Equine Veterinary Journal

Equine Veterinary Journal ISSN 0425-1644
DOI: 10.1111/evj.12238

Water intake, faecal output and intestinal motility in horses moved from pasture to a stabled management regime with controlled exercise

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Summary

Reasons for performing study: A change in management from pasture to stabling is a risk factor for equine colic.
Objectives: To investigate the effect of a management change from pasture with no controlled exercise to stabling with light exercise on aspects of gastrointestinal function related to large colon impaction. The hypothesis was that drinking water intake, faecal output, faecal water content and large intestinal motility would be altered by a transition from a pastured to a stabled regime.
Study design: Within-subject management intervention trial involving changes in feeding and exercise using noninvasive techniques.
Methods: Seven normal horses were evaluated in a within-subjects study design. Horses were monitored while at pasture 24 h/day, and for 14 days following a transition to a stabling regime with light controlled exercise. Drinking water intake, faecal output and faecal dry matter were measured. Motility of the caecum, sternal flexure and left colon (contractions/min) were measured twice daily by transcutaneous ultrasound. Mean values were pooled for the pastured regime and used as a reference for comparison with stabled data (Days 1–14 post stabling) for multilevel statistical analysis.
Results: Drinking water intake was significantly increased (mean ± s.d. pasture 2.4 ± 1.8 vs. stabled 6.4 ± 0.6 l/100 kg bwt/day), total faecal output was significantly decreased (pasture 4.62 ± 1.69 vs. stabled 1.81 ± 0.5 kg/100 kg bwt/day) and faecal dry matter content was significantly increased (pasture 18.7 ± 2.28 vs. stabled 27.2 ± 1.93% DM/day) on all days post stabling compared with measurements taken at pasture ($P<0.05$). Motility was significantly decreased in all regions of the large colon collectively on Day 2 post stabling (-0.76 contractions/min), and in the left colon only on Day 4 (-0.62 contractions/min; $P<0.05$).
Conclusions: There were significant changes in large intestinal motility patterns and parameters relating to gastrointestinal water balance during a transition from pasture to stabled management, particularly during the first 5 days.

Keywords: horse; management; ultrasonography; intestine; water; faecal

Introduction

The management of horses may be affected by a range of factors, such as season, geographic region, horse's breed, age or use, and the owner's finances [1]. Most horses in the UK have some access to pasture throughout the year, but are also stabled at some time [1–3], which means that most will experience management changes.

Simple colonic obstruction and distension (SCOD) is one of the common causes of colic [4–7]. Risk factors for SCOD are a recent change in exercise, increased time spent in a stable (with stabling 24 h/day associated with the greatest risk), and a recent change in concentrate feeding [8,9]. Pelvic flexure impactions are the most common type of SCOD [8], often associated with transferring a horse from pastured to stabled management. It is not yet clear from existing research whether the underlying mechanism of impactions is dehydration of ingesta, or an alteration in motility, or both [10,11]. The aim of this study was to investigate the effects of a management change from pasture with no controlled exercise to stabling with light exercise on large intestinal motility and features of gastrointestinal water homeostasis in the horse. The hypothesis was that drinking water intake, faecal output, faecal water content and large intestinal motility would be altered following a transition from a pastured to a stabled regime.

The objectives were: 1) to evaluate drinking water intake, faecal output and faecal dry matter in horses during a transition from pasture with no controlled exercise to stabled management with light exercise; 2) to compare and evaluate changes in motility in 3 regions of the equine large intestine (caecum, sternal flexure and left colon) using ultrasonography during a transition from pastured to stabled measurement; and 3) to determine the duration and magnitude of any changes in gastrointestinal function during a transition from pastured to stabled management.

Materials and methods

Horses

All subjects were working military horses, housed at the Defence Animal Centre in Melton Mowbray, Leicestershire. Selection criteria were: no history of gastrointestinal disease within the previous 12 months, participation in an established anthelmintic programme and clinically normal at the start of the study.

Seven geldings and one mare, aged 6–10 years, ranging in height 133–173 cm were recruited. Breed types were Irish crossbreeds, Dutch Warmblood and Highland. Body weights, estimated using the formula described by Carroll and Huntington (1988), were 500–800 kg and mean body condition score was 4 [12].

Study design

A within-subject study design was used. Horses were monitored during pasture management, moved to a stabled regime and monitored for 2 weeks following the transition, and therefore each horse acted as its own control. Horses were randomly allocated into 2 groups, and the date of transition from pasture to stabling was staggered by one week between the groups, giving crossover between the 2 regimes.

All horses were at pasture for a minimum of 3 weeks prior to the study. At pasture, horses were kept in grass paddocks for 24 h/day, with constant access to fresh water, no controlled exercise and no supplemental feed. Horses were partitioned into individual paddocks during two 24 h monitoring periods in each 7 day study period. The staggered design meant that horses in *Group 1* had 2 monitoring periods at pasture over a 7 day period, and horses in *Group 2* had 4 monitoring periods at pasture over a 14 day period (with the second week overlapping *Group 1's* first stabling week). Grass within the paddocks was mature permanent pasture, with a mix of grasses including ryegrass, rough meadow grass, cocksfoot and timothy. Rock salt blocks were available at pasture prior to the study. All the horses were accustomed to pasture turnout, and were not active beyond grazing and walking in the fields. The paddocks were <2 ha in size.

Under the stabled management regime, horses were housed individually on shavings, with continuous access to fresh water. Meadow grass hay containing timothy and ryegrasses was fed twice-daily according to body weight and condition score (1.8–2.7% bwt/day of hay). No concentrates were fed. Horses were exercised between 10.30 h and 12.30 h for 60 min/day: consisting of two 30 min sessions on a horse walker during the first week, progressing to 60 min of light schooling by the end of Week 2 post stabling. Environmental conditions were evaluated from data collected by the meteorological station based at the University campus (Sutton Bonington, Location: 4507E 3259N) and included mean hourly and daily temperature, relative humidity and rainfall [13].

Water intake and faecal assessment

During monitoring periods, drinking water intake, total faecal output and faecal dry matter were assessed. Drinking water intake (l/100 kg bwt/day) was assessed as the volume (litres) drunk over a 24 h period and calculated according to the horse's body weight (per 100 kg bwt). Drinking water was given in fixed containers that were weighed at the start and end of each monitoring period and checked a minimum of 4 times/24 h.

Faecal output (kg/100 kg bwt/day) was measured as total weight (kg) of faeces collected per 24 h period, calculated according to body weight. All faeces passed during the monitoring period were collected from the stable floor or pasture (minimum of 4 collections/24 h) and weighed on collection using a manual weighbridge.

Faecal dry matter (% DM/day) was assessed by taking a 0.5–1 kg subsample from a pooled sample of faeces collected twice-daily for each monitoring period (am and pm). The subsample was stored for transport in a sealed plastic bag, before drying in a forced draught oven at 90°C to a constant dry weight.

Ultrasonographic assessment

Transcutaneous ultrasonography was used to assess motility of the caecum, sternal flexure and left colon, as described by Williams *et al*. [14] using a MyLab 30 with a 5–7.5 MHz curvilinear transducer (Esaote)[a]. Horses were not sedated and were restrained in a stable with which they were familiar using a headcollar. No food was available during the ultrasound assessment, and horses were always brought into the stables and assessed in pairs. The sites were not clipped. Site preparation, imaging sites and technique were as previously described [14]. The caecum was identified by its large diameter, presence of sacculations, hyperechoic contents, dorsoventral or ventrodorsal contractions, and location within the dorsocaudal right flank. The sternal flexure was identified by its large diameter, presence of sacculations, acoustic shadowing from contents and its location in the midline of the cranioventral abdomen, caudal to the sternum. The left colon was identified by its large diameter, acoustic shadowing from contents, and its location directly overlying the caudal ventral body wall, adjacent to the inguinal region. Contractions were classified as rhythmic deviations of the intestinal wall or contents of >2 cm that propagated along the region of intestine within the imaging plane and were not related to respiratory or other movements of the horse. Contractions were not categorised by type/orientation. Motility was assessed twice daily during each monitoring period: in the morning between 08.00 h and 10.00 h, and in the afternoon between 13.00 h and 15.00 h. The frequency of contractions was measured for four 1 min periods for each region of the intestine, and repeated at each measurement time (am or pm). The time taken to obtain the ultrasound measurements was <20 min for each horse, and the order in which horses were assessed was consistent throughout the study. The number of contractions/min was evaluated independently by 2 observers at each measurement time, and were recorded using the video software on the ultrasound machine. The measurement was repeated or the video reviewed if there was disagreement between the 2 observers. The observers were not blinded to the management regime.

Data analysis

Daily mean measurements of motility for each region of the intestine were pooled for statistical analysis. Statistical analysis comprised an initial assessment of the data to explore covariate distributions and associations. Final inferences were based on conventional random effects generalised linear models using MLwiN 2.10 software [15]. Further details of the model are available in Item S1. Results were considered significant at a value of $P<0.05$.

Model fit was evaluated using conventional residual analysis (graphical assessment of residuals, checking for normality, and any evidence of data outliers that may have had an excessive influence on the model parameters).

Results

Data

Data were collected for 7 horses; one was excluded due to an unsuitable temperament. One horse developed palmar heel pain at pasture (positive to hoof testers), presumed to be soft tissue bruising; it remained in the study but was on a reduced exercise programme (horse walker only) throughout the stabling period. Ultrasonographic measurements were not obtained for one region of the large intestine in 2 horses: caecal contractions could not be reliably identified in one horse with a thick coat and excess abdominal fat, and one horse would not tolerate ultrasonographic examination of the left colon region.

Environmental conditions

The study was conducted between 24 August 2009 and 24 September 2009. The temperature and humidity and rainfall were similar during the pasture and stabled phases of the study (Item S2).

Data analysis

The model fit was found to be good. The graph of residuals is available in Item S3. The effect of the 'Group' each horse was allocated to (*Group 1* or *2*, which determined the week in which they moved to stabled management) was investigated as a fixed effect but had no significant effect so was not included in the final model. The coefficients from the final model results showed significant differences ($P<0.05$) in drinking water intake, faecal output, faecal dry matter content and some differences in intestinal contractions (Items S4, S5).

Drinking water intake

While at pasture (Day 0), horses drank a mean ± s.d. volume of 2.4 ± 1.8 l/100 kg bwt/day (Fig 1). While stabled, horses drank a mean volume of 6.36 ± 0.57 l/100 kg bwt/day. Drinking water intake was significantly higher on all days post stabling compared with when horses were at pasture ($P<0.05$). In the stabling regime, drinking water intake was greatest on Day 10 after stabling (7.31 ± 0.03 l/100 kg bwt/day; Item S4, Fig 1).

Faecal output

Mean daily faecal output of horses at pasture was 4.62 ± 1.69 kg/100 kg bwt/day (Fig 1). Mean daily faecal output of horses under the stabling regime was 1.81 ± 0.5 kg/100 kg bwt/day. This was significantly lower on all days post management change compared with when horses were at

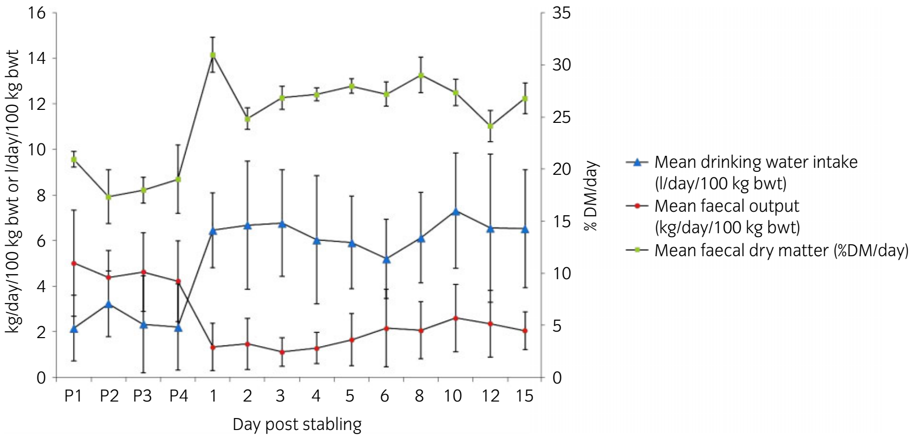

Fig 1: Changes in mean ± s.d. drinking water intake (l/day/100kg bwt), faecal output (kg/day/100 kg bwt), and faecal dry matter content (% DM/day) in 7 horses during a transition from a pastured management regime (P1–4) to a stabled management regime (Days 1–15). All values from Day 1 to 15 were significantly different (P<0.05) from the reference category (Pasture values). *Pasture values were obtained during 2 consecutive 24 h monitoring periods during Days 7–14 prior to stabling (P1 and 2) and Days 0–7 prior to moving to stabling (P3 and 4). A staggered study design was used, whereby 4 horses were moved to stabling first, and the remaining 3 horses moved a week later. Values P1 and 2 therefore are from 3 horses, and values P3 and 4 are from all 7 horses.

pasture (P<0.05). Lowest faecal output was recorded on Day 3 after stabling (1.11 ± 0.63 kg/100 kg bwt/day), and the highest faecal output after stabling was on Day 10 (2.60 ± 1.49 kg/ 100 kg bwt/day; Item S4, Fig 1).

Faecal dry matter

The mean percentage faecal dry matter content for horses at pasture was 18.7 ± 2.28% DM/day (Fig 1). Mean percentage faecal dry matter content for horses under the stabling regime was 27.2 ± 1.93% DM/day. Faecal dry matter content was significantly higher on all days post stabling compared with when horses were at pasture (P<0.05). The highest percentage of faecal dry matter was recorded on Day 1 post stabling (31 ± 4.17% DM/day; Item S4, Fig 1).

Large intestinal motility

Under the pastured regime (Day 0), the mean frequency of intestinal contractions was 2.79 ± 0.13 contractions/min in the caecum, 2.34 ± 0.09 contractions/min in the sternal flexure and 1.18 ± 0.09 contractions/min in the left colon (Item S5, Fig 2).

The mean frequency of intestinal contractions were significantly less on Day 2 post stabling (0.76 contractions/min lower, confidence interval [CI] -1.03, -0.49) in all 3 regions of the intestine compared with the pasture reference category (Day 0). Recordings from Day 2 post stabling were the lowest overall (caecum = 2.03 contractions/min, sternal flexure = 1.58 contractions/min, left colon = 0.42 contractions/min). The mean frequency of intestinal contractions was significantly greater on Day 5 post stabling (0.31 contractions/min higher, CI 0.04, 0.58) in all regions of the large intestine compared with the pastured regime (caecum = 3.1 contractions/min, sternal flexure = 2.65 contractions/min, left colon = 1.49 contractions/min; Fig 2).

The mean frequency of intestinal contractions of the left colon only was significantly lower on Day 4 post stabling (0.62 contractions/min lower, CI -1.18, -0.08) compared with when horses were at pasture (Item S5, Fig 2).

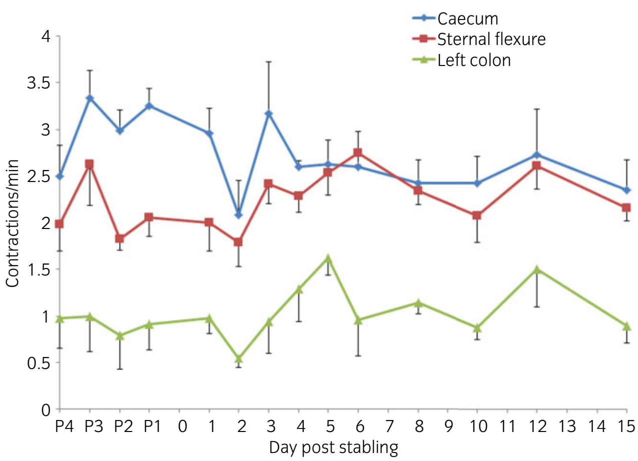

Fig 2: Changes in mean ± s.d. contractions/min of the caecum (n = 6), sternal flexure region (n = 7) and left colon (n = 6) for horses during a transition from a pastured management regime (P) to a stabled management regime (Days 1–15). Contractions/min were measured using transcutaneous ultrasonography. A crossover study design was used, resulting in pasture values from 2 consecutive monitoring periods during Days 7–14 prior to stabling (3 horses) and 2 consecutive monitoring periods Days 0–7 prior to moving to stabling (7 horses).

Discussion

Previous research has identified a link between a change in management and risk of SCOD, but how this actually affects intestinal function remains unclear. Impactions can be caused by decreased water intake [7,16], physical changes in the size of the lumen [10] and motility modifying drugs [11], and therefore several factors may be relevant in management change. There are a number of differences between pastured and stabled horses: pastured horses have a more continuous and higher volume of intake of forage with a higher water content, and spend a large amount of their time moving and eating. Mares that were stabled (with concentrates and hay fed twice daily) spent 15% of their time eating, compared with 55% of their time while pastured [17]. There are also significant differences in activity levels, with horses in paddocks travelling distances of 4.7–7.2 km/day compared with 1.1 km/day when confined in a stable or yard and 1–2.4 km during an intensive 30–40 min training session [18].

This study monitored a working horse population, during a scheduled change in management from pasture to stabling. The study monitored a natural situation, but has some limitations compared with a more controlled experimental study design. There are many differences between pasture and stable management, including a change in feed type, nutritional content, electrolyte composition, forage water content, feeding pattern, and exercise or activity levels, all of which may affect gastrointestinal function [8,9,18–21]. All of these factors are relevant in this study, and therefore it is not possible to draw any conclusions about the significance of individual factors. We have identified significant effects during a transition between the specific management regimes described, highlighting the need for further investigation to determine which individual factors are most important.

A recent change in management is a risk factor for colic [22], and therefore this study evaluated the transition period between management regimes to monitor how horses responded and adapted to change. The study evaluated a 2 week period following management change, with the horses monitored more intensively during the first week. A direct comparison of different management regimes would require a blinded crossover study with a 'wash-out' period between each different regime.

Other limitations of the study are the use of noninvasive methods only (which precluded the measurement of plasma and electrolyte values, ingesta hydration and renal and urine output), the lack of blinding, the small numbers of horses involved, and the loss of data from some horses. The loss of some data was anticipated and initial recruitment numbers were targeted to allow for this. A within-subject study design with data analysis by multilevel modelling was used to minimise possible confounding effects such as variations in an individual animal's responses and environmental conditions, and loss of individual data points.

In the transition between the specific management regimes described here, there were significant and persistent changes in water intake, faecal output and faecal water content. Normal volumes for drinking water intake of 0.05–0.07 l/kg bwt/day have been recorded in healthy horses previously [21,23,24]. There are a number of factors that may affect this, including diet, exercise and environmental conditions [21]. In the current study, the changes in drinking water intake were equivalent to a 500 kg horse drinking 12 l/day (0.024 l/kg bwt/day) at pasture, compared with 31.8 l (0.06 l/kg bwt/day) while stabled. Furthermore, these values are based on overall mean values for each regime, and on certain days, there was an even greater difference. Despite this dramatic increase in drinking water intake, this did not seem to compensate for the diet change; stabled horses produced significantly drier faeces, compared with the pastured horses. The overall changes in faecal water output were equivalent to a 500 kg horse producing 18.75 kg faecal water/day at pasture changing to 6.6 kg faecal water/day when stabled. Faecal output also decreased dramatically – equivalent to 23.1 kg faeces/day at pasture to 9.0 kg faeces/day during stabling for a 500 kg horse. Overall, the horses in the stabling regime were drinking significantly more water, but producing less water in their faeces, which suggests significant changes in fluid movement across the gastrointestinal tract between the 2 management regimes.

The duration and pattern of changes following the transition to stabling was interesting, particularly in the context of SCOD. Both drinking water intake and faecal water content showed an abrupt significant change immediately following the change in management, but the pattern of changes and peaks differed between the 2 parameters. Some of the highest values for drinking water intake were in the first 3 days, but with a second higher peak resulting in the greatest intake 10 days post stabling. Rapid changes in faecal water content in response to changes in hydration, have been reported previously, consistent with this early response [24]. This second peak may correspond to the changes in the content of the colon and the bacterial flora gradually changing in response to a new diet [25]. Drinking water intake is dependent on a number of factors including environmental conditions, exercise, diet and feeding patterns [7–9,26,27]. In the current study, environmental conditions were similar, and differences in diet, activity levels and feeding patterns are likely to be the main factors.

The pattern of changes was slightly different for faecal parameters. The greatest changes (highest faecal dry matter and lowest faecal output values) were recorded on the first day of the stabling regime. The gastrointestinal tract holds large volumes of water and can act as a reservoir to maintain circulatory fluid volumes [24,28,29]. Fluid transit through the equine gastrointestinal tract is rapid, and the small colon also has a role in the retention of faeces and absorption of water. Ingesta transit is slower, with changes in colonic bacterial population and the dry matter content of colonic ingesta and faeces occurring more than 28 h after a change in diet between forage types with different dry matter content [25]. The rapid changes in faecal water content in the current study probably represent a response to changes in hydration or electrolyte levels, or changes in activity level, and/or stress associated with management change. There are marked differences in the dry matter content of hay (84% DM for timothy hay) and grass (60% DM content for autumn grass in the UK) [30]. The continued increase in water intake, combined with stabilisation of the faecal dry matter content probably reflects the slower changes in ingesta content, as the horses were adapting to the increased dry matter of the feed.

The ultrasound assessments showed significant motility changes in the first 5 days post stabling, with the most marked effects in the left colon. This region also showed the most variation over time post management change, and did not follow a similar pattern of motility to that in the caecum and sternal flexure region, similar to previous work [14]. Pelvic flexure impactions have been attributed to its anatomical features but it has also been identified as a possible pacemaker region [31]. The current study shows regional differences in large intestinal motility; the more marked effect in the left colon could contribute to the predisposition for impactions in this region.

Overall, this study showed that drinking water intake, faecal output, faecal dry matter content and large intestinal motility change significantly in horses during a transition from pasture to stabled management. Together, these changes will result in a slowing and drying of ingesta, which was most significant within the first 5 days, suggesting a possible aetiology for large intestinal impactions in horses moving from pasture to stabled management.

This study did not identify either faecal dehydration or motility changes as the main factor affected by the management change – instead there were significant changes in both. It seems likely that dysfunction may result from interactions between different components of gastrointestinal physiology, or a failure to adapt and compensate for the changes.

Authors' declaration of interests

No competing interests have been declared.

Ethical animal research

The study was reviewed and approved by the School of Veterinary Medicine and Science, University of Nottingham Ethics Committee.

Sources of funding

S. Williams was funded by the University of Nottingham IDTC studentship. J. Horner was funded by a Wellcome student vacation scholarship. E. Orton was funded by a World Horse Welfare Undergraduate Bursary.

Acknowledgements

The authors would like to thank the Defence Animal Centre, Melton Mowbray, for providing access to their horses and facilities.

Authorship

S. Williams was the main researcher, undertaking this work as part of her PhD, with a major role in data collection, data analysis and manuscript preparation. E. Orton and J. Horner undertook data collection. M. Green contributed to study design and statistical analysis. S. McMullen and A. Mobasheri contributed to study design and project supervision. S.L. Freeman contributed to study design, data collection and study execution.

All authors contributed to manuscript preparation.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Item S1: Details of the modelling method.
Item S2: Table of environmental data.
Item S3: Q–Q plot of standardised Level 1 residuals for faecal dry matter model and intestinal contractions model.
Item S4: Final model of faecal output, water intake and faecal dry matter content.
Item S5: Final model of intestinal motility.