Effects of density on displacement, falls, injuries, and orientation during horse transportation


Department of Animal Science, Texas A&M University, College Station, TX 77843-2471, USA
Accepted 20 October 1999

Abstract

Three groups of slaughter-type horses, totaling 30 mares and 29 geldings, were used to determine density effects on displacement (distance moved during a stop), falls, injuries, and orientation using a single-deck, open-topped commercial semi-trailer. Each horse was assigned to one of two treatments: high density (1.28 m²/horse with 14 horses) or low density (2.23 m²/horse with eight horses). Both treatments occurred sequentially on the same day (treatment order was alternated each trial), using the middle 2.44 x 7.32 m compartment of a large semi-tractor trailer. The horses were transported for two laps around a 7.28-km course, averaging 25 min and 36 ± 89 s. Each lap consisted of two 60° turns, four 90° turns, two 120° turns, one 180° turn, six hard brakes, and six rapid accelerations, which were more severe than conditions usually experienced in commercial transport. Displacement, falls, and orientation were recorded for each horse using overhead video cameras. Average displacement between the two densities was not different (P = 0.47). The proportion of horses that fell in the high-density treatment (40%) was greater (P = 0.046) than the low-density treatment (17%). The proportion of horses injured was greater (P = 0.006) in high density (64%) than low density (29%). However, there was not a significant difference in the average severity of injury for the high-density treatment (1.77) versus the low-density treatment (0.92). P = 0.48. Overall, the horses did not show a preference (P = 0.38) for facing toward (47.5%) or away (40.7%) from the direction of travel and orientation did not differ (P > 0.18) between the high and low-density treatments. High stocking density of horses during transport increases the incidence of falls and injuries, and made it more difficult to get up when a subject was floored. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Horse; Transport; Welfare; Orientation; Trailer; Density; Injury

Corresponding author. Tel.: +1-409-845-5265; fax: +1-409-845-5292.
E-mail address: t-friend@tamu.edu T.H. Friend.

1 Technical article from the Texas Agric. Exp. Station, the Texas A&M System.

0168-1591/00/$ - see front matter © 2000 Elsevier Science B.V. All rights reserved.
PII: S0168-1591(99)00105-7
1. Introduction

Unregulated and unprotected large-scale transport of equines to slaughter is a significant problem in the horse industry (Reece, 1994). In response to public concern, the USDA has been mandated by Federal legislation (Pub. L. 104–127, Title IX, Subtitle A, Sections 901 to 905, Apr. 4, 1996, 110 Stat. 1184) to regulate the transportation of horses to slaughter in the US.

One of the major concerns is the effect of density on balancing ability and injuries during slaughter horse transportation. Some livestock haulers maintain that animals transported at a high density are better able to sustain their balance and less likely to be injured because they "hold each other up." This is not, however, supported by research conducted on cattle transportation which concluded that high stocking density increases bruising (Eldridge and Winfield, 1988). Sheep also suffer negative effects from over-loading because the frequency of slips and losses of balance increase with a smaller space allowance (Cockram et al., 1996).

Research has been conducted on dehydration (Friend et al., 1998), orientation and balance (Clark et al., 1993; Smith et al., 1994; Kusunose and Tonkai, 1996; Gibbs and Friend, 1999) and orientation and injuries (Roberts, 1990) of horses during transportation, but those studies did not take density effects or horse interaction (aggressive behavior) into account. Some of these studies did indicate that certain orientations of horses do possibly have adverse effects during transportation. When facing the direction of travel, Cregier (1982) proposed that horses sense an increased vulnerability to head and chest injuries. Horses are then forced to carry their head in an uncharacteristically high position to prevent sudden impacts. This unnatural carriage of the head tires the horse by upsetting the natural equilibrium of the ligamentum nuchae, an elastic ligament that allows the horse to maintain its head at withers height or slightly above without tiring.

Individual (Smith et al., 1994) and paired horses (Kusunose and Tonkai, 1996) prefer to face away from the direction of travel. Waran et al. (1996) concluded that horses seemed to find transportation less physically stressful when they are facing backward than facing forward. Cregier (1982) hypothesized that rear-facing horses can better absorb the shock at impact during decelerations by exposing their fleshy rump to impact areas instead of their rather fragile head and chest. Rear-facing horses can also lean over their forequarters, which are better adapted to swaying and normally carry a majority of its weight, during sudden decelerations. The rear facing orientation in small trailers thus leads to fewer side and total impacts and losses of balance during trailering (Clark et al., 1993). Gibbs and Friend (1999) did not observe a preference for facing away from the direction of travel, in untethered individually transported horses in large semi-trailers. Those authors also did not observe a difference in the ability of horses to maintain their balance when positioned either toward or away from the direction of travel, or when positioned at a 45° angle to the direction of travel.

There is a need for further behavioral study aimed at determining whether horses transported in a group benefit from a rear-facing orientation (Leadon, 1994). Previous orientation and balance experiments were mostly conducted using a single horse or a few horses without considering space allowance and density. This experiment was
designed to determine density effects on orientation, balance, falls, and injuries during transportation of horses in groups on a large commercial trailer.

2. Materials and methods

2.1. Horses

Three groups of horses of various ages and body condition scores ranging from two to six were purchased from local auctions by a commercial order-buyer. Twenty-one horses were purchased for trial 1, but only 18 were used due to concerns over the health of three of the horses. In trial 2, 22 horses were acquired but only 19 horses were considered to be in suitable health for the trial. Twenty-six horses were purchased for trial 3, but five of those horses were not transported because they were deemed unfit for travel. After each trial, the horses were sold and a new group of horses was purchased. A total of 30 mares and 29 geldings were used in the trials. A halter with each horse’s identifying number printed on the cheek pieces was placed on each horse upon their arrival. The horses were kept on grass pastures with ad libitum access to hay and water for an average of 7.9 days before the trial and 5.6 days after the trial.

2.2. Equipment

The 15.9-m, single-deck, open-topped commercial trailer had four $2.44 \times 3.66$ m compartments. The middle divider between compartments 2 and 3 was removed to obtain one $2.44 \times 7.32$ m ($17.86$ m$^3$) compartment for the trials. The aluminum floor of the trailer originally had a raised diamond pattern but it had been almost worn smooth. However, approximately 8 mm in diameter aluminum rods were welded across the floor of the trailer at 0.3 m intervals to provide a degree of footing.

Two video cameras (Panasonic WV-BP312 with 2.8 mm lens) were mounted on towers 5.5 m above the deck of the compartment to record orientation and behavioral data. Behavior was recorded at real time on two video recorders (Panasonic AG-1070 DC) inside the cab of the truck. A Dynamometer and Braking Test Computer (VC-2000 Performance Computer, Vericom, Minnetonke, MN, 1995) was also used to obtain inertial force measurements during acceleration, braking, and turns.

2.3. Experimental design

There were a total of three replications conducted, each using a different group of horses. Each replicate consisted of the two treatment groups, one containing eight horses (low density) and the other containing fourteen horses (high density). Before each trial, the horses were inspected for scars, injuries, and overall soundness for transportation. For identification purposes, latex paint numbers were applied with numbers straddling the spine and intersecting a line at the point of the hips of the horses. Horses were then randomly grouped into treatments, herded on to the truck, and allowed to orient themselves prior to transport. One treatment group was hauled at a time and both
Table 1
Number of horses in each trial and treatment from which data was utilized. There were always a total of eight horses in each low-density treatment and a total of 14 horses in each high-density treatment.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Low-density treatment (2.23 m²/horse)</th>
<th>High-density treatment (1.28 m²/horse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 out of 8</td>
<td>14 out of 14</td>
</tr>
<tr>
<td>2</td>
<td>8 out of 8</td>
<td>11 out of 14</td>
</tr>
<tr>
<td>3</td>
<td>7 out of 8</td>
<td>14 out of 14</td>
</tr>
</tbody>
</table>

Treatments per replication were hauled on the same day. The order of hauling treatments alternated for each replicate, to prevent any biases such as time of day, etc. Due to a limited number of horses, some were transported in both treatment groups to achieve the desired density (Table 1). Orientation and displacement data from the second time these horses were transported (three in trial 1, three in trial 2, and one in trial 3) was disregarded to prevent including possible adaptations learned from the experience of the previous run. However, injury data for those horses was not excluded from the second set of data because only horses that sustained no injuries in the first run were hauled in a subsequent run.

Each group of horses was transported for two laps around a 3.64-km course (Fig. 1) for a total transport distance of 7.28 km that averaged 25 min and 36 ± 89 s. A time and a maximum inertia force reading, measured in g’s (9.80 m/s²), was recorded for each turn, braking, and acceleration. Each lap consisted of two 60° turns (0.005 ± 0.0473

![Diagram](image-url)

Fig. 1. Standardized track — one lap includes turns 1–5 clockwise and turns 5–1 counter-clockwise. Distance for one lap is 3.64 km for a total of 7.28 km per treatment. Distance between brakes and turns are in kilometers (not drawn to scale).
g’s), four 90° turns (−0.011 ± 0.050 g’s), two 120° turns (−0.038 ± 0.058 g’s), one 180° turn (−0.040 ± 0.057 g’s), six hard brakes (−0.316 ± 0.071 g’s), and five rapid accelerations (0.108 ± 0.028 g’s). The 180° turn in the middle of the first lap was executed as a clockwise turn while the 180° turn on the second lap was counter-clockwise. The speed of the truck was standardized to make the course challenging for the horses. That is, the speed for each turn was relatively high, but not to the point of risking overturning the truck. Braking was also harder than what we would expect from a good truck driver. However, the inertial forces these horses experienced are not uncommon in the commercial trucking industry.

During trial 1, mechanical failure of the tractor occurred during the last half of the second lap of the high-density treatment. A different tractor was connected to the same trailer to prevent unloading the horses and the trial was completed. Data recording ceased when the mechanical failure of the original tractor occurred and commenced when the new tractor was used to conclude the trial.

2.4. Injury data

Upon completion of each treatment the horses were unloaded, examined for injuries, and returned to pasture. Injury severity was determined using a scoring system from zero (no injury) to five (relatively severe injury). Small (not more than 2 cm) superficial skin abrasions or cuts with just a trace or no signs of bleeding characterized a severity score of one. Injuries typical of severity score three were moderate (4–5 cm) cuts and scrapes resulting in some bleeding. Large cuts (7–10 cm) with obvious bleeding were classified as five.

2.5. Behavioral data

The balancing ability of horses at the two different densities was determined from the videotapes by calculating maximum ‘displacement’ during braking. The latex number painted on the backs of the horses in the vicinity of their hips served as a reference point to measure displacement. Using an erasable marking pen, a dot was placed on the screen of a 15-in. monitor at the reference point before the brake. A second dot was placed on the monitor on the same reference point after the brake. The distance between the two marks was then measured and a conversion factor of 1 to 91.44 cm was used to convert the distance moved on the screen to actual distance.

Number of falls and length of time down were also recorded in the video tape. Falls were defined as dropping to the deck on both the front and hind quarters. A partial fall was characterized by dropping either the front or hind quarters.

The orientation of each horse was recorded every minute during transport. There were eight 45° ranges used to characterize orientation (Fig. 2). As in a previous study in this lab (Gibbs and Friend, 1999), the 0° and 180° axis was defined as parallel to the direction of travel with 0° being when the horse’s head was facing away from the direction of travel.
Fig. 2. Percentage of time spent in various orientations. Orientation ranges were classified with the horses’ head facing the middle of the circle.

Two observers also rode in the forward compartment of the trailer during all the trials to obtain direct observations. They were in radio communication with the tractor in the event that a problem occurred and the truck had to be stopped.

2.6. Statistical analysis

The General Linear Model of the Statistical Analysis System Institute (SAS, 1989) was used to analyze displacement and orientation data. The effect of the two densities on average displacement for each horse over all brakes was determined using inertial force as a covariate. Displacement data from brakes with an inertial measurement of less than 0.2 g’s were disregarded because these brakes were not sufficiently abrupt. Percent time spent at each orientation was compared within each density and between densities. The effect of density on the average time spent facing forward (112–247°) versus facing
backward (292–67°) was also determined using the General Linear Model. Proportion of horses injured and proportion of horses that fell were analyzed using a chi-square.

3. Results

3.1. Direct observations

The researchers traveling in the trailer observed many incidences of aggressive horses repeatedly biting an adjacent horse in an apparent effort to get the horse to move away. Movement was very difficult in the high-density treatment so submissive horses were repeatedly bitten. Occasionally, a submissive horse that was being bitten would kick with its hind feet in an apparent attempt to stop the biting, but they invariably struck the wrong horse. Aggressive horses also kicked in an attempt to obtain space or maneuvering room. However, maneuvering room did not exist so recipients of aggression could not yield and frustration among aggressive horses appeared to increase. The high-density horses also had a difficult time finding a position or place for their neck and head. Some horses adopted a strategy of keeping their heads low (leg level) while most horses kept their heads relatively high and occasionally positioned their heads on or over the backs of other horses.

3.2. Injuries

There was a higher proportion of horses injured in the high-density treatment (64%) than horses in the low-density treatment group (29%), $P = 0.006$ (Table 2). Animals in the high-density treatment group also tended ($P = 0.48$) to have a more severe average injury score (1.77) than those in the low-density treatment group (0.92). The horses in the high-density treatment group also had more ($P = 0.11$) injuries per horse (2.29) than

<table>
<thead>
<tr>
<th>Trial</th>
<th>Density</th>
<th>No. of horses</th>
<th>$m^2$/horse</th>
<th>Total no. of injuries</th>
<th>Proportion of horses injured (%)</th>
<th>No. of injuries/horse</th>
<th>Average severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>11</td>
<td>35</td>
<td>0.79</td>
<td>1.91</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>6</td>
<td>25</td>
<td>0.75</td>
<td>1.33</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>43</td>
<td>93</td>
<td>3.07</td>
<td>1.77</td>
</tr>
<tr>
<td>Average</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>6</td>
<td>29$^a$</td>
<td>0.75$^b$</td>
<td>0.92$^c$</td>
</tr>
<tr>
<td>Average</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>32</td>
<td>64$^a$</td>
<td>2.29$^b$</td>
<td>1.77$^c$</td>
</tr>
</tbody>
</table>

$^a P = 0.006.$  
$^b P = 0.11.$  
$^c P = 0.48.$
the low-density treatment group (0.75), but they were not significantly different (Table 2) due to the high amount of variation caused by a few horses in each treatment having no injuries.

3.3. Displacement

The average displacement for the low-density (76.7 cm) and high-density (67.3 cm) treatments were not different, $P = 0.47$.

3.4. Falls

A greater proportion ($P = 0.046$) of horses fell in the high-density treatment (40%) than the low-density treatment (17%), as shown in Table 3. The proportion of horses that partially fell tended to be greater ($P = 0.099$) in the high (50%) than in the low-density treatment (29%). The average time down for falls in the high-density treatment was 39.8 s per fall while the average time down for the low-density treatment was 15 s, $P = 0.14$. One horse fell and was down for 973.2 s in the high-density treatment in the third trial. After it ceased trying to rise, it became obvious that the horse might not be able to stand by itself. The researchers stopped the truck, cleared some space for the horse, urged it to stand, and then moved it to an empty compartment.

3.5. Orientation

Horses in the low-density treatment spent the most time in the 112–157° orientation (mean % = 23.4), whereas horses in the high-density treatment spent the most time in the 157–202° orientation (mean % = 19.1) (Fig. 2). However, there were no significant differences ($P > 0.18$) between the two densities in the average time spent in any one of the eight orientation classifications. Average time spent in each of the three forward-facing orientation classifications (15.74%) did not differ from the three rear-facing classifications.

Table 3
Comparison of falls and length of time down between densities

<table>
<thead>
<tr>
<th>Trial</th>
<th>Density</th>
<th>No. of horses</th>
<th>m²/horse</th>
<th>Total no. of falls</th>
<th>Proportion of horses that fell (%)</th>
<th>Avg. down time (s/fall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>1</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>2</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>1</td>
<td>13</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>8</td>
<td>57</td>
<td>17.5</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>2</td>
<td>25</td>
<td>41.5</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>7</td>
<td>50</td>
<td>93.9</td>
</tr>
<tr>
<td>Average</td>
<td>Low</td>
<td>8</td>
<td>2.23</td>
<td>1.3</td>
<td>17b</td>
<td>15b</td>
</tr>
<tr>
<td>Average</td>
<td>High</td>
<td>14</td>
<td>1.28</td>
<td>5.7</td>
<td>40b</td>
<td>39.8b</td>
</tr>
</tbody>
</table>

* $P = 0.046$.

b $P = 0.14$. 
cations (13.80%) for all the horses, $P = 0.3811$. The mean percentages for the 67–112° and 247–292° orientations perpendicular to direction of travel were 4.5 and 6.0 for the high and 7.9 and 5.3 for the low-density treatment, respectively (Fig. 2). Percentage time spent facing toward (112–247°) the direction of travel, (47.5%) did not differ ($P = 0.38$) from time spent facing away (292–67°) from the direction of travel (40.7%).

4. Discussion

Evidence from this study disputes the claim that higher density transport is more advantageous to horses than moderate density transport, concurring with studies on cattle (Eldridge and Winfield, 1988; Tarrant and Grandin, 1993; Tarrant et al., 1988, 1992). Average displacement of both densities was not significantly different, indicating that horses in the high-density treatment did not “hold each other up” any more than those in the low-density treatment. While the transport conditions in this study were more severe than those normally experienced in commercial transport; hard brakes, rapid accelerations and high speed turns comparable to the study conditions do occasionally occur while horses are being transported. From our direct observations of the horses, it appears that the truck drivers’ claim that horses hold each other up is based on the driver’s feeling and hearing the impacts of horses’ hooves and bodies in the tractor. In moderate density situations, horses have more opportunity to move and, hence, there are more body and hoof impacts. More head and body impacts may also be heard and felt during rapid changes in speed because the horses under high-density conditions are already pressed against the walls of the trailer. This concurs with the conclusion of Tarrant and Grandin (1993) with cattle that shifting within trailers is inhibited at high stocking density and that there is a corresponding increase in struggles and falls at high stocking density. In addition, the ability of our horses to stand up after a fall was clearly hampered in the high-density treatment, which may have contributed to the greater number and severity of injuries.

When stocking density increases, horses may not be able to adopt improved balancing strategies because the high density does not allow them any freedom to change their behavior. Dominant and aggressive horses may bite, kick, shove, and displace other horses when establishing their orientation, assuming that even the aggressive horses are successful in obtaining maneuvering room. Mounting and pushing in cattle occur more frequently with increased stocking density (Tarrant and Grandin, 1993).

The rear-facing orientation that Cregier (1982) proposed as a preference for singly transported horses and that was associated with improved ability to maintain their balance (Clark et al., 1993), occurred at a lower frequency in this study than the forward-facing orientation. The lack of an apparent preference was also consistent with a previous study from this lab using a large semi-trailer (Gibbs and Friend, 1999). The lack of a preferred forward or rear-facing orientation may be attributed to density effects, horse interaction, the preference of horses to look out ventilation slots in a forward direction, or possibly individual preferences in the horses selected for this experiment.
The average down time (39.8 s) for those that fell in the high density tended to be longer than the average down time (15 s) in the low density. We concur with the observation of Tarrant and Grandin (1993) that when animals went down at a high stocking density, they were trapped on the floor by the remaining animals ‘closing over’ and occupying the available standing space. The horse in the high-density treatment that was unable to erect itself after falling without the assistance of the researchers sustained a moderately severe shoulder injury (severity classification 4) which may be attributed to the ‘closing over’ effect and other animals possibly stepping on the horse while it was down. After a brief struggle, that horse also ceased attempting to get up until the researchers came to its aid. Any horse that goes down under high-density conditions will likely perish if aid is not rendered quickly.

The increased incidence and severity of injuries in the high-density treatment were due to a number of factors. Experienced horses avoid contacting surfaces during transport (Gibbs and Friend, 1999) and prefer to maintain their balance independently of other horses. Horses in the high-density treatment were crowded to the point that they could not move more than several inches and were forced to have contact with other horses and the sides of the truck. They were constantly repositioning their feet in an apparent attempt to maintain their balance and frequently stepped on the hooves and pasterns of other horses. Aggressive horses biting and kicking other horses to obtain maneuvering room also caused some injury. As also noted by Grandin et al. (1999), one or a few aggressive horses may inflict most of the injuries incurred in a trailer-load of animals. In addition, the attempts of the horse being bitten to stop the biting by kicking with its hind feet also contributed to injuries. Horses that fell down in the high-density treatment sustained more injuries due to the ‘closing over’ effect. The type of flooring and other factors affecting the horse’s traction may also influence injuries. Both densities of horses sustained more injuries in the second and third trial than in the first trial, possibly because there was more dry manure on the trailer floor in the first trial. The dirt and manure was removed from the floor in the second and third trial to reduce blowing manure, but it may have slightly reduced traction and balancing ability of the horses, as compared to the first trial. In the third trial, light rain from the night before the trial and the resulting increased humidity that helped keep the floor wet when a horse urinated, may have caused increased injuries as a result of less traction due to portions of the floor being wet.

Moderate stocking density would likely reduce injury and bruising during transportation, but would also increase transport costs. High stocking densities create a situation of constant struggle for the horses. Decreasing density would reduce the overall stressfulness of long distance transport by allowing the horses some maneuvering room to avoid aggressive horses, to stand in a more comfortable position, to adopt their preferred orientation, and perhaps allow them to rest during periods when the truck is stopped.

Acknowledgements

The authors thank the USDA NRICGP and USDA APHIS for partially funding this project.
References


