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1 Effects of the different transport phases on equine health status, behavior and welfare: a review**2 *Barbara Padalino*****3 *Faculty of Veterinary Science, Sydney University, Australia;*****4 *Department of Veterinary Medicine, University "Aldo Moro" of Bari, Italy;*****5 **Corresponding author:*****6 *Barbara Padalino*****7 *Faculty of Veterinary Science, Shute Building, 425 Werombi Road, Camden, 2570, NSW, Australia*****8 *Fax. +61293511693*****9 *E-Mail: barbara.padalino@sydney.edu.au;*****10 **Abstract:******11 The aim of this review is to provide practical outcomes on how to manage equine transport stress.****12 Many horses travel frequently during their life and transportation is one of the major causes of injuries,****13 health disorders and economic loss for horse breeding and the wider equine industry. There are a****14 number of recent publications in this area, but practical strategies aimed at reducing transport stress are****15 still limited. The results published over the last twenty years are reviewed here in order to suggest****16 improved procedures to follow before, during and after a journey. Transport stress involves physical****17 and mental stressors during handling, loading, transportation itself, unloading and adaptation to a new****18 environment. This article reviews how all these transport phases affect equine health status and****19 behavior and best practice management strategies. The suggested outcomes could be useful for equine****20 technicians, owners, breeders, grooms, and veterinarians to safeguard horse wellbeing.****21 **Keywords:** road-transport; stressor; health status; welfare; horses****22**

23 1. Introduction

24 Transportation is an integral aspect of horse management, but transport stress is still an issue and
25 many problems are associated with it. Horses are transported more frequently than any other type of
26 livestock (Friend, 2001). They are moved for many different reasons: in the past for war and, today,
27 mostly for competitions, breeding, pleasure activities, sale, or slaughter (Fazio et al., 2008). Three
28 thousand horses are transported daily in Italy (Giovagnoli, 2008). Around \$3 billion annually are spent
29 in transportation in the United States, with an estimated population of 9.2 million horses (American
30 Horse Council, 2005). It has been reported that a typical Texan horse owner transports an average of
31 2.5 horses, 24 trips (average 380 km per trip) per year (Gibbs et al., 1997; Gibbs et al., 1998).

32 Horses can develop loading, travelling or post-transportation problems. Many injuries to horses and
33 owners occur during the loading procedure (Ferguson et al., 2001). Some horses move or kick inside
34 the trailer, causing driving problems and fatal road accidents. Poor performance problems, health
35 disorders and infectious diseases are the most common complications after transportation. Thus,
36 assessing best practice transporting procedures for horses warrants comprehensive investigation
37 (Cregier, 2010).

38 In the last twenty years many scientists have conducted research aimed at improving horse welfare
39 during transport and at reducing the incidence of related problems. Results are often conflicting, and
40 how best to manage transport stress is still a matter of debate. One reason for the conflict is that some
41 results are not comparable because the studies used different trucks or trailer models, in different
42 seasons, on different horse breeds. Moreover, it seems that the level of stress caused by transportation
43 is related to the temperament of the horse and its historical travel experience (Fazio et al., 2013),
44 orientation during travel, the provision for head movement, and factors such as driver skill, ventilation
45 and/or window placement.

46 This paper reviews approximately 20 years of publications concerning horse transport. The aim of
47 this review is to split transport into its critical points, highlighting the effects that each phase has on
48 horse behavior and pathophysiology. Suggestions for managing journeys to encourage practical
49 outcomes that safeguard equine wellbeing before, during and after different types of transport are
50 discussed.

51 52 2. Different means of transport: ship, train, truck, plane

53 The earliest form of water borne horse transport likely utilized a waterproofed hide stretched over a
54 wooden frame; a form of transport thousands of years old. Specialized water-borne transport for horses
55 has been in use for centuries, and has evolved with different types of ship/vessel construction for river,
56 lake, or sea transport (Cregier, personal communication, 2014). Byzantine historian Theophanes

57 described such specialized horse transport in 762 AD. *Chelandia* were relatively small ships designed
58 to carry up to a dozen horses with a specific landing ramp (Pryor, 1982). Later, horses were carried
59 regularly by ships (Cregier, 1982), and sea transport was the only means of transport for horses until
60 the late 19th Century. Today sea transport is still in use because it is the cheapest form of transport,
61 particularly for slaughter horses travelling from South America to Europe (Giovagnoli, 2008). In
62 modern cargo ships, horses travel in boxes whose dimensions range from 4.5 x 4.5 m to 6.0 x 4.5 m
63 and have access to a sand yard to exercise during the voyage (Waran et al., 2007). The key
64 disadvantages of sea transport are mainly duration and risk of injury (Judge, 1969). Long transfers by
65 ship are well accepted by horses, although after the journey animals can develop jet lag, medical
66 conditions associated with a change in management and conditions or caused by hierarchical conflicts
67 associated with adapting to the new stall and social group (Cavallone et al., 2002).

68 The earliest mode of land transport was via horse-drawn wagon. Performance horses were drawn by
69 those of lesser value beginning sometime around the reign of Queen Anne in the early 18th century.

70 Transport by rail was very common from the mid-nineteenth century to the mid-twentieth century
71 with various wagon designs being used. The smaller horse car with two wheels on each end carried
72 eight horses. The larger car, supported by a four wheeled truck or bogie on each end, could carry 16 to
73 20 horses at speeds up to 145 km/h. Since more than one animal occupied a wagon, the risk of treading
74 on and kicks from cohorts was high. Thus, there was a special single horse van used for more valuable
75 horses. The disadvantage of train transport has been mainly the rough, uncomfortable journey and,
76 often, prolonged waiting times at rail-heads for collection or delivery (Judge, 1969). Today, transport
77 by rail is still in use in developing countries because it is a relatively low cost transportation method.

78 After World War II, following the building of interstate highway systems, road-transport became
79 the most popular means of transport (Friend, 2001). The 1960s and 1970s are known as the "Trailer
80 Age", because many different kinds of trailers and trucks were designed and built. Consequently, today
81 there are many different types of road vehicles used to transport horses, the major difference being
82 found between lorries or vans and trucks, and trailers. The "motorized horse box" or "horse lorry van"
83 varies in capacity from 1 to 10, 12 or even 16 or more individually stalled or grouped horses. The most
84 common trailer is for two horses and it is usually attached to the towing vehicle at one point via a tow
85 hitch, which makes trailers less stable than lorries or trucks (Cregier, 1982). Trucks and trailers
86 generally have a rear and/or a side ramp for loading and unloading. In some countries (e.g., the US),
87 there may be no ramp and the horses are trained to "step up" into the trailer. In the U.K, Canada and
88 New Zealand, platform loading horse trailers were designed to reduce transport stress and increase
89 loading and unloading safety. The horses step onto the platform from the off side, reverse into the

90 trailer, and face away from the direction of travel to allow hind-quarter resting and freedom to balance
91 with their heads during transit (Equi Balance™).

92 The first reported air transportation of horses was during the early 1920's with the first race horses
93 being flown across the Atlantic in 1946 (Judge, 1969). To date, air transport has become very common
94 even though it is the most expensive form of horse transport. In the plane, horses travel in air stables or
95 jet stalls designed to accommodate a maximum of three horses, side by side, separated by partitions
96 (Waran et al., 2007). Air transport is used primarily for competitions and breeding purposes: in this
97 manner stallions can be mated with mares in both the Northern and Southern Hemispheres in the same
98 calendar year.

99 The most stressful phases of air transport are loading, unloading, taking off and landing (Stewart et
100 al., 2003). During the flight horses tend to have resting heart rate values and engage in resting
101 behaviors, indicating that they may settle better to air transport than road transport (Munsters et al.,
102 2013). Quarantine regulations are generally applied after air travel to minimize biosecurity risks,
103 however, restraint in the quarantine boxes can cause an increase in heart rate associated with
104 environmental stress (Ohmura et al., 2012).

105 The vast majority of studies have focused on effects of transport stress in horses moved by road. It
106 is this mode of transport that is the focus of the remainder of this review.

107

108 **3. Different destination of transport: toward a slaughterhouse, a new stall or a competition**

109 Horses travel for different reasons, but the primary difference that can determine the kind of travel
110 is the destination: a slaughterhouse or a different stall.

111

112 *3.1. Transportation of horses for slaughter*

113 Globally, many horses travel daily to slaughterhouses. Horsemeat consumption became popular in
114 Europe after World War II amongst people with lower-incomes. At the time beef was scarce, and old
115 or lame draft horses were slaughtered for affordable lean meat with a high iron content. Horsemeat has
116 become a delicacy associated with high prices in Europe (Stull, 2001), although the 2013 scandal
117 involving beef tainted with phenylbutazone containing horsemeat may have altered this profile.
118 According to the most recent data from the Food and Agricultural Organization (FAO) the largest
119 producer and consumer of horse meat in the world is China, which produced 170,848 tonnes of horse
120 meat in 2010. The second largest producer and consumer is Kazakhstan. In many European countries
121 horse meat is used as an ingredient in traditional meals, and is imported for this. In USA, even though
122 Congress cancelled federal funding to inspect horse meat destined for human consumption in 2007,
123 68,444 tonnes of horse meat was produced in the USA in 2010 for pet food (FAOSTAT). In Canada,

124 horsemeat exports, primarily to markets in Europe and Asia, exceeded \$60 million in 2011, and it is
125 reported that more than 2,000 tonnes of horsemeat are consumed in Canada each year
126 (www.equinecanada.ca). There are some countries (e.g., the United Kingdom) that have never
127 accepted horsemeat as part of their diet (Reece et al., 2000).

128 In South America horsemeat is popular, Argentina is the largest equine meat exporter, and Chile
129 slaughters nearly 50 thousand horses annually (Werner et al., 2008).

130 Meat horses travel loose in the truck toward the slaughterhouse, and density during transport is
131 variable. In high-density compartments horses can fall during shipment, resulting in injury or death,
132 but injuries due to kicking may be less frequent (Whiting, 1999). In a lower density shipment, horses
133 can escape biting situations and aggression, lowering the mentally stress for the horses (Collins et al.,
134 2000), but aggressive behavior during transport may be related more to individual horse temperament
135 than to conditions (Iacono et al., 2007a). Further studies are needed to define optimal travel density
136 and environment.

137 Interestingly, the effects of travel on meat quality have been well studied in cattle and pigs (Ritter et
138 al., 2008), but there are few studies in horses. After transportation increased blood lactate and glucose
139 have been reported in horses after transport, factors which impair meat quality (Werner et al., 2008).
140 The stress associated with transport, lairage and stunning also affects horse meat quality.

141 *3.2. Transportation toward a new stall*

142 There are an estimated 58 million horses worldwide, and the equine transport industry is a wealthy
143 one. In industrialized countries horses reared primarily for pleasure or sport are most commonly
144 transported professionally. . Tamed horses travel in single stalls within the vehicle, whereas unhandled
145 horses are more inclined to be transported in groups. It is common for mares to travel loose with their
146 foal within a box inside the truck (Weeks et al, 2012).

147 Every time a horse travels to a new place, there is an associated adaptation period during which the
148 horse needs to adjust to the stall, management and training styles, and diet. Because horses may also
149 be exposed to pathogens which they have limited immunity to, standard-of-care recommendations
150 include a quarantine period and gradual transitions to new diets. It is advisable to avoid abrupt dietary
151 changes and prevent intense exercise sessions during the period following transportation (Waran et al.,
152 2007).

153 *3.3 Travel before competition*

154 Despite many horses being transported specifically for performance purposes, surprisingly little is
155 known about the effect transportation has on performance and the results are often conflicting.

156 It has been suggested that for experienced horses, transport over short distances had little affect on
157 performance (Beaunoyer and Chapman, 1987). However, other research found that a 194 Km journey

158 could negatively affect the performance in a close race, particularly in front facing transported horses,
159 which displayed the effects of slight stress (Slade, 1987). The effect of transport on competition
160 jumping horses' performance was also studied. In this case, only horses with less travelling
161 experienced showed signs of major stress and reduced performance (Covalsky et al., 1991)

162 A recovery period of two hours after three hours travel was suggested on the basis of the increase of
163 muscle enzyme concentration caused by the transport (Tateo et al., 2012). Travel longer than 8 hours is
164 discouraged before a competition, as it could compromise racing performance and require some days
165 of recovery (Linden et al., 1991).

166 After a 100 km transportation distance in a one-horse trailer, facing in the direction of travel, an
167 increase in the concentration of free triiodothyronine (T3) was recorded. Triiodothyronine (T3) is a
168 thyroid hormone involved in growth, metabolism, heart rate and thermoregulation. Elevated levels of
169 T3 are commonly associated with sessions of intense exercise (Fazio et al., 2008a). Since T3 is
170 intricately associated with the other thyroid hormone, known as thyroxine or T4, by an endocrinology
171 feedback mechanism, it may be supposed that an elevated T3 value recorded at unloading before a race
172 could impair performance. But there has been no study to date that correlates the specific affect of
173 elevated T3 levels resulting from transportation with performance results.

174 The relationship between transport and performance needs more investigation. However,
175 developing good scientific methodologies for definitively assessing the effects of transportation on
176 performance is deemed very challenging due to the confounding effects of factors including horse
177 temperament, position and orientation in the vehicle, fitness level of the horse, historical transportation
178 experience and driver ability/skill level.

179

180 **4. Phases of transport and their effects on horse behavior and physiology**

181 The transport of animals is a complex procedure involving several potential stressors. The
182 transportation process includes the following critical factors which can all impact on stress levels:
183 handling, separation from familiar physical and social environments, loading, confinement, vibration,
184 changes in temperature and humidity, inadequate ventilation, often deprivation of food and water and
185 unloading (Waran, 1993). Factors that induce stress during transport are mostly psychological (White
186 et al., 1991), but physical factors such as the trailer motion, noise, the driver's ability and road
187 conditions also may play a major role (Jones, 2003). Confinement itself is stressful for horses (Mal et
188 al., 1991), but for many farm animals a stationary vehicle is generally considered to be less stressful
189 than a moving one (Tarrant, 1990). Indeed, during transportation, horses are subjected to changing
190 forces primarily due to acceleration, deceleration, and the turning movements of the vehicle (Waran
191 and Cuddeford, 1995).

192 Accordingly one survey reported horses have problems both in loading (53.4%) and travelling
193 (51.5%). During travel the majority of problems were recorded when the vehicle first began to move
194 (53%) or when it went around a curve (47%)(Lee et al., 2011). It has been reported that breed has no
195 effect on the problem type, whereas the trailer orientation and the horses' mental association to
196 negative experiences may be significant important factors in the etiology of trailering problems (Lee et
197 al., 2011).

198 It should be highlighted that horses can associate the transportation itself with what they experience
199 during and after the journey. So it seems that horses used for sporting and recreational purposes with a
200 number of positive experiences of loading and transportation are less adversely affected by
201 transportation than horses with no experience and horses who have negative previously experienced
202 situations including falling or over-crowding (Leadon et al., 2008).

203

204 *4.1. Handling*

205 Handling refers to how animals are touched, moved and interacted with during husbandry
206 procedures. The handling methods (reinforcement or punishment) can have a significant affect on
207 animal welfare. It has been found that for horses sent for slaughter, handling without the use of sticks
208 or electric goads resulted in improved welfare and lower risk of poor quality meat (Broom, 2005).
209 Restraint is often part of the handling procedure. During restraint animals are often separated or
210 isolated from their conspecifics which is a known factor causing stress. Both handling and
211 transportation involve the interaction of animals with humans and it is important to know how animals
212 react to human behavior aimed at effectively moving and restraining them (Fazio et al., 2003). The
213 taming/training method (ethological or traditional), can have an ongoing influence on the horse-human
214 relationship, thereby having long term effects on the horses' behavior during subsequent handling
215 procedures (Casamassima et al., 2008).

216 Age, sex and physiological condition also influence the behavior of horses during handling and
217 transport; indeed handling young animals, such as foals and yearlings, which are usually not tamed
218 extensively, can be significantly more difficult and risky than handling older animals. Although it is
219 generally assumed that intact males are more difficult to handle than castrates, this difference may also
220 be age dependent. Rearing environment and previous experience are generally agreed to be of
221 considerable importance. Animals respond to challenges in their immediate environment through
222 several interacting mechanisms including behavioral, hemato-chemical, physiological and neuro-
223 hormonal (Fazio, 2013). The response of animals to handling and transport can also depend on their
224 sensory capabilities, the visual field and flight zone. Some behavioral indicators of discomfort are
225 vocalizations, attempts to escape, kicking, or struggling. Identifying stressful situations by key

226 behaviors could be useful during handling and transport and would promote greater wellbeing in
227 horses (Siniscalchi et al., 2014).

228 Overall, it is generally more desirable to transport horses that are already well accustomed to
229 handling so that they do not associate the stress of being handled with the process of being transported.

230

231 5.2. Loading (*Injuries and Fear*)

232 Loading is considered to be one of the most stressful components of transport (Waran, 1993).
233 Loading fear comprises different stimuli, such as fear of entering an enclosed space, the height of the
234 step leading onto the ramp and the instability and incline of the ramp (Houpt and Leib, 1993). It is
235 these factors that result in inexperienced horses often exhibiting extreme evasive behavior and a strong
236 reluctance to step up onto the ramp. Accustoming the foal to loading has been proven to reduce
237 behavioral problems associated with loading and transporting later in life (Houpt, 1982).

238 The heart rate during loading is usually higher than the average heart rate during transport,
239 regardless of the level of experience. In fact, climbing a ramp is probably a frightening experience for
240 a naïve horse, and although horses may become accustomed to the situation, experienced horses are
241 still stimulated in some way. This elevation in heart rate can be ascribed partly to the energy expended
242 in climbing the ramp and partly to the emotional fear (Waran, 1993). Evasive behavior during loading
243 is typical of very young horses and the time taken to load is influenced by age. In fact, it is reported
244 that yearlings took more time to load (368 s) than 2-year-olds (29.5 s), 3-year-olds (21.5 s) and those
245 over 3 years-old (5 s) (Waran and Cuddeford, 1995).

246 As a fear response, many horses fight during loading which in itself is a source of stress and can
247 result in injury to the horse and/or handler. Behaviors such as rearing, pulling back, head-tossing,
248 pawing, and turning sideways are commonly exhibited. These behaviors are likely to be negatively
249 reinforced when the loading process is aborted by the handler (Baron, 1991). The combination of
250 loading a 'problem' horse and an owner who applies physical punishment can produce a very
251 dangerous situation. Rope burns, lost fingers, broken bones, or bruises and lacerations have been
252 reported as most common owner injuries. Lacerations to the head from banging into the trailer, scrapes
253 and cuts on the legs, broken legs from falling, or even a broken back if the animal falls backwards
254 while rearing are the most common horse injuries occurring during loading (Ferguson and Ruiz, 2001).

255 Some studies have been conducted to determine procedures which reduce loading fear. To reduce
256 the likelihood of injury, horses that are difficult to load can be trained to load more willingly.
257 Successful training procedures involve increasing the horses' confidence by breaking loading into
258 simpler, separate tasks that can be accomplished in a relaxed mental and physical state. These tasks

259 include moving forward on command, stepping onto and backing off an unstable floor, and moving
260 into a confined space (Scoggins, 1996).

261 The Tellington-Touch Equine Awareness Method (TTEAM), developed by Linda Tellington-Jones
262 takes this concept of relaxed, progressive training one step further (Curcio-Wolfe, 1996). This method
263 uses non-aversive touch and commands in novel situations as a means for inducing behavioral changes
264 in horses. Horses are generally neophobic, and TTEAM is specifically designed to teach horses to
265 relax and function in the presence of novel and potentially frightening stimuli. Non-aversive retraining
266 methods (based on TTEAM) were effective in reducing loading time for horses with a history of
267 reluctance to load onto a trailer and were also associated with a decreased post-loading heart rate and
268 saliva cortisol levels (Shanahan, 2003).

269 Loading fear is innate in the horse, but some environmental stimuli can be attributed to exacerbating
270 loading fear. One such example would be loading a horse directly from a brightly lit arena into a dark
271 trailer (Cross et al., 2008).

272 People have used winches, whips, war bridles, chains, cattle prods, and a variety of other punitive
273 methods to force horses to load. Although professional horse trainers do not openly advocate
274 extremely aversive methods, most of their methods of loading horses include some form of negative
275 reinforcement and the use of punishment in response to undesirable behaviors.

276 On the other hand, recent literature has proven that in particular for horses which refused to load,
277 positive reinforcement (PR) provided the fastest training solution with the lowest levels of stress
278 response (Hendriksen et al., 2011). It has been also reported that the use of applied equine training
279 systems, based on positive reinforcement, results in increased probability of appropriate behavior
280 being displayed during handling and loading procedures in loading problem horses (Slater and
281 Dymond, 2011).

282

283 *5.3. Transportation*

284 Transportation involves many stressful factors. During the journey, the internal truck temperature,
285 relative humidity and level of environmental contaminants can change dramatically (Leadon et al.,
286 1990). The horses in the vehicle may also have to adapt to unfamiliar factors including traveling
287 companions, confinement spaces, movement beneath their feet, acceleration and deceleration,
288 ascending and descending, taste of drinking water, exposure to vibrations and noise and so on.
289 Transport stress should be considered as a multi-factorial physical and emotional status, where the
290 sympathetic nervous system shifts from alert to fear many times and where the maximal effort is spent
291 in balance preservation. To maximize the wellbeing of any horse during transportation the following
292 factors should be taken into account and/or checked during the journeys.

293

294 5.3.1. Confinement and Isolation

295 Both confinement and isolation are stressful and may suppress feeding behavior during
296 transportation (Mal et al., 1991).

297 Once loaded into the vehicle, the horse is placed in a restricted space, either due to being confined
298 in an individual stall using partitions, or due to pressure on individual space exerted by the other loose
299 horses with which it may be travelling. Tamed yearlings transported in individual stalls or loose had
300 similar cortisol levels measured both during and after transport. In both situations transportation was a
301 significant stressor (Garey et al., 2010).

302 Since transport often requires the animal to travel alone, the effects of transporting horses alone, in
303 company or with a mirror that provided surrogate companionship were investigated. Behaviors
304 (vocalizing, eating, head-tossing, pawing, and head-turning) and physiological parameters were
305 recorded. When traveling with a live companion significantly less time was spent vocalizing, head-
306 turning, head-tossing and pawing and eating behavior increased. Heart rate and temperature also
307 significantly decreased when travelling with a live companion. Travelling with the mirror did not
308 significantly affect physiological responses when compared to travelling alone, but did significantly
309 reduce time spent turning the head, vocalising and head-tossing while eating behavior also increased
310 (Kay and Hall, 2009).

311 In general, the provision of surrogate companionship in the form of an unbreakable (e.g., stainless
312 steel) mirror is preferable to travelling alone, but where possible a live companion is recommended.

313

314 5.3.2. Effect of Density

315 During loose horse transportation, high stocking densities create a situation of constant struggle for
316 the horses. Medium stocking densities likely reduce injury and bruising during transportation, but also
317 increase transport costs. It was suggested that decreasing density would reduce the overall stressfulness
318 of long distance transport by allowing horses more opportunity to avoid aggressive horses, to stand in a
319 more comfortable position, to adopt their preferred travelling orientation, and perhaps allow them to
320 rest during periods when the truck is stopped (Whiting, 1999). It was recently shown that there was no
321 difference in the movements recorded in unrestrained horses transported in low or moderate density.
322 However, the movements of the unrestrained animals inside the truck were strongly influenced by a
323 small number (one or two) more active horses causing disruption of the group (Calabrese et al. 2009).

324 For individual horses stall size is important and there is legislation about the minimum space
325 required during road transport according to age and type of horse, but minimum space allowances
326 differ between countries (Waran et al., 2007).

327

328 5.3.3 Effect of fasting and water intake

329 Depending on the final destination, horses may or may not have the opportunity to feed and drink
330 en route. Sport horses transported to a racetrack are often allowed to feed on some hay, usually offered
331 in a net, because it has been shown that it does not impair performance, whereas horses transported to
332 a slaughterhouse are usually fasted to reduce the risk of soiling and resultant meat contamination
333 (Waran, 1995). Some studies suggest avoiding hay in the lorries in all cases, because it affects the air
334 quality. Dry hay is likely to pose a risk to horses prone to recurrent airway obstruction (RAO), which
335 could become symptomatic after allergen exposure: for these horses it is better to use wet/dampened
336 hay or pellets (Hotchkiss et al., 2007). However, if the hay is offered during the journey, it is generally
337 better to dampen it and to place it on the floor, to minimize the dust risk. Furthermore, this location
338 could stimulate travelling horses to eat with a lowered head position, which seems to be fundamental
339 in reducing the development of respiratory diseases (Raidal et al., 1996). Regardless of whether or not
340 feed is provided during travel, weight losses are reported after a journey (Waran, 1993). Weight loss is
341 likely to be due to a combination of reduced feed and water intake and increased energy expenditure
342 and fluid loss through sweating (Smith et al., 1996). It is important to emphasize that horses always
343 tend to reduce feed and water intake during the journey, because they are less willing to eat and drink
344 in unfamiliar and stressful surroundings and from unfamiliar sources (Kay and Hall, 2009). Generally,
345 it is better if familiar water and food are offered to the horses during the journey, as well as during
346 planned rest periods. It has been proven that increasing the resting time and cleaning the interior of the
347 truck during rest stops decreases transport stress and respiratory insults (Oikawa et al, 2005).

348 During long trips water should be offered to the horses, while the vehicle is stationary, at least every
349 2 to 4 hours, especially when the environmental temperatures are high (Haupt and Leib, 1993). During
350 a 24 hour trip, a stop is needed at least every 4 hours to provide the horse with the opportunity to
351 urinate; horses urinate approximately six times daily and male horses in particular need to be able to
352 stand in a particular posture which is difficult to do comfortably en route (Weeks et al., 2012) .

353 In many codes of transport practice it is deemed acceptable to remove all access to water and food
354 for up to 8 hours during transportation, but the effects of such long periods of fasting have not yet been
355 well investigated.

356

357 5.3.4. Environmental Challenges

358 Temperature, humidity and ventilation inside the vehicle are critical aspects of a journey.
359 Ventilation for horses during transportation has been a topic of research since the 19th century with
360 links reported between level of ventilation and the occurrence of both heat stress and shipping fever.

361 Despite research findings, and proof that trailers are under-ventilated at all speeds (from 13 to 90
362 Km/h) and ventilation configurations, trailer design has not been modified (Purswell et al., 2006). The
363 suitability of the trailer thermal environment is generally well assessed for other livestock but is still
364 lacking with regards to horses. The thermo-neutral zone (TNZ) in horses is also not well defined, but it
365 is estimated to be in the range between 25°C and 30°C. Thermal comfort depends not only on
366 temperature, but also on humidity and it is expressed by a calculated index. For horses the upper limit
367 of this thermal-index was set at 28°C by the Federation Equestre Internationale (FEI) for competitions.
368 The problem is that inside the truck this limit is not valid and it is often exceeded. In traditional
369 trailers, inside-to-outside temperature differences decrease with increased speed and the open vent
370 area, but it still ranges from 5.1°C to 9.5°C (Purswell et al., 2010). This means that horses should not
371 be transported during hot and humid days, when outdoor temperatures exceed about 30°C. Since it
372 impractical to restrict horse transportation on days that exceed 30°C (particularly in hot arid countries),
373 future research should include new engineering and design solutions to improve thermal environment
374 and ventilation characteristics of trailers and trucks. Increasing vent and window area, increasing the
375 height of the vehicle and adding fans have all been suggested for vehicles transporting other species,
376 but should also be applied in horse transport vehicles (Mitchell and Kettlewell, 2008). The risk of heat
377 stress shock is increased dramatically when the vehicle is stationary and when more than one horse is
378 aboard the vehicle and under such circumstances it is advisable to park the vehicle in shaded areas with
379 all windows and ramps open during rest stops (Waran et al., 2007).

380 Animals produce CO₂ through respiration and ammonia with their urine, in addition to
381 microorganisms. As a result, the confined space inside the moving vehicle is not usually conducive to
382 a healthy environment. Consequently, good ventilation is vital to ensure not only acceptable air
383 temperature and relative humidity, but also low levels of airborne contaminants such as gases and dust.
384 Many studies in this research area were conducted by Leadon et al. (2008) who reported that air
385 usually enters the horse lorry through the windows or vents along the side, but that this air tends to
386 drop toward the floor and become contaminated. As a consequence the air quality in a lorry becomes
387 very poor. Further studies are needed on ventilation design to improve air circulation and air quality.

388 It is important to limit the concentration of noxious gases in the air because it has been proven that
389 during transportation horse respiratory clearance is reduced following exposure to ammonia, nitric
390 oxide and carbon monoxide. Those gases damage the pulmonary epithelial barrier, thereby increasing
391 the permeability to bacteria (Traub-Dargatz et al., 1988). In a study reported by Smith et al. (1996),
392 ammonia concentration was recorded in a standard 2-horse trailer. The mean concentration during a 24
393 hour journey was 0.8 ppm with no detectable odor. Although there is no recommended upper limit for
394 exposure of equines to ammonia and other gases the safe human limit should be taken into account.

395 The current recommended exposure limit is 25 ppm for ammonia and 9 ppm for carbon monoxide
396 (Pickrell, 1991). Endotoxins in air can also create inflammation of the airways. While it has been
397 proven that stabled horses are exposed to 8-fold higher concentrations of endotoxin than pastured
398 horses (Berndt et al., 2010) there are no reported studies of endotoxin levels in transportation vehicles.

399 Another critical equine health consideration is the risk of disease spread during and after
400 transportation. In the truck, animals from different farms often travel together, so pathogen
401 (bacteria/viruses/parasites) transmission risk is relatively high. Wherever possible, loading of animals
402 from different farms and of different ages should be avoided. Since trailers and trucks are saturated
403 with potentially harmful bacteria and spores after transporting horses, they must be disinfected prior to
404 reuse. However, effective disinfection is challenging especially in winter. An effective cleaning
405 procedure should involve cleaning with hot water, prior to removing excess water with a suitable
406 vacuum cleaner and the concentration of the disinfectant should be elevated at least by a factor of 3.
407 Mechanical actions, such as scrubbing, will improve disinfection of vehicles as well as preliminary
408 disinfection prior to cleaning (Boehm, 1998).

409 Monitoring of the microclimate can be conducted with the use of probes located at various positions
410 within the trailer to measure temperature, humidity and air movement. Monitors located in the vicinity
411 of the horses head(s) should be used to measure concentrations of ammonia and other gases (Smith et
412 al., 1996). The use of a commercial data logger inside the truck is strongly recommended with the
413 collected data being used to modify the vehicle and management practices in manners that neutralize
414 environmental challenges thereby improving animal welfare (Miranda-de la Lama, 2013).

415 Finally, to eliminate odors, neutralize some gases and disinfect hard surfaces, the use of vinegar,
416 zeolite or baking soda as alternative microbiological agent can be used for routinely cleaning of the
417 vehicle (Fong et al., 2011).

418

419 5.3.5. Direction of travel

420 Body orientation during travelling is an important matter of debate. Equine anatomical
421 conformation is such that 60% of the equine body weight is carried over the forelegs, and the
422 hindquarters are poorly designed for continual shifting of weight and bracing against directional
423 change (Cregier, 1982). It is probably for this reason that the most commonly observed body posture in
424 horses travelling in a forward facing direction involves standing with the front and hind limbs apart
425 and the forelegs stretched forward. This exaggerated limb position during transit likely helps the horse
426 to retain its balance by exerting inclined thrusts with one leg or the other, as occasion demands
427 (Roberts, 1990).

428 Inappropriate orientation, and consequential loss of balance, can cause injury during horse transport
429 (Whiting, 1999). There are different opinions amongst experts about travel positions that minimize
430 transport stress and optimize the horses' post-transport performance (Gibbs, 1999). Several studies
431 have been performed in order to determine the effects of orientation on a horses' ability to maintain
432 balance during transport, but results have often been conflicting due to differences in trailer design and
433 lack of simultaneous comparisons. When transported in a 2-horse trailer, backward-facing horses had
434 fewer side and total impacts and losses of balance when compared with forward-facing horses (Clark
435 et al., 1993). Horses transported in a 2-horse lorry without a saddle compartment and facing backward
436 had a significantly lower heart rate, moved less frequently, and showed a greater tendency to rest their
437 rumps on a partition (Waran et al., 1996).

438 Comparison of three different positions (backward, forward and sideways) during a three hour
439 journey for Standardbred trotters accustomed to travel, revealed that backward facing was the most
440 ideal orientation. Backward-facing horses moved more but lost their balance less and were able to rest
441 a hind quarter in a three leg position during the journey (Padalino et al., 2012).

442 However, since some horses have demonstrated a superior ability to maintain their balance in a
443 particular orientation, individual characteristics and other factors, rather than travel orientation alone,
444 may affect the ability of horses to maintain their balance during transport (Toscano and Friend, 2001).
445 Therefore, further studies are needed on the travel position.

446 447 5.3.6. Duration of travel: short *versus* long trip

448 In order to understand the effects of road transport on equine physiological and behavioral
449 parameters many studies have been conducted and it seems that a key variable is the duration of the
450 journey.

451 Long transport times likely have a strong effect on both equine physiological and endocrinal
452 parameters. The effects of nine hours of transport on in-foal mares showed increased concentrations of
453 cortisol and progesterone. Despite the increases, no early embryonic deaths were reported (Baucus et
454 al., 1990).

455 After 24 hours transport, equine body weight decreased by 6% immediately after unloading with a
456 3% deficiency remaining at 24 h post transit. The white blood cell (WBC) counts, hematocrit and total
457 proteins concentrations showed a progressive increase with the duration of travel, peaking at the
458 termination of transport. Serum lactate, creatine kinase and aspartate aminotransferase concentrations
459 increased during transport and in the early post-transit period. They returned to normal levels 24-h
460 after unloading, whereas glucose concentrations tended to rise with the initiation of transport and did
461 not decrease to baseline concentration within the 24 hour post transportation period (Stull and Rodiek,

2000). Plasma cortisol and the neutrophil:lymphocyte ratio also increased during transportation, as a stress response. Those hematological and endocrinal changes may increase disease susceptibility and influence energy availability for athletic performance following transportation of horses over long distances.

Due to the long journey, stress-related respiratory diseases and even death have been reported in horses (Anderson et al., 1985; Oikawa et al., 1994; Racklyeft et al., 2000). It was observed that in healthy horses traveling in a trailer for 36 h (1,100 Km), the number of alveolar macrophages and their bactericidal function decreased and cortisol concentration remained elevated one week after transport; favoring the development of lower airway diseases (Laegreid et al., 1988).

According to European law, a journey is considered to be long if it lasts more than 8 hours, requiring that some rest must be planned to minimize the risk of the above mentioned health problems and to safeguard equine welfare.

Horses are transported mainly over shorter distances, in particular before competitions, so the effects of short journeys are also a topic of importance and relevance.

Comparing a short-duration (300 Km) journey and an exercise bout of cantering 1,500 m, similar effects on serum enzymes and metabolic processes were reported in race horses (Codazza et al., 1974).

In a comparison of one hour vs. three hour journeys the number of movements recorded per kilometer was greater during the short journey than the long one. More forward and backward movements were reported, possibly as a result of the greater agitation shown by the horses at the start of the journey. In addition, horses subjected to the short journey showed a higher serum cortisol concentration at unloading, suggesting that they could not adapt to the travel in one hour (Tateo et al., 2012). Many authors have argued that horses need around 5 hours to adapt to a transportation experience, and the first phase is always the most critical (Baucus et al., 1990; Iacono et al., 2007b). Other studies have confirmed that the period of adaptation to a journey is longer than one hour which increases the importance of animal management during short journeys, because the horse is under an acute stress situation (Fazio et al., 2008b).

In conclusion, long and short journeys both affect equine behavior and endocrinology differently, but both require a restore time and appropriate management. Long journeys should be planned with frequent and long stops, during which the horses should be fed and watered, the male horses allowed to stale or urinate, and the truck cleaned. It is important to choose quiet and shaded rest areas. The horses could be more nervous than usual, so unload them only if the area is fenced and deemed 'safe'.

5.3.7 Effect of driver behavior

495 Driving style is another important factor which influences horse welfare during transportation. The
496 driver's ability could affect the movement of the vehicle and consequent balance ability of the
497 transported animals, in particular during accelerations, braking, cornering and any other difficult
498 maneuvers. There are two main components in driver behavior: style and skill, where "skill" is the
499 ability to control the vehicle and "style" is the way in which the vehicle is driven (West et al., 1993).
500 European rules require the driver to demonstrate skill and ability in transporting animals. Driver
501 behavior and road quality (motorway vs. minor road vs. city traffic) affect the behavior of transported
502 animals as has been shown for sheep (Cockram et al., 2004), cattle, young calves and pigs (Cockram
503 and Spence, 2012). In horses, heart rate seems to be highly correlated with muscular activity spent in
504 balance preservation, and both are strongly affected by the degree of experience of the driver.
505 Consequently, it has been suggested that vehicle condition (suspension, tire pressure), road quality and
506 driver's professional ability are crucial factors in determining the magnitude of transport stress
507 (Giovagnoli et al., 2002).

508

509 5.3.8 Effect of noise and vibration

510 Animals can perceive high frequency sounds and it is possible that they are disturbed or scared by
511 sounds that are inaudible to man. During loading, transportation and unloading, noises audible to
512 humans can arise from different sources such as human voices, whips, animal vocalizations (including
513 other species e.g. barking dogs), noisy machinery, alarm bells/klaxon, and compressed air brakes on
514 vehicles. We cannot quantify easily all sources of ultrasounds, but animals are exposed to many
515 'annoying' noises. It has been proven that intensive noise results in a central nervous system
516 excitation, which causes immune system suppression, fatigue and cell death (Minka and Ayo, 2009).

517 Vehicle vibration has been correlated with liver and muscle glycogen depletion and consequent
518 fatigue in bird (Warriss et al., 1999); this effect could be contribute to reduced animal performance or
519 horse meat quality after transportation.

520

521 5.4 Unloading

522 Unloading at journey's end may be another physical stressor. Some horses are particularly difficult
523 to unload, particularly if the ramp is very steep or if the animal is exhibiting lameness.

524 Heart rate tended to remain higher than 'at rest heart rates' up to 30 minutes after unloading, but it
525 is difficult to apportion this to the unloading vs. the cumulative transport stress (Waran and
526 Cuddeford, 1995). However, it has been recently proven that Quarter Horses were stressed more
527 during loading into a truck and stepping off a 20 centimeter step than during unloading (Siniscalchi et
528 al., 2014).

529

530 *5.5 Adaptation period in a new environment*

531 Little is known of horses' behaviors after a journey, and very often, behavioral alterations noted
532 may be a result of environmental change (Waran, 1993). The behaviors of horses transported both
533 short and long distances were studied. To allow the researchers to account for the confounding effect
534 of environmental change, a group of control horses was included in the investigation. These control
535 horses did not experience a journey but were relocated to unfamiliar stalls. Comparing the 3 groups
536 upon arrival in the new stalls, it was clear that horses which had made the journey sniffed less and
537 snorted later than the control group. In the first 2 hours following travel, horses were attracted
538 immediately to concentrated food and then started feeding on hay. After the long journey, the horses
539 performed more bouts of drinking, and drank earlier, than the short journey and control groups (Tateo
540 et al., 2012). The latter behaviors could be explained due to the slight dehydration caused by a long
541 journey, which could have had been a direct cause of the positive influence on drinking behavior
542 (Iacono et al., 2007a). It was in agreement with another study where horses, after 6 hours
543 transportation, tended to spend more time standing, playing or resting only after drinking and eating
544 (Waran, 1993).

545 After a journey, horses are usually more interested in feeding than in other behaviors, including
546 exploration, rest, and play, which are usually concentrated in the post-feeding hours, probably to
547 recover energy spent to maintain balance in the truck. Consequently, to guarantee favorable adaptation
548 to a new stall, it is recommended that food and fresh water are offered to the horses at their arrival
549 (Padalino et al., 2012).

550 A common practice to encourage rapid adaptation after a journey is to stall horses adjacent to a
551 familiar stable companions on arrival at the destination.

552

553 **6. Major Pathology Connected with Travel**

554 Another important research area relating to transport is the development of pathology and disease
555 during and after travelling. Higher risks are connected with long transportation. These include acute
556 colitis, laminitis, transit tetany, shipping fever and mild azoturia (Mansmann and Woodie, 1995).
557 However, short and frequent transportation can also result in injuries and health disorders. Frequently
558 traveled horses are likely to show disrupted feeding patterns, weight loss, and fatigue (Cregier, 1982).

559 Notably, each horse journey implies some risk of disease transmission. Safeguarding the horse
560 industry against this danger is one of the major responsibilities borne by equine clinicians. The
561 occurrence in 2002 of West Nile fever in a stallion in post-arrival quarantine and the catastrophic
562 outbreak of equine influenza recorded in 2007 in Australia provide some examples of the risk and

563 importance of quarantine periods. Clinicians also need to be aware of the potential problems relating to
564 horse transport and the way in which these problems may arise (Herzolz et al., 2008).

565

566 6.1. Traumatic Injuries

567 The second (second to paddock/yard) most common source of injuries to horses is the transportation
568 trailer (Darth, 2014). At loading leg injuries associated with to the loading ramp are very common.
569 During the journey halter rubbing at the poll or muzzle and tail rubbing are specific types of abrasion.
570 To avoid these problems, it is useful to use specialized protections such as head bumper or soft
571 wrapping around the halter and protective bandaging on the tail. Long tie-ropes are suggested to allow
572 lowering of the head, but protective screens must be in place to eliminate the risk of biting between
573 neighboring horses. Wither wounds can be caused through contact with the vehicle ceiling While leg
574 wounds most commonly occur as a result of loss of balance after braking and cornering. Rapid and
575 extreme braking has been reported to result in vertebral fracture and dislocation in horses facing
576 forward and restrained with short tie-ropes (Masmann and Woodie, 1995).

577 A recent Australian survey reported that 72% of horse owners blamed the horse's behavior for travel
578 incidents. However, the author highlighted that many incidents are actually related to the driver ability
579 particularly on winding country roads. Among the most commonly reported behaviors were
580 scrambling and slipping during cornering – both of which are exacerbated by wet flooring. Injuries
581 resulting directly from horse-horse interactions and conflict were also common as were injuries caused
582 during loading and unloading (Noble, in print).

583 Injuries during transportation can also be related to road accidents; 2500 known transport accidents
584 involving horses have occurred in the USA over the past 30 years. Often the blame is attributed largely
585 to 'poor' design of vehicles or inappropriate use of vehicles (e.g. overloading). While traumatic
586 injuries are very common; correct transporting procedures and appropriate levels of care could reduce
587 their prevalence.

588

589 5.2 Respiratory illness post transport

590 Recent transportation is frequently associated with the development of pleuro-pneumonia or
591 *shipping fever*, which is a mixed bacterial pneumonia with varying involvement of the pleural space
592 (Raidal, 1995). Although its etiological role is uncertain, *Streptococcus zooepidemicus* has been
593 frequently isolated from pneumonic lesions in those cases (Mair and Lane, 1989). *S. zooepidemicus* is
594 an ubiquitous bacterium in the upper respiratory tract and a secondary invader. It may be activated
595 when host susceptibility to respiratory infection is increased by stress associated with events such as
596 transportation. It has been suggested that transportation predisposes the upper respiratory tract and the

597 lower airways to invasion by the bacterium, with resultant occurrence of episodic pyrexia and acute
598 pneumonia (Oikawa et al., 1994). Pleuro-pneumonia has a 5% incidence after long transportation, with
599 a significant negative affect on horse welfare, largely because it associated with a relative high case
600 fatality rate (Wilkins, 2003). Early identification and appropriate treatment results in survival rates in
601 the range of 43 to 76%, but only approximately 60% of affected horses are able to resume their athletic
602 career (Copas, 2011).

603 The initial clinical signs of shipping fever can be insidious with the most common symptoms being
604 fever, depression, and sometimes stiffness. A lack of coughing or nasal discharge is not uncommon
605 and clinical signs are not specific. Factors that may contribute to transport-related respiratory disease
606 in horses are: presence of subclinical respiratory diseases, prolonged restraint in a “head-up” posture
607 that affects the pulmonary clearance mechanisms, stress-related impairment of the immune response,
608 the presence of noxious gases, high concentrations of airborne dust and bacteria in the truck, poor
609 ventilation, length and duration of journey and any mentioned emotional and physical stressor, which
610 results in immune system suppression (Oikawa et al., 1995). Recent studies have also proven that an
611 imbalance in oxidative status could be a related cause in the development of respiratory disease in
612 horses (Po et al., 2013), but validation is required to ascertain the link with transportation.

613 In the traditional hauling of horses, it is common to place hay in a net at the horses’ nostrils to allow
614 feeding and to keep the horse entertained. Unfortunately, normal, good quality hay contains many dust
615 particles and small mold spores that can be inhaled. Dampening the hay and placing it on the trailer
616 floor, or replacing hay with pellets reduces the risk of significant air contamination.

617 To reduce the insult to the respiratory system, it is important also to choose a good bedding material
618 which is not dusty but which is also very absorbent.

619 Since it has been proven that horses restrained with their heads elevated for 24 hours developed an
620 accumulation of purulent airway secretions and bacteria, which increased the pulmonary risk (Raidal et
621 al., 1996), cross tying horses should be limited and it restrain the horses with a rope which is long
622 enough to allow the horse to lower its head. Horses may be secured by the "log and rope" method, that
623 allows head movements up and down as well as side to side. Using the "log and rope" method it is
624 feasible to provide hay at floor level thereby allowing the horse to eat in a natural position (with head
625 lowered). Another approach is to anchor the tie-rope alongside the withers. The operator then has the
626 option to route the tie rope through a second ring positioned such that the horse cannot worry the
627 neighboring horse. In well-designed trucks where the stall dividers are well designed and there is no
628 risk of horses biting travelling companions, horses can travel untied.

629 Another preventative measure for reducing shipping fever is to avoid transporting horses which are
630 undergoing drug therapy. For example, phenylbutazone can mask the early signs of pneumonia while

631 corticosteroids are known to further decrease the horses' defense mechanisms and may also increase
632 the risk of laminitis (Mair and Lane, 1989; Racklyeft et al., 2000).

633 Increasing the rest time and frequency and cleaning the interior of the vehicle during rest stops
634 reduces transportation stress and respiratory insults which may lead to respiratory diseases (Oikawa et
635 al., 2005).

636 Diagnosis of early stage pleuro-pneumonia and other respiratory diseases associated with transport is
637 an area that deserves investigation and is not widely reported in the literature. Infrared thermography
638 (IRT) has been shown to have merit in the early detection of bovine respiratory disease complex before
639 it was otherwise manifested (Schaefer et al., 2012). There are also many other reported examples of the
640 use of IRT for early disease detection across many species including humans.

641 Since recent significant findings have linked hydrogen peroxide, a common oxidant marker, in
642 exhaled breath condensate to *R. equi* pneumonia in foals (Crowley et al., 2013), the latter method
643 could become useful to test the travelled horses at unloading, to evaluate the pulmonary antioxidant
644 status and likelihood of subclinical pneumonia.

645

646 *5.3 Dehydration, laminitis and colic syndrome*

647 Even when water is available, horses tend to dehydrate during a journey which predisposes them to
648 other pathologies.

649 Dehydration status can range from mild to severe after transporting and is largely dependent on the
650 travel conditions (e.g. environmental condition and journey duration). Despite an increased
651 physiological requirement for water, drinking behavior is generally suppressed by the travel stress
652 (Mars et al., 1992).

653 The earliest stages of dehydration are difficult to determine clinically, because a horse could have
654 up to 5% dehydration without showing any significant clinical signs. For the athletic horse 2-3%
655 dehydration can affect performance, so preventing even slight dehydration may be extremely important
656 for racehorses or any horse travelling to competition.

657 Dehydration can also cascade into more serious metabolic situations. Moderate dehydration can
658 initiate abnormalities in blood flow to the hooves thereby inducing laminitis. This problem is probably
659 often accentuated by the hoof inflammation caused by removing shoes (a practice for reducing kick
660 injuries) from a horse that normally wears shoes. Other compounding factors that may significantly
661 increase the risk of laminitis could be the duration of the journey relative to the state of fitness of the
662 horse, the level of carbohydrate intake maintained during the journey and any potential endotoxic
663 disorders initiated by the travel event itself. Preventive measures would include: not changing the

664 shoeing status of the horse, adding frog support to higher risk horses, and reducing carbohydrate intake
665 before and during transportation (Masmann and Woodie, 1995).

666 Diarrhea can also be caused by transport stress and increases the risk of laminitis, since it is always
667 associated with endotoxemia.

668 Severe dehydration could induce the development of large colon impaction. In fact, there is a higher
669 risk of colic in horses that have more than six transports/year compared with horses that are not
670 transported and those transported fewer than six times per year (Tinker et al., 1997).

671 Another potential risk caused by dehydration is the reported decrease in renal function which is
672 particularly relevant for horses due to undergo medical treatments (MacAllister and Taylor-
673 MacAllister, 1994).

674 There are several techniques which are often implemented to minimize the risk and extent of
675 dehydration. One involves the familiarization of horses with an aqueous normalizing substance, such
676 as apple flavoring which reportedly offsets any difference in water taste during transportation and at
677 the destination (Mars et al., 1992). Mineral oil or electrolyte-enriched water via naso-gastric tube has
678 also been successfully implemented, pre-transport, for the prevention of gastrointestinal impaction.
679 Care should be taken with the administration of both mineral oil which can affect the absorption of
680 other nutrients and electrolyte which should not be given in a concentrate form (such as paste) close to
681 a stress event (including race, extreme exercise or transportation). Electrolytes should be always
682 administered in an iso-osmotic solution (Pagan, 2005). The recommendations for stopping frequency
683 during transportation are every 4-6 hours and over-nighting horses at least every 12-16 hours. During
684 stops and over-nighting, to prevent dehydration and correlated pathologies, the horses should have the
685 ability to exercise and to be examined by a veterinarian who can administer fluids as required. Oral
686 electrolytes and water can be easily administered via naso-gastric tube to mild or moderately
687 dehydrated horses or intravenously if dehydration is severe. A 450-500 kg horse's stomach can
688 tolerate 6-8 liters of electrolyte-enriched water every 15 minutes for 1 to 2 hours (Masmann and
689 Woodie, 1995).

690

691

692 **6. Transport and Oxidative Stress**

693 Oxidative stress (OS) occurs when the oxidant/antioxidant imbalance results in excess production of
694 reactive oxygen metabolites (ROMs) and leads to cellular and tissue damage. Oxidative stress plays an
695 important role in diseases such as cancer, laminitis, neurological disease and heart and pulmonary
696 diseases (Dunlap et al., 2006).

697 The imbalance occurs during and after stressful events such as travel, exercise and intensive
698 management in both humans and animals (Kirschvink et al., 2002). Racehorses are often transported
699 long distances and endure maximal exercise during training and races and have been shown to suffer
700 frequently from oxidative stress (Hargreaves et al., 2002). It has been found that in horses oxidative
701 stress has an effect on the development of airway disease, such as chronic obstructive pulmonary
702 disease and exercise induced pulmonary hemorrhage (EIPH) (Soffler, 2007; Kirschvink et al., 2008).
703 However, the potential role of oxidative stress in the pathogenesis of transport pneumonia is still
704 unclear.

705 A recent study was conducted to evaluate oxidative stress indicators in ten horses, transported 528
706 km by road. Physical (rectal temperature, respiratory and heart rates), hematological, biochemical and
707 oxidative stress (malonedialdehyde (MDA) and superoxide dismutase (SOD) parameters were
708 measured before and after transportation. The transportation induced significant increases in
709 respiratory and heart rates, and in haematocrit and glycemia levels While the other clinical,
710 haematological and biochemical parameters remained unchanged. The occurrence of oxidative stress
711 induced by a 12 hour journey was evident by a significant increase in plasma MDA concentrations
712 coupled with a significant reduction in plasma SOD activity compared to baseline values (Onmaz et
713 al., 2011). The effects of an 8-hour journey by road on plasma total antioxidant status (PTAS) and
714 general clinical appearance were also investigated in horses and showed that the average PTAS
715 increased soon after unloading and remained elevated even after 24 hours stall rest (Niedźwiedź et al.,
716 2013)

717 One approach to reducing the affect of oxidative stress during horse transportation would be to
718 supplement their diets with antioxidants prior to transporting, which has been assessed in other
719 production animals (Adenkola et., 2011). In goats it is reported that long distance travel affected their
720 oxidant/antioxidant status and decreased their excitability and grazing behavior after unloading. In
721 contrast, goats supplemented with ascorbic acid before the journey, did not display similar behavioral
722 changes after unloading and their oxidant/antioxidant systems remained in balance after the journey
723 was completed (Minka and Ayo, 2013).

724 Further study is needed to investigate the relationship between transport stress, oxidative imbalance
725 and respiratory pathologies development.

726

727 **7. Conclusions**

728 To safeguard horse welfare during transportation it is important to minimize transport stress.

729 A horse which is disturbed when first coaxed into a transport vehicle may show various signs of
730 disturbance, but most of these signs will disappear by the tenth transport experience (Broom and

731 Johnson, 1993; Schmidt et al., 2010). Thus, loading and transport training with appropriate provision
732 of positive and negative reinforcement are strongly recommended (McGreevy and McLean, 2007).
733 Sport horses should be transported occasionally for pleasure riding, decreasing the association between
734 the truck and the competitions. As transport is a stressor even for experienced horses, it may be
735 reasonable to give a rest period (a period with no travelling) to “frequent traveler horses”.

736 To limit health problems post transportation, it is important to examine the health status of the
737 horses before traveling, to give provide them with electrolytes and antioxidants (Vitamin E, C and
738 selenium) and to optimize the environmental conditions inside the truck.

739 During long distance journeys it is essential to plan rest stops (of at least thirty minute duration)
740 every 4 hours for watering, feeding, urination (particularly for male horses), and cleaning the vehicle.
741 Horses should not be loaded more than 18 hours without being unloaded and being able to do some
742 physical exercise. Upon arrival at the destination it is important to offer fresh water and high quality
743 food, since it is apparent that drinking and feeding are the horses’ highest priority needs after
744 transportation.

745 While significant research has been conducted and reported allowing the development of best
746 practice management guidelines, further research is required to more fully understand the
747 relationships between transport stress, immune system status and risk of post transport disease
748 development. Transport stress is caused by a mosaic of stressors and the travelling horse's wellbeing
749 can be best improved only through a multi-factorial approach.

750

751 **Conflicts of Interest**

752 The author declares no conflict of interest.

753

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How to manage equine transport stress.

How each transport phase affects horse behavior and health status.

How to prevent the principal pathologies connected with transportation.

Practical outcomes useful to safeguard the travelling horse welfare.

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