quality and quantity, the method established in this study could be preferable for farm managers looking to limit weight gain of horses without needing to bring horses into stalls or dry lots every day. Horses still grazed for a majority of the time in both restricted and continuous grazing systems similar to horses in more open grazing conditions, which could be ideal for owners looking to limit stereotypical behavior and maintain a relaxed environment. The results of this study can be applied by owners who are unable to bring horses out of pastures due to limited time or behavioral needs that would like to limit potential weight gain.

Ethical statement

Hereby, I, William Strunk, consciously assure that for the manuscript "Time budgets in horses during continuous and space-restricted rotational grazing" the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.
8) Experiment was approved by International Care and Use Committee – Animal Welfare Assurance #A3558–01 designation #17–14.

I agree with the above statements and declare that this submission follows the policies of Journal of Veterinary and Animal Science as outlined in the Guide for Authors and in the Ethical Statement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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