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A survey of welfare problems associated with transporting horses by road in Germany (2022–2024)

Anna May [a,*], Christopher B. Riley [b], Annabel Scharre [a], Yury Zablotski [c], Barbara Padalino [d,e]

[a] Equine Hospital, Ludwig Maximilians University Munich, Sonnenstrasse 14, Oberschleissheim 85764, Germany
[b] Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON, Canada
[c] Clinic for ruminants, Ludwig Maximilians University, Munich, Germany
[d] Department of Agricultural and Food Sciences, University of Bologna, Viale Giuseppe Fanin 46, Bologna 40127, Italy
[e] Faculty of Science and Engineering, Southern Cross University, East Lismore, NSW 2480, Australia

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ABSTRACT

Equine road transport is stressful and associated with an increased risk of behavioral problems, injuries, respiratory and gastrointestinal diseases. This cross-sectional survey-based study aimed to describe transport-related practices and the perception of behavioral and health issues in Germany. The survey targeted horse owners (amateurs and professionals) and obtained demographic details, the participant's experience, frequency and duration of transportation, and behavioral and health problems related to equine transportation. Associations among behavioral and health problems and transport parameters were examined with logistic regression analysis. In total, 432 horse owners participated, but only 59.7 % (258 respondents) completed the questionnaire. Most journeys (72.5 %) were < 2 h in duration and 45.8 % fed hay in transit. One-third of respondents observed behavioral and 42.6 % reported health problems. Diarrhea was most common (33.9 %), followed by injuries (19.3 %), muscle disorders (4 %), respiratory problems, and colic (each 2.4 %). Professionals were less likely to observe diarrhea in transported horses than amateurs (OR 1.04). In single transportation, horses were significantly more likely to show behavioral problems than when transported together (OR 0.53, CI 0.35–0.76, $P = 0.001$). In conclusion, most of the journeys in Germany were short (<2 h). A high rate of behavioral problems was reported, whereas health issues were considerably less frequently observed. This may be associated with management practices, implementation of safety equipment, shorter travel distances, and favorable climatic conditions in comparison to other studies.

Introduction

Horses are often transported during their life for sporting or breeding purposes. Road transport has been identified in many studies as a significant stress factor for horses (Smith et al. 1994, Fazio and Ferlazzo, 2003, Arfuso et al. 2023), and has been objectively evaluated for its effects on various physiological, clinical, and behavioral stress parameters (Schmidt et al. 2010, Munsters et al. 2013, Fazio et al. 2013 a,b, Fazio et al. 2015). Transport includes different stressful phases (Padalino, 2015), which have been examined separately, including loading and the loading ramp itself (Waran, 1993, Siniscalchi et al. 2014), restricted movement and isolation within the vehicle (Mal et al. 1991, Garey et al. 2010), the limited space in the trailer (Riley, 2016, Padalino and Raidal, 2020), noise levels (Minka and Ayo, 2010), and the event of unloading (Siniscalchi et al. 2014, Messori et al. 2016). Transport can have negative effects on equine health, as it is associated with an increased incidence of injuries, respiratory problems, and gastrointestinal diseases (Padalino et al. 2016a, Riley et al. 2018, Padalino et al. 2018a,b, Roy et al. 2015). Shipping fever, a predominantly bacterial pleuropneumonia, is a feared complication after equine transport among horse owners and veterinarians (Yoshikawa et al. 2003, Padalino et al. 2015, Maeda and Oikawa, 2019). A 12-h transport duration of fasted horses has been associated with ulceration of the squamous mucosa of the stomach, increased pH of the stomach contents and possibly reduced gastrointestinal motility in horses (Padalino et al. 2020). However, the management of horses during transport can directly influence the associated risk of injury and illness directly (Marahrens et al. 2011). Factors that influence the risk of

* Correspondence to: Equine Hospital, Sonnenstrasse 14, Oberschleissheim 85764, Germany
E-mail address: anna.may@lmu.de (A. May).

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transport-related diseases, for example, include the duration of transport, the horses' head position and the inability to lower their heads, space allowance, and access to water and hay (Raidal et al. 1997, Stull and Rodiek, 2002, Oikawa et al. 2005, Padalino and Raidal, 2020, Racklyeft et al. 2000, Yoshikawa et al. 2003, Takahashi et al. 2024).

To ensure the welfare of the horses, international regulations for land transport of live animals have been updated based on recent publications (Eur-Lex, 2024, Land Transport, 2024). However, there is still no consensus among the European countries, and the scientific base on which recommendations are made is limited (National Avian Welfare Alliance NAWA, 2011, Efsa - European Food Safety Authority, 2022).

Based on data from the Federation Nationale (FN), the national German equestrian federation, 3600–4000 equestrian events are organized in Germany each year, and there are 1.3 million attendees (one horse may attend more than one test, multiple entries). Because horses need to travel to an event and return home, the number of transport events associated with equestrian events is approximately 2.3 million per year. This figure does not include journeys to equine hospitals and to other boarding stables. There are approximately one million horses in Germany and nearly as many people involved in equine industry according to the German Equestrian Federation (FN, 2022).

There has been little investigation of equine road transport practices or outcomes in Germany. This study aimed to investigate the transport management practices of horses in Germany to obtain insight into the indications for the application of welfare measures, and respondents' information on reported health and behavioral problems and their possible association with road transport practices.

Materials and methods

Respondents

The survey was designed for a target audience of equine industry amateurs and professionals in Germany who had transported horses in the past two years (2022–2024). A professional in the survey's context is a person who accepts remuneration for equine related services, whereas amateur status is defined as a person not receiving money for riding, training, or handling horses.

Ethics approval

Ethical approval was granted by the Ludwig-Maximilians-University's ethics committee, state of Bavaria, protocol number: 396–03–04–2024.

Survey – study design and data collection

A commercial survey software (UmfrageOnline; www.umfrageonline.com) was used to create the survey. The questions were modeled on surveys that had been conducted by two of the authors (BP, CR) in other countries (New Zealand, Australia, Italy, and Switzerland). In the current survey, more emphasis was placed on questions relating to transport-related internal medicine problems (e.g., gastrointestinal, and respiratory problems, "shipping fever"). Invitations for this survey were sent via email and posted on social media platforms (e.g., Facebook, Instagram). Since it was therefore impossible to trace how often the invitation was read and forwarded, the exact number of people contacted is unknown.

The link and the questionnaire were active from March to July 2024. The questionnaire included 61 questions (Supplementary item), addressing the circumstances of the road transport situation, the type of trailer, horse related factors, and the persons handling the horses.

Amongst demographic details (age, gender, federal state) and their involvement and experience with horses (i.e., equine industry sector, amateur or professional, number of horses owned, travel frequency and duration, number of transported horses, typical transport management routines at the different transport stages), the participants were asked to report any perceived transport-related problems such as behavioral and health issues during the two years immediately prior to survey completion (see supplemental file).

Outcome variables

The key transport-related health problems of interest were traumatic injuries, musculoskeletal issues, respiratory issues, and gastrointestinal problems (e.g., colic and diarrhea). Furthermore, respondents were asked to report perception of behavioral issues and the transport phase in which they occurred for further analysis to determine correlation with the different types of reported health issues.

Predictive variables

Predictive variables investigated in this study were: respondents' details, and transport management practices (e.g., feeding hay, water, implementation of safety equipment) before, during, and after the journey (Padalino et al. 2018a).

Data analysis

Data analysis was performed using R 4.3.1 (2023–06–16, R Foundation for Statistical Computing, Vienna, Austria). Given the exploratory nature of the study, a power analysis was not conducted but numbers of the horses' return journeys were extrapolated from the total number of equestrian events in Germany.

Data was analyzed to generate descriptive statistics, and variables were reported by number of responses and percentages. Univariable logistic regression was performed to test the associations of behavioral problems versus amateur/professional status, years of experience, and number of horses transported. Furthermore, the association of health issues, especially respiratory problems and diarrhea, and feeding management, transport duration, transport frequency, and amateur/professional status was tested. P-values < 0.05 were considered statistically significant.

Results

Respondents

In total, 432 horse owners participated in the study, but only 59.7 % (258/432) completed the questionnaire sufficiently for their answers to be fully used for statistical analysis. Some answers were completed by more than 258 owners, as respondents dropped out of the questionnaire at a later stage.

Percent responses to some questions were not always 100 percent, as some questions allowed multiple responses. Answers to the individual answer questions were related to the number of respondents.

Respondents' details

Most participants were female (90.1 %, 389/432), with 7.6 % (33/432) male and 2.3 % (10/432) other. Most of the respondents came from Bavaria (63.9 %, 276/432), with fewer from Baden-Wurttemberg (7.9 %, 34/432), Lower Saxony (6.9 %, 29/432) and North Rhine Westphalia (6.7 %, 29/432). The remaining federal states were each represented by a small number of participants. Of the participants, 80.3 % (334/416) were self-declared as amateurs and 19.7 % (82/416) regarded themselves as professionals. Engagement in the sport rider sector (show jumping, dressage, and eventing) was reported by most people (63.4 %, 265/411), whereas 30.7 % (126/411) were non-competitive leisure riders. The other equine disciplines (Western riding, horse racing, breeding) were less frequently represented in this study (Table 1).

Table 1
Respondents' details of the people participating in a survey on equine transport-related events in Germany. Frequency (n) and percentage of total people answering the specific question are shown.

Gender (n = 432)	Frequency (n)	Percentage (%)
Female	389	92
Male	33	7.8
No response	10	
Age, years (n = 422)		
20–29	100	24
30–39	110	26
40–49	105	25
50–59	88	21
60–70	19	4.5
No response	10	
Federal State (n = 418)		
Bavaria	267	63.9
Baden-Wurttemberg	33	7.9
Lower Saxony	28	6.7
North Rhine Westphalia	27	6.5
Rhineland Palatinate	21	5
Hessen	14	3.3
Schleswig-Holstein	8	1.9
Brandenburg	7	1.7
Saxony	5	1.2
Berlin	2	0.5
Thuringia	2	0.5
Saarland	2	0.5
Hamburg	2	0.5
No response	12	
Equestrian sector (n = 410)		
Dressage, showjumping, or eventing	260	63.4
Leisure riding (non-competitive)	126	30.7
Breeding	15	3.7
Western riding	7	1.7
Horse racing	2	0.5
No response	21	
Background (n = 418)		
Amateur	336	80
Professional	82	20
No response	29	

Number of horses and horse transport events – demographics

The frequency of transportation based on the responses received by the participants is shown in Table 2. Most respondents transported two horses together or a single horse and stated an average journey time of less than two h. Most horses were transported with the head facing in the driving direction (Table 2). The space allowance in the trailer was also distributed similarly among respondents: 50 % (111/222) had 90–100 cm width, whereas 44 % (98/222) reported 60–70 cm/width. Only 12 people had more space available for the horses (> 100 cm), and only one person answered < 60 cm width.

Pre-transport practices

While 26 % (109/426) of respondents reported not taking any pre-transport precautions, many people (42.9 %, 183/426) protected their horses with either limb bandages or boots and rugs. Other pre-transport practices were not common among respondents in this study (Fig. 1).

Transport management

Most respondents reported that hay feeding during transportation was a routine measure without watering the horses, while less than 18.1 % provided water and hay to their horses (Fig. 2). Video monitoring of the horses during the journey was performed by 56.8 % (145/256) of survey respondents while 43.2 % (110/256) did report to not monitor their horses in transit. Most people used shavings or straw in their trailers (72 %, 180/250 and 16.8 %, 42/250, respectively), whereas 11.2 % (28/250) of respondents did not use any bedding (straw or shavings). Examination of the horse's health status before the journey was carried out by non-veterinary staff in 48.8 % (82/168) of transports, whereas no examination was performed in 36.3 % (61/168) of the cases. After transportation, the health status was not assessed for 30.8 % (91/295) of the horses. For 62.4 % (184/295) non-veterinary staff assessed the horse's well-being, and for 7.1 % (21/295) veterinarians were involved in their assessment (Fig. 3).

Table 2
Demographics of horse transportation and their situation in the trailer (transport direction and movement ability of the head). Frequency (n) and percentage of total people answering the specific question is shown. Results are presented from the most frequent to the least frequent answer.

Frequency of transportation (n = 420)	Frequency (n)	Percentage (%)
Occasionally	154	36.7
Once a month	134	31.9
Every week	57	13.6
Every two weeks	48	11.4
Twice per week	17	4
Daily	10	2.4
No response	83	
Number of horses per trip (n = 346)		
2	176	50.9
1	149	43.1
3	14	4
5	4	1.2
4	2	0.6
8	1	0.3
No response	107	
Duration of the trip in h (n = 344)		
< 2	249	72.4
2–4	76	22.1
4–8	14	4.1
> 8	5	1.5
No response	86	
Direction of the horse during journey (n = 303)		
Head facing the driving direction	236	77.9
Oblique direction	40	13
Head facing rearwards from the driving direction	25	8.3
Free	2	0.7
No response	127	
Ability to lower head below withers height (n = 248)		
Yes	218	87.9
No	30	12.1

Reported behavioral problems

Of the 328 respondents, 34.2 % (112/328) reported experiencing behavioral problems with their horses associated with road transport. These problems included fear, flight reactions, aggressive behavior, rearing, and reluctance to load. Of those respondents, most people (38.7 %, 43/112) reported behavioral issues at different time points: 7.8 % (9/112) had problems that occurred before loading, 35.2 % (39/112) reported issues during loading, 15.5 % (17/112) during the journey itself, and 2.1 % (2/112) during unloading.

There was no difference in the perception of behavioral problems when amateurs and professionals were compared (OR 0.99; CI 0.54–1.75). Professionals were more likely in this survey to transport more than one horse (mean number of horses = 2.07) than amateurs (mean number of horses = 1.59; $P < 0.001$). Horses transported alone were significantly more likely to display behavioral problems than horses transported together (OR 0.53, CI 0.35–0.76, $P = 0.001$; Fig. 4).

Reported health problems

Most respondents, 57.4 % (167/291) did not experience any health problems or injuries in their horses, whereas 42.6 % (124/291) reported transport-related health issues. Injuries were reported by 19.3 % (24/

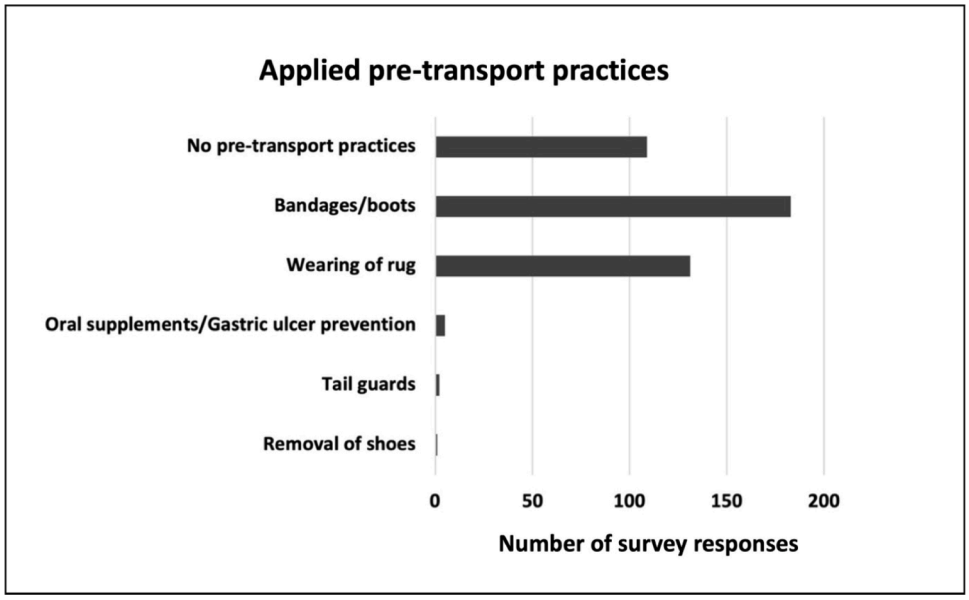

Fig. 1. Common pre-transport practices indicated by survey respondents. Multiple answers were possible (n = 426).

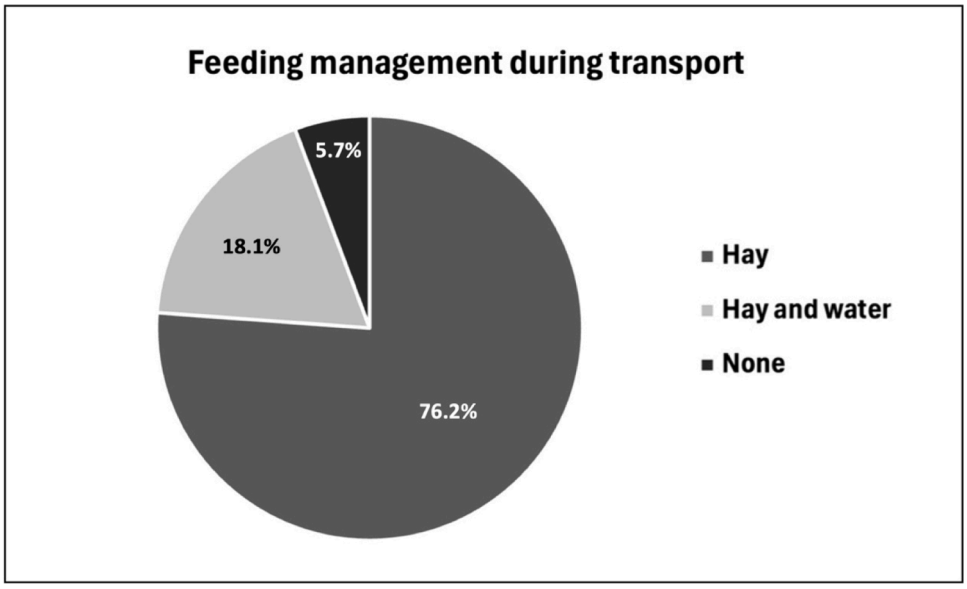

Fig. 2. Feeding management during road transport. Hay feeding during the journey was performed by most of the respondents (214/281), whereas 16 respondents did not feed and water the horses at all, and 51/281 of the respondents provided water and hay during the journey.

124) of these respondents, 2.4 % (3/124) of respondents had horses that developed respiratory diseases ("shipping fever"), 2.4 % (3/124) of respondents reported horses with colic, and 33.9 % (42/124) of respondents answered that their horses had diarrhea (Table 3). The reported incidence of diarrhea was not associated with the perceived occurrence of behavioral issues (OR 1.73; $P = 0.058$), whereas professionals were less likely to observe diarrhea in transported horses than amateurs (OR 1.04; P = 0.001). In 37.1 % (46/124 surveys) respondents reported horses with more than one condition or injury, and in 4 % (5/124) of responses indicated horses developed muscular disorders. There was no significant association detected between the transport durations and the perceived occurrence of at least one health issue (OR < 2 h/2–4 h: 1.60, OR < 2 h/> 4 h: 2.53, OR 2–4 h/> 4 h: 1.58). The transport direction of the horse (driving direction, against driving direction) also had no statistically significant influence on reported health problems in this study.

Discussion

This is the first study to investigate road transport-related parameters and associated perceived behavioral and health problems in horses in Germany. The results from this study gave insights into a diverse range of domestic transport settings and different journeys, filtering out the most important factors to apply further studies on road transportation in Germany.

Survey participation included 90 % female respondents. Given that about 80 % of the people involved in equestrian sport in Germany are women, this percentage approximates the industry distribution of genders (FN, 2022).

Most of the journeys had a duration of less than two h, as reported in Switzerland, Britain, New Zealand, and the USA (Rosanowski et al. 2013, Boden et al. 2013, Benedetti et al. 2023, Jacquay et al. 2024). On the contrary, traveling times in Australia exceed 2 h in 42 % of transport

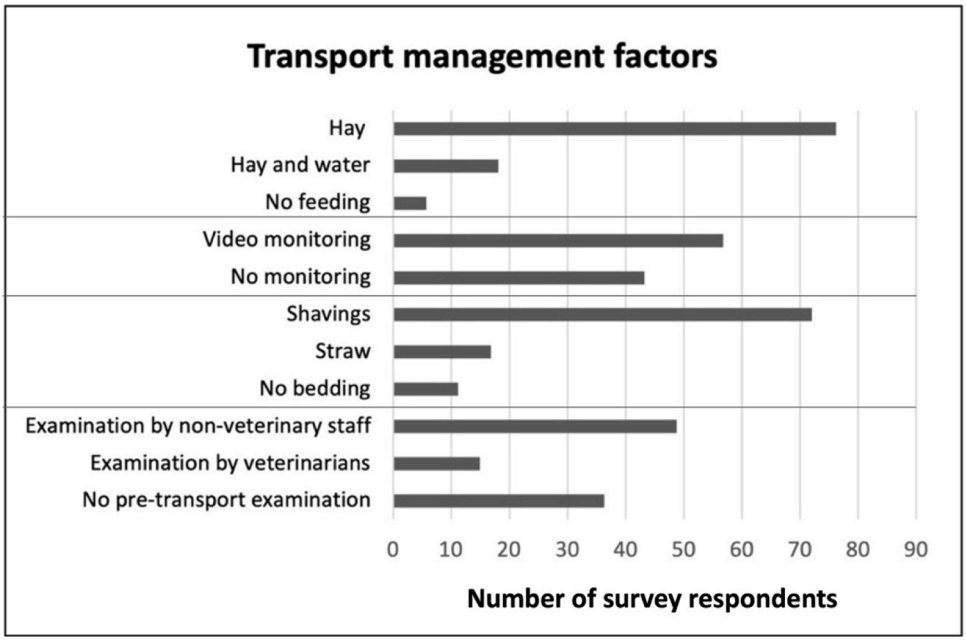

Fig. 3. Transport management factors. The answers addressing these factors chosen by most respondents were hay feeding (76.2 %, 214/281), video monitoring (56.8 %, 145/256), shavings for bedding (72 %, 180/250), and pre-transport examination by non-veterinary staff (62.4 %, 184/295).

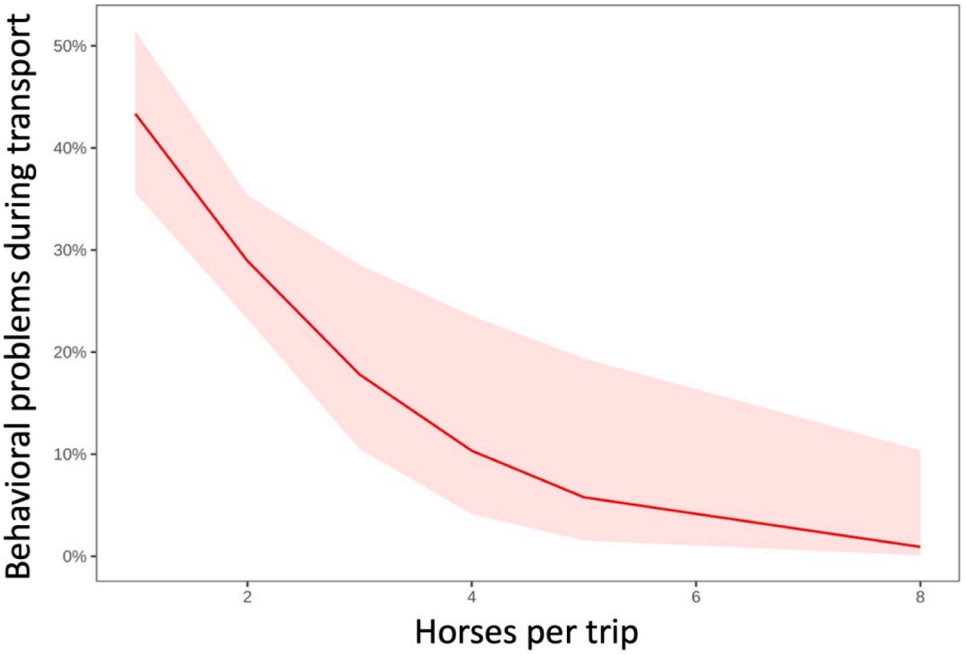

Fig. 4. Association between transport-related behavioral problems and the horses that were transported per trip. Depicted is the reported occurrence of behavioral problems when horses were transported alone or together in groups of 2–8 horses. There was a significant difference, with horses showing fewer reported behavioral problems when they had traveling companions ($P = 0.001$). Transport of a single horse: n = 149, 2 horses: n = 176, 3 horses: n = 14, 4 horses: n = 2, 5 horses: n = 4, 8 horses: n = 1. Odds ratio (OR) 0.53, 95 % confidence interval shown (pink): CI 0.35–0.76.

events (Padalino et al. 2016b). The shorter duration of journeys in this study (72.4 %) is likely because Germany is a geographically smaller country than Australia.

In our study one-third of perceived behavioral problems occurred in the loading phase. This phase appears to be a stressful period for many horses, and the associated reactive behavior involving backing and rearing may lead to serious injuries to the horse and handler (York et al. 2017, Hall et al. 2020, Riley et al. 2023). The impact of behavioral problems may be reduced when handlers are more skilled, even though there was no association shown in this study. The transport of a single horse significantly increased the occurrence of behavioral problems in this study, which may be a sign of social isolation stress.

Compared to most contemporary studies, the reported equine injury rate (19.3 %) was modest. In a study of equine transport in Australia, the injury rate was 45 % (Padalino et al. 2015), whereas a Swiss study reported an injury rate of 72.1 % (Benedetti et al. 2023). In contrast, Italian and New Zealand studies described lower injury rates for transport-related injuries of 11.5 % (17/148) and 17.7 % (201/1133

Table 3
Transport circumstances in the horses that developed diarrhea (33.9 %, 42/124) in this study. Frequency data listed for drivers' backgrounds, health checks before transportation, the duration of the trip in h, feeding management on the trip, the horses' ability to lower their head, and the number of horses transported together on the trip. Data is based on descriptive statistical results done on the subset of respondents who declared to have at least one perceived diarrhea case.

Drivers' background	Frequency (n)	Percentage (%)
Amateur	38	90.5
Professional	4	9.5
Health check before transportation		
None	8	19.0
Non-professionals	27	64.3
Veterinarian	7	16.7
Duration of the trip (h)		
< 2 h	35	83.3
2–4 h	7	16.7
4–8 h	0	0
> 8 h	0	0
Feeding management		
None	18	42.9
Hay	0	0
Hay and water	24	57.1
Ability to lower head below withers height		
Yes	39	92.9
No	3	7.1
Number of horses transported together on that trip		
1	19	45.2
2	23	54.8
More	0	0
Behavioral problems		
Yes	17	40.5
No	25	59.5

over two years), respectively (Dai et al. 2021, Riley et al. 2022). The reason behind these differences remains unclear and may be due to the earlier mentioned short duration of transport and professional handling, but also associated with the studied equestrian population, variations in road conditions, driver behaviors, vehicle design, space allowance and topography.

The reported rate of perceived muscular problems in this study was also lower (5/124, 4 %) when compared to findings for other countries such as Australia (13 %; Padalino et al. 2015) and Switzerland (9.8 %; Benedetti et al. 2023). Muscular problems reportedly occur more often during intermediately long journeys than shorter ones (Padalino et al. 2017). The development of muscular disorders has been associated with the driver's ability, as horses driven by less experienced drivers use more effort to maintain balance than horses driven by experienced drivers (Giovagnoli et al. 2002). Three of the five incidents were reported by professionals and two by amateurs; therefore, no conclusions can be drawn. Some of muscular disorders may also go unnoticed as horses are infrequently examined by veterinarians after the journey (only in 7.1 % in this study), and muscle enzymes are not normally assessed in these horses (Riley et al. 2022).

A low occurrence of respiratory problems (3/124, 2.4 %) was announced compared with other studies where they are the most reported health issues in transported horses after physical injuries (Leadon et al. 1989, Padalino et al. 2017). The duration of the journey is correlated with the occurrence of respiratory disease (Kohn, 2000, Oikawa et al. 2004, Marlin, 2004). A fixed elevated head position reduces mucociliary clearance of the airways and allows accumulation of dust and bacteria in the airways (Raidal et al. 1997, Maeda and Oikawa, 2019). In this study, most owners answered that the horses (87.9 %, 218/248) were able to lower their heads below the withers, which is considered good practice to reduce transport-related respiratory problems. The three horses that developed respiratory problems according to respondents were described as experiencing a longer duration of road transport (180–320 min), but only one horse was unable to lower its head. Horses that are nervous or alert may spend extended time with a raised head – but no conclusion can be drawn here due to the limited data obtained from this questionnaire.

In earlier studies, the risk for gastrointestinal disorders significantly increased in journeys longer than 24 h (Padalino et al. 2015). Despite the average journey being of short duration, the most reported health issue in this study was diarrhea (33.9 %). The occurrence of diarrhea may be overreported by some owners, as horses often produce loose feces as a reaction to stress; owners may not be capable of differentiating between these conditions. Many horses with diarrhea reportedly showed behavioral problems, underlining the fact that gastrointestinal signs may be due to stress. Most people announcing diarrhea were amateurs (90.5 %), and their experience with horses and interpreting clinical signs of diarrhea is unknown. Furthermore, one study associated the limited experience of amateurs in handling horses with increased stress for the affected animal and the likelihood of developing diarrhea (Padalino et al. 2016a). However, private owners may also have been more concerned about slight symptoms whereas professionals may be more likely to ignore minor symptoms and may be less likely to be self-critical. Moreover, about half of the horses that developed diarrhea were transported alone, which is also known to increase stress through social isolation (Alexander et al. 1988, Jezierski and Gorecka, 2000).

Most people used shavings or straw in their trailers, whereas 11.2 % (28/250) did not use any bedding (straw or shavings). This is interesting, as absorbent, non-slippery bedding is compulsory for horse transportation in Germany according to the national animal transport conduct code (§1 Viehverkehrsverordnung) and fines apply if these requirements are not met.

Several studies have examined the effects of travel direction and posture on a horse's ability to maintain balance (Clark et al. 1993, Waran et al. 1996, Padalino et al. 2012). Standing with the front and hind legs apart and extending the front legs forward was the most observed posture of horses during transport in one study (Roberts, 1990). Therefore, postural adjustment that allows the horse to do so helps it to maintain balance. However, to assume this position, horses need sufficient space between their body and the vehicle partitions or other horses. According to studies on trailer width, wide bays of 1.9 m^2 allow for better balance and minimize negative effects on behavior, health, and welfare of the horses (Padalino and Raidal, 2020). In this study, half of the horses (50 %) were reportedly transported in wide bays of 90–100 cm width in their trailer, which is sufficient for the horse to adjust posture and maintain balance (Padalino et al. 2020). A 100 cm width is in line with the new proposed regulations by EFSA (EFSA 2022), but 44 % of the described horses had less space available.

About half of the respondents protected their horses with limb bandages or boots during the journey. The use of these protective measures is controversial as there is a connection between the use of this equipment and behavioral issues and stress if horses are not used to wearing bandages or boots (Creigier and Gimenez, 2015).

Only 3/257 people (1.2 %) reported transport-related death or euthanasia of a horse which is in line with the results obtained by a survey in Switzerland (Benedetti et al. 2023). Unfortunately, the data relates to owner recollections and perceptions only and no more information on the circumstances leading to death in the affected horses was given by the respondents. No inference can be drawn on the actual incidence.

Study limitations

As is common with most survey-based studies offering self-selected participation and the self-reported nature of transport-related problems, this study had several limitations. Firstly, the survey was not distributed randomly, and participants may have self-selected based on their experience with horse transport and on reported problems. This may have caused a selection bias and may have led to over- or underestimation of behavioral or health issues. As the diagnosis of health problems was not verified by a veterinarian, but was reported by the

participant, it may not have been accurate in some cases; e.g., diarrhea (Ireland et al. 2012). Of 124 respondents, 46 (37.1 %) reported multiple health-associated problems. As simultaneously occurring health problems were not specified further, it may lead to a distortion of the health subcategories, as the real numbers may be higher. Some German states were less represented than others (e.g., Bavaria was over-represented), but because horses are equally dispersed in Germany and equestrian events take place all over the country, the impact of the over-representation of some federal states may not be strong (STMELF, 2024).

It is questionable whether the number of participants in this survey is representative of the number of people involved in the German equine industry as this survey reports management practices, and perceived health and behavioral issues arising during road transport of only approximately 0.5 % of German horses.

Conclusion

These findings provide insights into transport management practices and related equine welfare concepts in Germany. The data of owners' perceptions showed that road transport may pose a risk for health problems, especially gastrointestinal conditions, and injuries for equines in this country. There is still opportunity for improvement regarding transport-related behavioral issues. Hay feeding, access to water, use of bedding material, and transporting more than one horse together or in company with another pet seemed to be best management practices to help reduce the risk of behavioral and health problems in Germany.

CRediT authorship contribution statement

Riley Christopher B.: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **May Anna:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Zablotski Yury:** Methodology, Formal analysis, Data curation. **Scharre Annabel:** Formal analysis. **Padalino Barbara:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2025.106322.

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