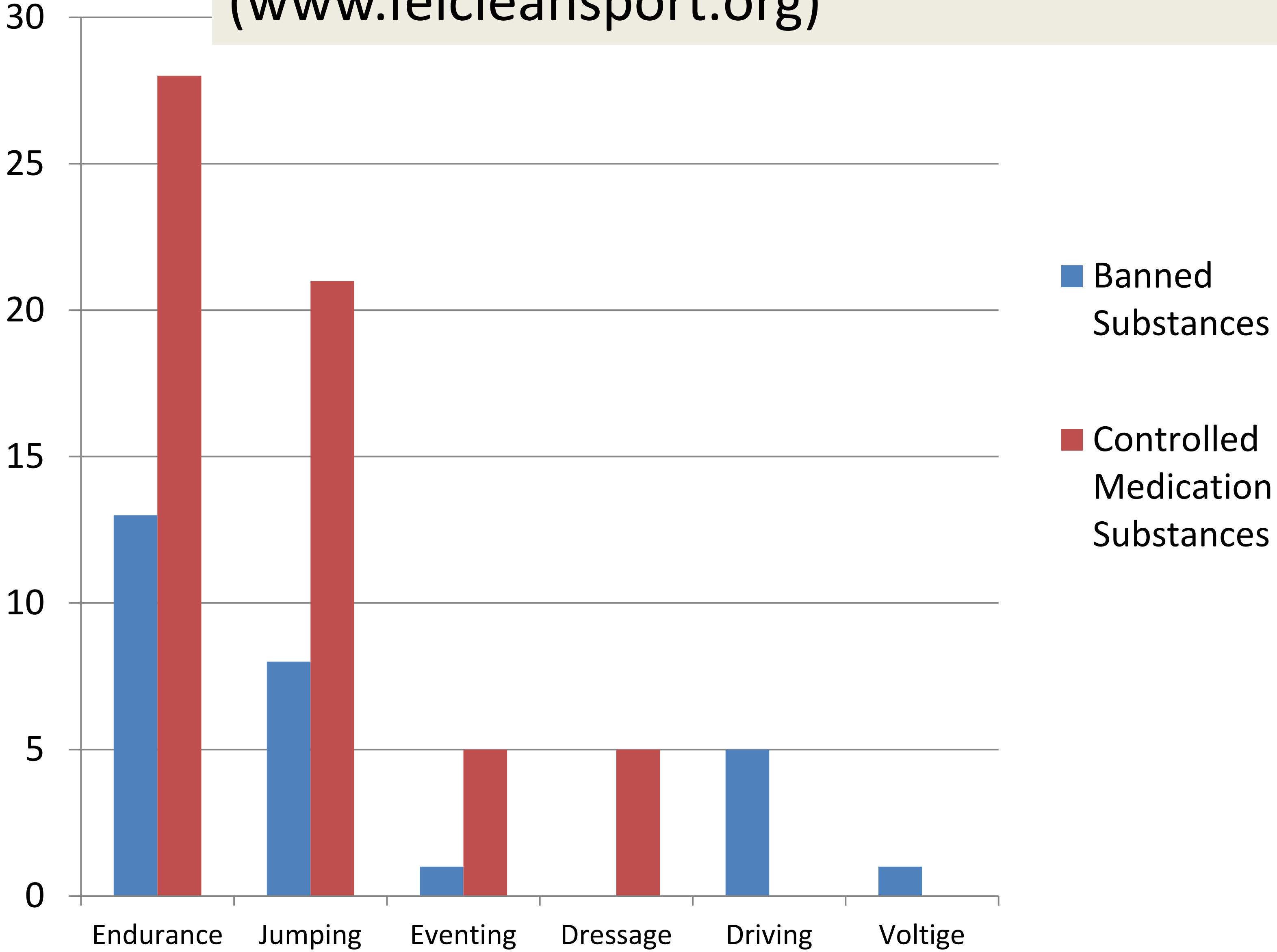
Table 1: Positive cases per discipline 2010-2012 (www.feicleansport.org)



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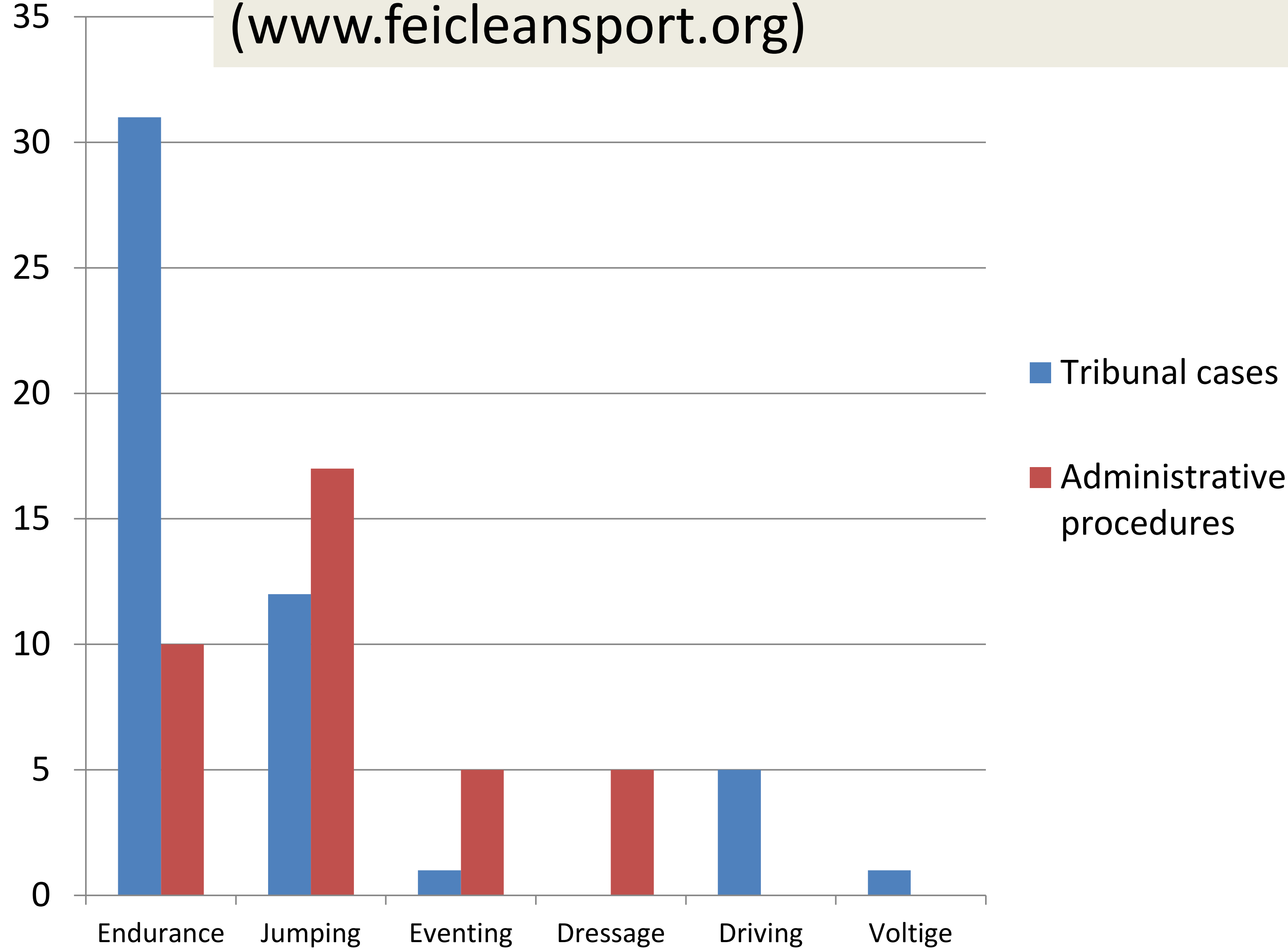

Table 3: Positive cases per nation 2010-2012 in all disciplines (www.feicleansport.org)

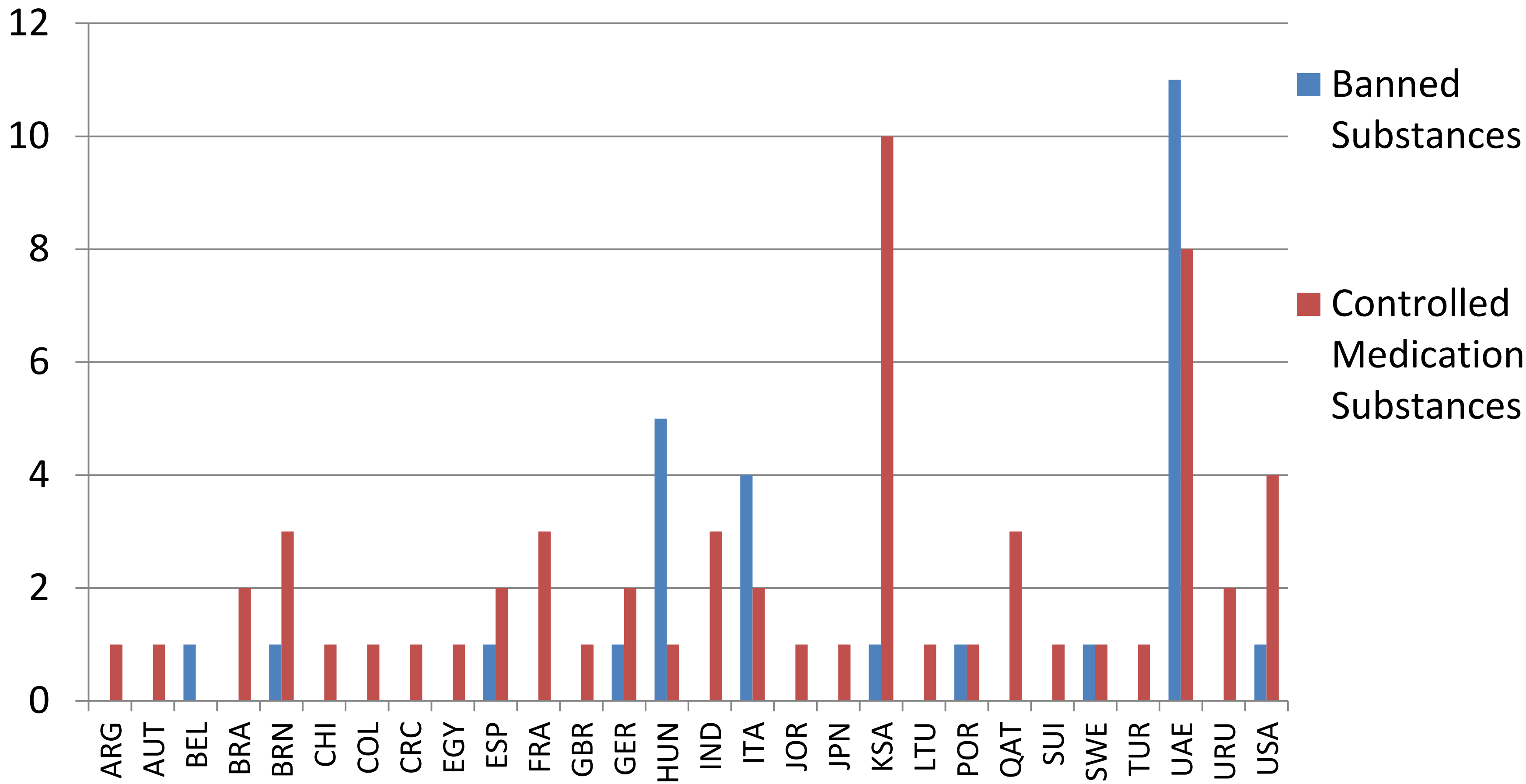

Table 4: Positive cases per nation 2010-2012 in all disciplines (www.feicleansport.org)

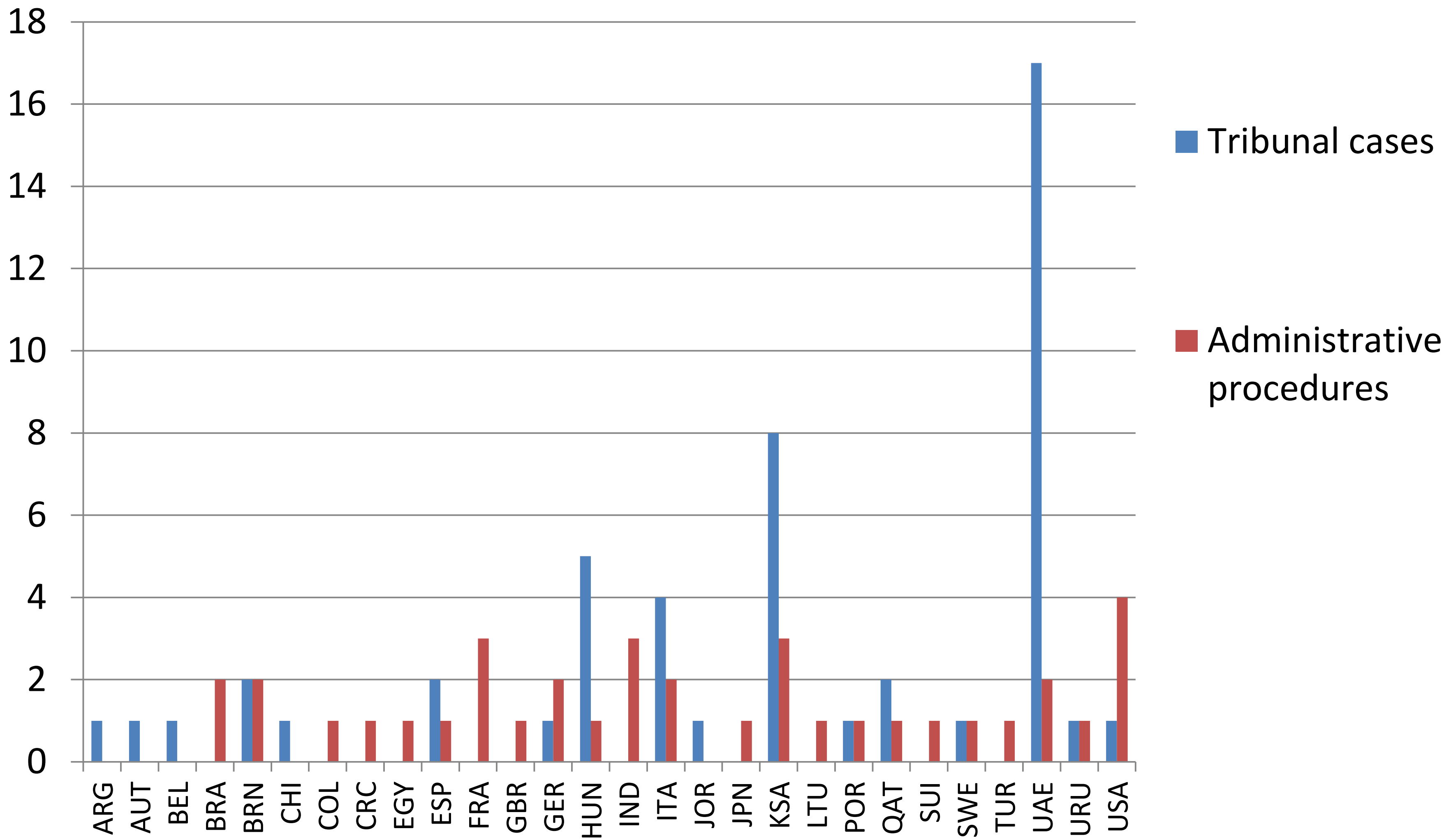

Table of Suspensions

Last update: 22 February 2013

FEI Statutes, Article 39.2 – Penalties an Enforcement: All penalties imposed by a competent body of the FEI or the CAS shall be accepted by all National Federations and enforced by the FEI and all National Federations concerned.

EAD Rules Article 13.4 + ECM Rules Article 13.4 + ADRHA Article 15.3 - Recognition of Decisions by FEI and National Federations: Any decision of the FEI regarding a violation of the Rules (EAD recognized and enforced by all National Federations including with respect to National Events, and Federations shall take all necessary action to render such results effective.

Case No.	Competitor/Other PR	Horse	NF	Discipline	Suspension Commences	Suspension Ends	Date of Decision of the FEI Tribunal
2012/CM02	Haytham Suliman Falahat **ID: 10047885**	JAWHARET AL PETRA **ID: JOR40163**	JOR	Endurance	09.01.2013	**08.09.2013**	09.01.2013
2012/CM07	Khalil Abdulsamad Abdullatif **ID: 10033439**	OBYAN AL AHMAR **ID: UAE02019**	BRN	Endurance	08.01.2013	**07.11.2013**	08.01.2013
2012/02 (Athlete)	Aleksandr Kovshov **ID: 10039044**	-	UKR	Dressage	27.11.2012	**26.11.2014**	27.11.2012
2012/CM04	Abdulrahman Alqurashy **ID: 10059994**	AZAM **ID: 103CH29**	KSA	Endurance	22.11.2012	**21.07.2013**	22.11.2012
2012/CM06	Ahmad Ali Humaid Al Razzi **ID: 10072441**	MANDIJI **ID: 102MT21**	UAE	Endurance	12.11.2012	**11.09.2013**	12.11.2012
2012/BS04	Miguel Caeiro **ID: 10041538**	DAKAR DE FONTNOIRE **ID: 103EK59**	POR	Endurance	**PR**: 29.08.2012; **Horse**: 29.08.2012	**PR: - Horse: 29.10.2012**	
2012/01 (Athlete)	Ali Nilforushan **ID: 10000657**	-	USA	Jumping	03.03.2012	**02.03.2013**	03.09.2012

Case No.	Competitor/Other PR	Horse	NF	Discipline	Suspension Commences	Suspension Ends	Date of Decision of the FEI Tribunal
2012/BS03	Rashed Mohd Ali Al Abbar **ID: 10063402**	CROMWELL **ID: 102TH69**	UAE	Endurance	**PR**: 14.03.2012; **Horse**: 14.03.2012	**PR: -** **Horse: 13.05.2012**	
2012/BS02	Ahmed Jaffar Abdulla Abdulrahim **ID: 10041791**	QEOPS DE KERBREDEN **ID: 103FT43**	BRN	Endurance	**PR**: 13.03.2012; **Horse**: 13.03.2012	**PR: 12.09.2014** **Horse: 27.05.2014**	28.01.2013
2012/BS01	HH Sheik Hazza bin Sultan bin Zayed Al Nahyan **ID: 10014761**	GLENMORGAN **ID: UAE40813**	UAE	Endurance	**PR**: 12.03.2012; **Horse**: 12.03.2012	**PR: -** **Horse: 11.05.2012**	
2011/BS15	Susanne Ankermark **ID: 10036596**	WINDY BOY ROCKET **ID: SWE40356**	SWE	Driving	14.11.2011	**13.11.2013**	29.08.2012
2011/CM02-03-04	Homoud Salman Alshammari **ID: 10020262**	ANWAR ALMAMMLAKAH **ID: AUS40452** FREEDOM'S GRACE **ID: 102TP66**	KSA	Endurance	**PR**: 08.11.2011; **Horse:** 08.11.2011	**PR: 07.05.2013;** **Horse: 07.05.2013**	08.11.2011
2011/BS16	Alexander Kernebeck **ID: 10047452**	SANTIAGO 218 **ID: 103IM18**	GER	Jumping	08.11.2011	**07.11.2013**	21.08.2012
2011/01 (Athlete)	Jonathon Millar **ID: 10001794**	-	CAN	Jumping	24.08.2011	**-**	
2011/BS13	Ali Salman Al Sabri **ID: 10048642**	TRIASSIC **ID:USA42516** HELLOW **ID: 102TD98** OCEAN EL DAHMAN **ID: 102OB73** ARMINS ZULU **ID: 102MC97**	UAE	Endurance	15.02.2012 16.08.2011	**01.04.2013**	15.02.2012

Case No.	Competitor/Other PR	Horse	NF	Discipline	Suspension Commences	Suspension Ends	Date of Decision of the FEI Tribunal
2011/BS12	István Kovács **ID: 10078173**	FREDDY 67 **ID: GER20045**	HUN	Driving	08.06.2011	**07.06.2013**	23.11.2011
2011/BS11	Michela Callegari **ID:10026646**	BURBERRY SPOT **ID: ITA42894**	ITA	Vaulting	25.05.2011	**16.04.2013**	11.10.2011
2011/BS09	Ali Mohammed Al Muhairi **ID: 10011714**	KARABIL KAIYA HAI **ID: UAE40399**	UAE	Endurance	09.03.2011	**21.03.2016**	21.03.2012
2011/BS08	Sheik Abdul Aziz bin Faisal Al Qasimi **ID: 10031263**	HOTSPUR OUARRA **ID: 102PY07**	UAE	Endurance	09.03.2011	**09.03.2013**	30.01.2012
2011/BS02	Abdulla Thani Bin Huzaim **ID: 10032533**	TRIASSIC **ID: USA42516**	UAE	Endurance	15.02.2012	**05.05.2013**	15.02.2012

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Original Article

Management of fractures in endurance horses

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Keywords: horse; endurance; fracture; condylar fracture

Summary

This paper provides relevant information for veterinarians responsible for treatment of endurance horses, including a retrospective study of fractures in endurance horses presenting to one referral hospital and to treatment clinics at 3 different race venues. Treatment and case outcome were also noted. The information presented provides clinicians working with high level endurance horses increased awareness of common sites of fractures, of prefracture stress related bone injury within this population of athletes and guidelines in order to manage them more effectively. The most common fractures involve the metacarpo-(tarso-)phalangeal joint. Most distal limb fractures can be diagnosed radiographically, but magnetic resonance imaging or scintigraphy may be required in some cases.

Introduction

The purpose of this paper was to characterise the kinds of fractures endurance horses incur, in order to alert veterinarians to the existence of these types of injuries and to strategies that can be employed in their management. Dissemination of this information will hopefully raise the index of suspicion for fractures or stress related bone injury as a cause of lameness in endurance horses. Additionally, recognition of the prevalence of certain injuries should assist in making a diagnosis. The intent is to raise awareness of the existence and skeletal distribution of fractures previously thought to be seen primarily in flat-racing horses.

The Fédération Équestre Internationale (FEI) is the governing body responsible for the equestrian sports of eventing, showjumping, dressage, reining, driving, vaulting, para-equestrian and endurance. Of these, endurance is the fastest growing FEI sport. It was first recognised as an FEI official discipline in 1982, and now more countries compete in international endurance championships than those of any other equestrian sport.

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As the sport has developed, speeds of competition have increased dramatically. World record times for 160 km have been set and broken in each year since 2008. A world record time of 6 h 28 min 28 s riding time was set in January 2008, improving the previous year's record by 13 min. Although the average speed was 24.71 km/h (over 15 mph), the final 19 km loop was covered at a speed of 30.29 km/h. The record was broken again in 2009 and 2010, and now stands at 6 h 21 min 12 s riding time. As winning speeds at the classic 160 km distance have increased, speeds at the shorter 120 and 100 km distances have increased even more. In a 120 km race in February 2010, the first 3 finishers broke the previous world record, with average speeds ranging from 26.52–26.69 km/h, and the winner finishing in 4 h 29 min 43 s. A new world record for 120 km was set again in March 2010, with the average speed increasing to 29.47 km/h and the ride time shaved to 4 h 4 min 17 s.

Veterinary controls are an integral part of endurance events, and horses must undergo and pass an inspection after each phase of the competition before being permitted to continue to the next phase. Horses can be eliminated from competition by the veterinary panel based on metabolic or musculoskeletal parameters. Despite these stringent controls, there are still significant numbers of metabolic emergencies and musculoskeletal injuries during competitions, and veterinarians and organisers responsible for the care of competitors must be prepared to stabilise affected animals effectively.

Many of the previous studies of endurance horses have focused on fluid deficits and metabolic abnormalities. It is the authors' observation that as endurance competition speeds have increased, musculoskeletal injuries that previously were thought to be more common to flat-racing horses are now seen in endurance horses. Specifically, athletically induced bone pathology is being seen with increasing frequency, sometimes presenting as complete fractures.

Repetitive loading of bone results in microdamage, which is usually repaired as a natural physiological process. However, sometimes microdamage exceeds the repair process, because of excessive load or repetition. A stress fracture may result, which is susceptible to becoming a complete fracture if exercise continues (Stover 1998). Early identification of stress fractures allows horses to be removed from training and competition before complete fracture occurs. Studies have shown increased risk of stress fractures in Thoroughbreds with increased training distance (Estberg *et al*. 1996a; Verheyen *et al*. 2006a). Although racing and training at lower speeds than Thoroughbred flat-race horses, endurance horses are at risk of athletically induced bone pathology because of the long distances covered, at ever increasing speeds.

Materials and methods

A retrospective study of all endurance horses presenting with fractures to one referral hospital or to treatment clinics at 3 race venues were recorded. The period covered was from mid 2005 to mid 2008. Horses registered as endurance horses with the FEI office or national federation were the population sampled. Horses that became lame in training or racing were included. Other criteria for inclusion were the presence of a fracture line detected radiographically or by magnetic resonance imaging (MRI), or the presence, on scintigraphic examination, of an area of increased radiopharmaceutical uptake (IRU) consistent with fracture pathology. Horses with avulsion fractures of the proximopalmar aspect of the third metacarpal bone (MCIII), chip fractures of the dorsoproximal aspect of the proximal phalanx, or fractures of MC/MT II and IV were not included in the study. The information was collected from the medical records and images. Radiographic images were taken with conventional film, digital radiographic and computed radiographic equipment. Choice of equipment depended on availability and personal preference. All images were interpreted by experienced clinicians, the majority by board certified surgeons.

The scintigraphic images were acquired 2–4 h after injection of 5 GBq/150 mCi of ^{99}Tc-MDP. Images were acquired and digitised using an Integrated Orbiter Gamma Camera System[1] consisting of a high-resolution circular digital camera with a 140 keV low energy general purpose collimator. The images were acquired, motion corrected and processed by nuclear medicine application software[2]. The images were interpreted by board certified surgeons on staff at the Hospital.

The MRI was performed with an Equiscan 3000 Standing Hallmarq[3] MRI scanner. Images were interpreted by an equine MRI specialist[4]. A fracture was diagnosed based on a linear increase, usually on T2* or short tau inversion recovery (STIR) sequences, and also a decrease in signal intensity, usually on T1 but sometimes also T2 sequences. The appearance was dependent on chronicity of the fracture, but usually involved cortical and trabecular bone, and was clearly active when surrounded by high signal intensity on STIR images, low signal intensity on T1 weighted images and/or high signal on T2* gradient echo sequences possibly with a hypointense rim.

Follow-up information was obtained by direct contact with the trainer or from the FEI race recording database. In all cases it was after a period of at least 12 months.

Results

A total of 38 horses, with 41 fractures, met the inclusion criteria.

There were 27 geldings (71%) and 11 mares (29%) in the series. During the 2007–08 season, the gender breakdown for all race starts was 76% geldings, 20% mares and 4% stallions. Horses are required to be ≥6 years, and have competed in qualifying races, before racing in FEI endurance races. The ages of the horses in this group ranged from 7–17, with a mean of 11 years. Twelve fractures (12/41, 29%) were in the left forelimb, 21 (51%) in the right forelimb, 4 in the left hindlimb and 4 in the right hindlimb. Twenty-two horses fractured at a race, and 16 horses during training. Analysing the data with a Chi-squared test, there were significantly more front than hindlimb fractures, but not significantly more right sided than left sided fractures ($P = 0.16$), and not significantly more right front than left front fractures ($P = 0.12$).

The fractures were categorised, firstly, on location. The summary of fracture location is presented in **Table 1**. Almost 75% of fractures involved either the proximal phalanx or MC/MTIII. Twenty of the 38 horses had fractures of MC/MTIII, and 17 of these had condylar fractures. A summary of the metacarpal/tarsal fractures is provided in **Table 2**.

Horses with displaced condylar fractures, and some with nondisplaced fractures, became acutely lame and were diagnosed following radiography at the race. Horses with unilateral condylar fractures were transported to the Hospital in a Kimzey[5] splint. Particularly in the case of nondisplaced fractures, surgery was often not performed until the following day, after overnight treatment with i.v. fluids. Some of the nondisplaced fractures were not diagnosed until several days after the fracture occurred.

TABLE 1: Fracture location and number of horses affected

Bone	Number of cases
Distal phalanx	1 (2.6%)
Middle phalanx	1 (2.6%)
Proximal phalanx	8 (21.0%)
MCIII/MTIII	20 (52.6%)
Radius	1 (2.6%)
Humerus	2 (5.3%)
Scapula	1 (2.6%)
Talus	1 (2.6%)
Femur	1 (2.6%)
Pelvis	2 (5.3%)
Total	38

MCIII, third metacarpal bone; MTIII, third metatarsal bone.

TABLE 2: Summary of metacarpal/metatarsal fractures

Case	Sex	Age	Limb	Fracture type	Imaging modality	Treatment and outcome
1	G	11	LF	Incomplete lateral condylar	Rad.	Rest, raced.
2	G	9	RF	Incomplete lateral condylar	Rad.	Sx - lag screws, raced.
3	G	10	RF	Incomplete lateral condylar	Rad.	Rest. Lost to follow-up.
4	G	9	RF	Incomplete lateral condylar	Rad.	Rest. Went lame RF next season. Continued fracture presence on MRI.
5	G	8	LH	Incomplete lateral condylar	Rad.	Sx - lag screws, raced.
6	G	9	RF	Incomplete lateral condylar	MRI	Rest. Back to training.
7	G	10	LF	Incomplete lateral condylar	Rad.	Sx - lag screws. Raced.
8	G	16	RF	Incomplete lateral condylar spiralling	Rad.	Sx - lag screws, performed standing. Raced.
9	G	17	RF	Complete, nondisplaced, lateral condylar	Rad.	Rest. Lost to follow-up.
10	M	11	LF&RF	Bilateral incomplete lateral condylar, in LF fracture lines spiral	Rad.	Sx - lag screws, performed standing. Raced.
11	M	11	LF&RF	Bilateral lateral condylar, RF complete displaced	Rad.	Sx - lag screws. Retired.
12	M	14	RH	Complete displaced lateral condylar	Rad.	Sx - lag screws. Retired for breeding.
13	M	8	RF	Complete, displaced, comminuted lateral condylar	Rad.	Euthanasia
14	G	12	RF	Complete, open, lateral condylar fracture	Clinical findings only.	Euthanasia
15	G	8	RF	Incomplete, spiralling medial condylar	Rad.	Sx - lag screws standing. Retired.
16	M	10	RH	Incomplete medial condylar, fracture lines coursing axially	Rad.	Sx - lag screw, performed standing. Raced.
17	G	10	RF	Complete displaced medial condylar with comminution.	Rad.	Sx - lag screws with arthroscopy. Lost to follow-up.
18	G	9	LF	Incomplete sagittal proximal palmar	Rad.	Rest, raced.
19	G	12	LF	Proximal comminuted displaced	Rad.	Euthanasia
20	G	13	LF&RF	Bilateral distal transverse compression	Rad.	Rest, raced.

G, gelding; M, mare; R, right; L, left; F, front; H, hind; Sx, surgical repair; Rad., radiography.

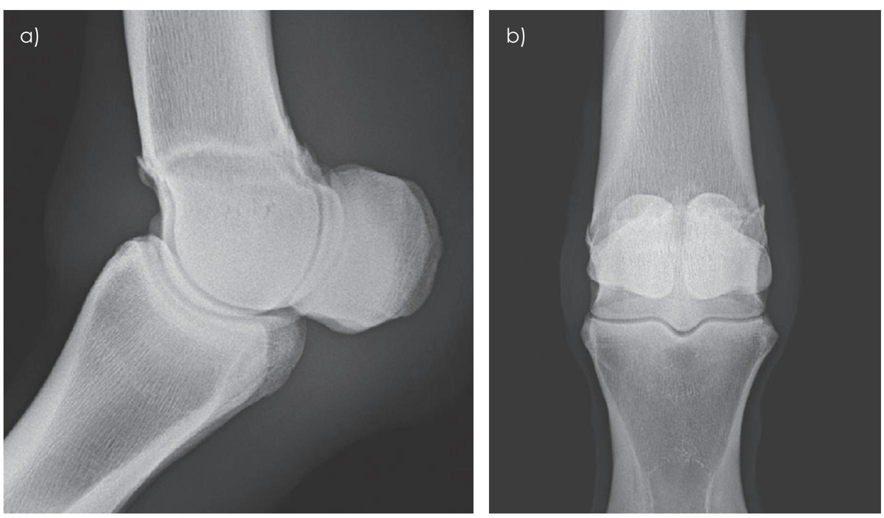

Fig 1: a) Lateromedial radiograph of* Case 20. *A curvi-linear radio-opacity due to a distal transverse metacarpal compression fracture is present. b) Dorsopalmar radiograph of the same limb. Cortical incongruity due to mild displacement and fragment formation is present.

The 2 horses with bilateral forelimb condylar fractures (*Cases 10* and *11*, **Table 2**) presented as horses reluctant to move and rocking back onto their hindlimbs, very similar in appearance to acute laminitis, in that they attempted to transfer as much weight as possible onto their hindlimbs. Each horse rapidly developed marked bilateral metacarpophalangeal joint effusion. The third horse with a bilateral forelimb injury had transverse compression fractures of the distal metacarpi (*Case 20*, **Table 2**, **Fig 1**). This horse presented for investigation of grade 3/5 left forelimb lameness, but had swelling around both distal metacarpal regions, and pain on palpation.

Of the 19 condylar fractures in 17 horses, 3 fractures spiralled or coursed proximally through the diaphysis. One was a medial hindlimb fracture, one a medial forelimb fracture and the third a lateral forelimb fracture. Additionally, a complete displaced forelimb medial condylar fracture was also present in the series.

TABLE 3: Summary of proximal phalanx fractures

Case	Sex	Age	Limb	Fracture type	Imaging modality	Treatment
21	G	16	RF	Complete, comminuted, sagittal with intact medial strut	Rad.	Sx - lag screws. Retired.
22	G	11	RF	Complete, comminuted, displaced sagittal without intact strut	Rad.	Returned to owner to be managed by casting only. Retired.
23	M	8	RF	Complete, displaced frontal fracture with comminution	Rad.	Sx attempted. Died under general anaesthesia.
24	M	9	RF	Complete frontal with large palmar fragment	Rad.	Sx - lag screws. Lost to follow-up.
25	M	13	RF	Complete, displaced, comminuted	Rad.	Cast only (was not presented to the hospital). Retired.
26	G	14	LF	Incomplete sagittal	Rad.	Sx - lag screws. Retired.
27	M	10	LH	Incomplete sagittal	Scin., Rad.	Rest. Raced again.
28	G	13	RF	Incomplete sagittal	Rad.	Sx - lag screws. Raced.

G, gelding; M, mare; R, right; L, left; F, front; H, hind; Sx, surgical repair; Scin., scintigraphy; Rad., radiography.

TABLE 4: Other fractures

Case	Sex	Age	Limb	Fracture type	Imaging modality	Treatment/Outcome
29	G	8	LF	P3, comminuted, *type V*.	Rad.	Rest, remedial farriery. Retired.
30	G	14	RF	P2, biaxial palmar eminence fractures	Rad.	Pastern arthrodesis. Retired.
31	G	10	RF	Radial ‘stress’ fracture	Scin., Rad.	Rest. Lost to follow-up.
32	G	10	LF	Incomplete distal humeral fracture	Scin, Rad.	Rest. Raced.
33	G	12	LF	Stress fracture distal humerus	Scin.	Rest, retired.
34	G	12	RF	Infraspinous fossa fracture of the scapula	Scin., U/S	Rest, raced.
35	G	12	LH	Non-displaced sagittal talus	Scin, MRI	Rest, retired.
36	G	12	LH	Left femur 3rd trochanter	Scin., U/S	Rest, raced.
37	M	9	RH	Stress fracture R ilium	Scin	Retired to become riding pony
38	M	7	RH	Complete fracture R ilial shaft	Scin., U/S	Rest, retired.

G, gelding; M, mare; R, right; L, left; F, front; H, hind; Sx, surgical repair; Rad., radiography; Scin., scintigraphy; U/S, ultrasound; P2- middle phalanx; P3- distal phalanx.

Treatment of metacarpal/tarsal fractures depended mainly on the severity of the injury, but also on owner, trainer or referring veterinarian's preference. The majority of the condylar fractures were repaired surgically with lag screws. Several condylar fractures were repaired standing, usually due to the preference of the referring veterinarian or surgeon. The technique was performed largely as previously described (Russell and Maclean 2006).

Eight of the 38 horses had fractures of the proximal phalanx. A summary of the proximal phalanx fractures is provided in **Table 3**. Complete fractures predominated. All horses had acute, marked lameness during, or shortly after, training rides or races. Treatment choice depended on the severity of the fracture and owner's wishes and the horses were treated by surgical fixation with lag screws, casting only, or rest only.

The remaining fractures (**Table 4**) were a *type V* fracture (comminuted) of the distal phalanx, a biaxial palmar eminence second phalangeal fracture, a radial fracture, 2 humeral fractures, a scapular fracture (transverse mid-body), a parasagittal talar fracture, one third trochanter fracture of the femur, one ilial and one ischial fracture.

The horse with the third phalangeal fracture was shod with quarter clips on the affected foot and returned home for stable rest. The second phalangeal fracture was treated by pastern arthrodesis. The remaining horses were treated by stable rest alone.

The radius fracture was investigated as a chronic mild to moderate RF lameness that improved to median and ulnar nerve blocks. It was diagnosed as a fracture of the lateral mid-diaphysis, with only mildly increased radiopharmaceutical uptake, but smooth periosteal new bone, and endosteal callus at the same site, radiographically. There was no history or clinical signs suggestive of direct trauma.

Both humeral fractures were diagnosed scintigraphically. One appeared as a typical distal craniomedial stress fracture, but the other had marked focal radiopharmaceutical uptake in the caudomedial aspect of the humeral condyle. Both had acute marked lameness following training rides.

The scapular fracture (**Fig 2**) was diagnosed scintigraphically 3 weeks after marked lameness developed during a race. The fracture was orientated transversely from the caudal border of the scapula to the spine, one-third of the distance from proximal to distal. It was subsequently visualised ultrasonographically.

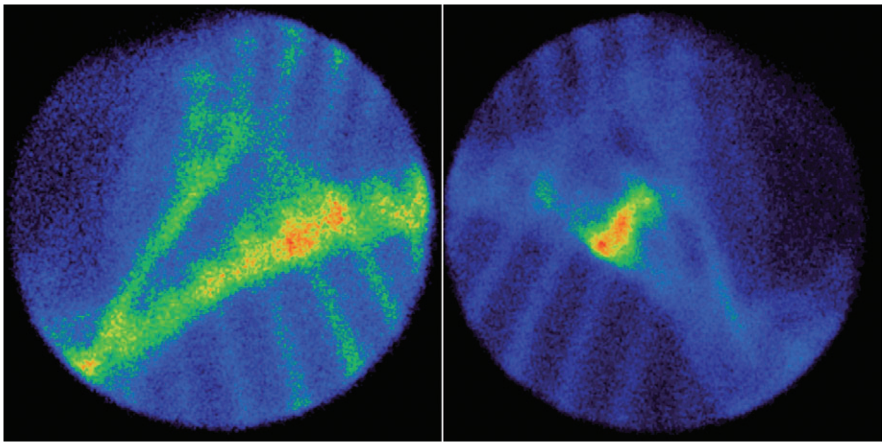

Fig 2: ***Scintigraphic images of the left (cranial to the left) and right (cranial to the right) scapulae of Case 34. Linear, marked, focal radiopharmaceutical uptake is present in the infraspinous fossa of the right scapula.***

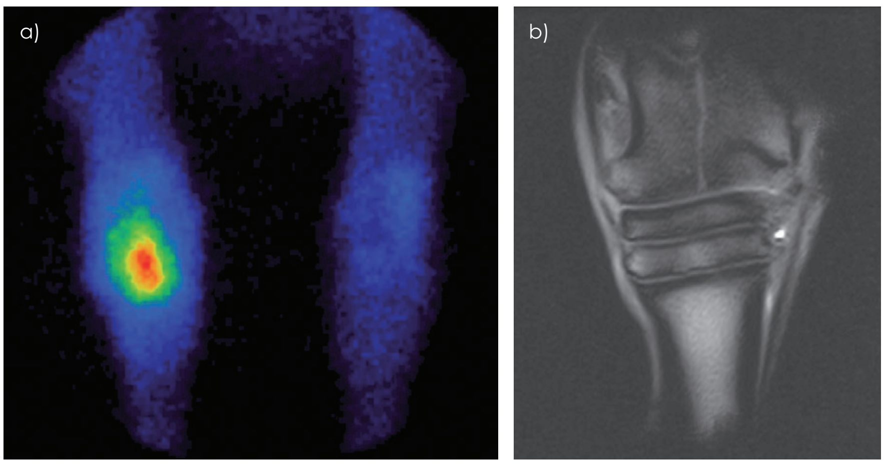

Fig 3: a) Plantar scintigraphic image of the tarsi of Case 35. Marked, focal, radiopharmaceutical uptake is present in the left talus. b) A frontal T1 MRI of the left talus of the same horse. A nondisplaced parasagittal fracture of the talus is present.

The fracture of the talus was a nondisplaced parasagittal fracture, with additional bone and joint pathology in the distal tarsus. The horse presented to the hospital with a marked left hindlimb lameness that occurred acutely during a race. There were no localising signs, and survey radiographs were negative. A low 6 point nerve block was negative, but there was marked improvement after tibial and peroneal nerve blocks. An intra-articular tibiotarsal block was negative, despite aspiration of blood tinged synovial fluid, and slowly increasing distension of the joint over several days after admission. Diagnosis was made with scintigraphic examination (**Fig 3a**), followed by MRI (**Fig 3b**). The MRI report noted that the talar fracture included the articulations with tibia and calcaneus, and that fracture of the central and third tarsal bones was also suspected. Osteoarthritic changes were also present in the proximal and distal intertarsal joints.

The femoral fracture was a third trochanter avulsion fracture, which presented as an acute lameness and was diagnosed scintigraphically, and confirmed ultrasonographically.

The pelvic fractures, both involving the ilia, were confirmed scintigraphically, and were in mares.

As noted in the tables, some horses were subjected to euthanasia, and others were salvaged for breeding. Also, some horses had surgical repair performed despite a decision having been made to retire the horse. Of the 38 horses, 14 have since raced (37%), with a further 2 horses (5%) in training. Eighteen (47%) have been retired or were lost to follow-up (but definitely have not raced) and 4 (11%) were subjected to euthanasia or died.

Of the 38 horses in this series, 12 sustained fractures while racing in the 2007–2008 season, of a total of 2837 starters in all races that season. One horse was subjected to euthanasia at the race, resulting in a fatal racetrack fracture rate of 0.35 per 1000 starts for that season.

Of the 17 horses with condylar fractures in this series, 7 (41%) have raced again.

Discussion

Competition fractures in endurance racehorses do occur, and particular attention should be paid to the possibility of stress related bone injury of the metacarpus in horses competing in this discipline. Several fractures were documented, and it was clear that most fractures in endurance horses emanate from the fetlock joint. Similarly to other racing disciplines, lateral condylar fractures predominated. However, some uncommon fractures were present in this category, such as the lateral metacarpal condylar fracture propagating axially (usually only seen in medial condylar fractures), and the development of a complete displaced medial metacarpal condylar fracture (Richardson 2006).

The most unique pathologies of which the clinician attending endurance races should be aware of are the presenting signs of horses with bilateral forelimb fractures, which are often initially confused with back or pelvic injuries, and the bilateral distal transverse metacarpal fracture, with a complete fracture at the level of, or just proximal to the physeal scar (*Case 20*, **Table 2**, **Fig 1**). Other cases of distal transverse metacarpal fractures have been seen subsequently by the authors (unpublished observation) and these differ from transverse fractures in Thoroughbreds, which are typically more proximal (Fulton and McKellar 1996; Ramzan 2009).

Riggs *et al*. (1999) proposed that condylar fractures in Thoroughbred horses were an example of stress fractures caused by shear forces acting between regions of different density, due to sclerosis of subchondral bone in response to training. The bone structure, consisting of plates of bone trabeculae in a sagittal plane, determines the fairly consistent fracture configuration (Boyde *et al*. 1999). Continued review of these cases in endurance horses will allow us to assess the common configurations for this set of athletes.

The other major group of fractures, those in the first phalanx, are common in racing disciplines (Ruggles 2003). It is likely that these fractures are also the end stage of a continuum of stress related bone injury, although not all authors agree with this (Ross 2007). Other fracture locations were rare, and warrant little further detailed comment, except to note that the uncommon scapular fracture (*Case 34*, **Table 4**, **Fig 2**) has subsequently been observed (unpublished) in other horses by the authors.

Noteworthy was the lack of tibial fractures, which are very common in young Thoroughbreds (Arthur *et al*. 2003; Pilsworth 2003). Additionally, despite the recognised propensity for endurance horses to develop suspensory desmitis (Misheff 2003), major damage to the suspensory apparatus does not extend to the proximal sesamoid bones, with no fractures in this series, despite the concentration of fractures in the metacarpo-phalangeal area. Fetlock support injuries, involving either proximal sesamoid bone fractures or suspensory apparatus rupture, were the single largest cause of fatal musculoskeletal injuries in Thoroughbred and Quarter Horse racehorses in a large California study (Stover and Murray 2008).

Comparisons with other disciplines are difficult, due to differences in study design. Most flat-race horse studies have looked at horse fatalities associated with fracture during racing. Reported rates for fatal fractures in flat-race horses vary from 0.33–1.7 per 1000 starts (Bourke 1994; Estberg *et al*. 1996b), and from 3.1–11 per 1000 starts for jump racing (Bourke 1994; Stephen *et al*. 2003). With the limited data we have available, the risk of fatal fracture in endurance horses falls within the range reported for flat-racing.

One of the limitations of our study was that it did not include all fractures recorded in racing and training in the sample population. In one large study (Verheyen *et al*. 2006a), 1178 Thoroughbreds in training were monitored for up to 2 years and 148 fractures were recorded within the study population. In comparison, the number of fractures in this series is small. However, in another study looking at musculoskeletal racing injuries per racing start in flat-race Thoroughbreds, there was a 0.33% prevalence of injury (Peloso *et al*. 1994). In this series we had 0.42% (12/2837) prevalence of fractures alone per start in the 2007–08 season, without including soft tissue injuries. In Quarter Horse racing, prevalence of musculoskeletal injury per race start is lower again (0.22%) (Cohen *et al*. 1999). These statistics support our clinical impression that fractures are a significant cause of lameness in endurance horses. We were aware of other fractures occurring during training that were managed conservatively at the stable. The authors have also seen cases of lameness in endurance horses, localised with diagnostic analgesia, then subjected to MRI, that have been diagnosed as stress related bone injury emanating from the articular surface of the proximal or distal metacarpal bone.

Other information on the horses in this series, such as previous lameness on the affected limb, or in some cases in other limbs, was known in some cases, but could not be reliably gathered for the majority of cases. The presence of concurrent sites of lameness would undoubtedly affect outcome. Also, other epidemiological data, such as training records for each horse, would be useful additional information but was beyond the scope of this retrospective report.

The number of horses in this study may not be large enough to make a definitive statement with regard to final outcome following treatment; however, there seems to be a trend toward a lower number of individuals returning to their former level of athletic competition. In one large study (Zekas *et al*. 1999), 65% of horses treated by internal fixation of metacarpal/metatarsal condylar fractures returned to racing, compared to 41% in our study. The reasons for this are probably multifactorial and include the fact that in some cases a decision was made to retire the horse at the same time as requesting surgical repair. In these cases, what was considered to be the best treatment for the horse was still desired. A second factor is the number of endurance horses that may have other areas of musculoskeletal pathology distant to the fracture site. Age has also previously been reported as a negative influence on the number of races post condylar fracture repair

(Martin 2000), and endurance horses are older than flat-racing horses.

Most epidemiological studies show a positive association between risk of fracture and exercise distance covered, although not all findings have been consistent (Verheyen *et al*. 2006b). There are many variables that should be considered when investigating risk factors for fracture, including the amount of fast work in total, and in the month preceding injury. In one study in young Thoroughbreds, total canter exercise increased the risk of fracture, whereas total gallop exercise was negatively associated with fracture risk (Verheyen *et al*. 2006a). Endurance horses are generally trained by relatively slow cantering over 10–60 km, but are often ridden at a gallop during competitions. Although slower speed is associated with lower bone strains, the number of cycles is very high. Gallop exercise can be more osteogenic than canter exercise (Lanyon 1990), and in one study it was concluded that the balance of canter and gallop exercise was important in fracture prevention (Verheyen *et al*. 2006a). Whether alterations in training patterns to include short bursts of fast work would decrease the risk of fracture, without increasing the risk of other injuries, is undetermined.

There was no statistically significant difference between left or right sided fracture. Endurance horses, unlike flat-racing horses that compete over shorter distances, do not race around an oval or continually turn in the same direction. It is therefore unlikely that they should favour a particular lead leg, or that this would relate to the side of injury. Variation in the ground surface and terrain over which endurance horses compete is quite marked in comparison to most other equine athletes that perform on a groomed and harrowed racetrack or arena. Even event horses usually compete on a relatively consistent turf surface. The inconsistency of surface, ranging from a smoothed graded base to deep loose sand, to fields and tarmac, coupled with distances of 120–160 km is likely to present a greater challenge to the adaptive response of bone in endurance horses than is always physiologically feasible.

The possibility of fracture occurrences in endurance horses emphasises the need for veterinarians attending these events to be prepared to provide appropriate stabilisation in order to optimise chances for successful repair. Appropriate splint materials or commercially available splints should be available at endurance race venues and attending veterinarians should be well versed in the principles of bandage and splint application, eloquently described elsewhere (Bramlage 1983). It is essential that veterinarians at endurance events be prepared to effectively stabilise distal limb fractures. Condylar fractures and fractures of the proximal phalanx have previously been seen most commonly in flat-racing horses, and have not traditionally been expected in this discipline. The Kimzey splint works well for most proximal phalanx fractures in the forelimb and for metacarpal condylar fractures that do not propagate proximally, but does not fit as well and is not well tolerated on the hindlimbs, unless it is a model specifically designed for the hindlimb. PVC pipe (6 mm thick, 15.5 cm in diameter) cut longitudinally into quarters and then to the appropriate length works well for stabilisation of hindlimb and bilateral forelimb fractures. In addition, longer lengths can be cut to stabilise fractures extending to the proximal metacarpus and fractures of the radius. PVC splints should be applied caudally and laterally over a pressure bandage. Although splinting of fractures proximal to the radius and tibia has been described, it is the authors' opinion that the advantage of splinting proximal fractures must be weighed against the danger of causing further damage with a splint that may act as a lever arm on the injured limb. In most instances, it is not advisable to wait for radiographic confirmation of the presence of a suspected fracture prior to stabilising the limb. However, it is important to be cognisant of the danger of applying a half-limb splint such as a Kimzey to a fracture propagating to the proximal metacarpus. This is clearly contraindicated, and radiographs should be taken it there is any suspicion that the injury may not be confined to the fetlock region.

Endurance horses usually require only minimum doses of sedatives or tranquilisers, if any, in order to apply a splint, but veterinarians should not hesitate to sedate an injured horse adequately in order to bandage and apply an appropriate splint effectively to the animal prior to moving or loading it. Horses that sustain fractures with overlying punctured or compromised skin should have the affected skin carefully cleaned with an antimicrobial substance of appropriate concentration, a sterile dressing applied prior to splint application, and be treated with broad spectrum antibiotics prior to referral. Because endurance horses may have concurrent metabolic compromise, it is important to not focus exclusively on a musculoskeletal injury when metabolic compromise may have a significant negative effect on the overall outcome. In particular, it is critical that veterinarians refrain from administering large doses of NSAIDs that may cause significant renal compromise in a hypovolaemic horse. If depleted, circulating fluid volume should be restored with i.v. fluid therapy prior to or simultaneous with the administration of NSAIDs.

In summary, clinicians working with endurance horses should be aware of fractures, or stress related bone injury, as a cause of lameness in this discipline. Despite the most stringent veterinary monitoring of any equine sport, fractures may occur on race day. Prior to surgery, horses should be stabilised metabolically. The equivalent bone on the contralateral limb should always be radiographed. The client should be warned that the prognosis for the horse to return to racing is more guarded than the same injury in other disciplines.

Manufacturers' addresses

[1]Siemens Medical Solutions, Erlangen, Germany.
[2]HERMES Medical Solutions, Stockholm, Sweden.

[3]Hallmarq Veterinary Imaging Ltd, Guildford, UK.
[4]Dr Rachel Murray, Ibikus Imaging Solutions, Newmarket, UK.
[5]Kimzey Inc., Woodland, California, USA.

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Review

A veterinary review of endurance riding as an international competitive sport

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ABSTRACT

The popularity of competitive endurance riding is growing worldwide and this has led to considerable changes in the discipline (e.g., fitter and faster horses and different types of injuries), which create challenges to all involved in the sport, including veterinarians. During endurance competitions, horses are closely monitored by veterinarians throughout the ride, with the aim of removing from the competition animals whose welfare appears to be endangered. This close monitoring provides veterinarians with an insight into problems during competitions. However, there is a relatively small amount of clinically relevant, evidence-based data published on endurance horses, and this article reviews the evolution of the discipline, the published information on epidemiological data on endurance rides, the problems veterinarians face at competitions, and highlights those areas where research is warranted.

Introduction

Endurance riding is a relatively young sport but its popularity has been growing fast. Research into veterinary problems in endurance horses is also increasing, but there is still relatively little evidence-based information available on clinical issues, particularly orthopaedic injuries. The sport has changed greatly in the past 15–20 years and there is now a great difference amongst endurance rides in different parts of the world, particularly with respect to speed. In some parts of the world horses reach an average speed exceeding 25 km/h over a 120–160 km competition distance, often galloping at more than 30 km/h in the last phase of the competition. This forms a challenge for the veterinarians involved in the diagnosis and treatment of newly recognised injuries and warrants research to investigate how these injuries can be minimised. It also tests the regulatory bodies and organisers, who strive to protect the horses' welfare (e.g., by reducing the average speed), whilst also designing courses and rules that increase the technical challenge of a competition.

The endurance discipline

Long-distance riding has roots dating back for many centuries. Military horses often completed 100–150 km a day, but the oldest, organised long-distance endurance competitions are probably the Vienna–Berlin ride in 1892 and the better known Budapest to Vienna ride in 1908. In the latter the winner completed the 230 km distance in 16 h and 38 min (13.8 km/h). In France a ride from Paris to Deauville (200 km) was organised in 1903.

The first organised endurance ride resembling the sport of today was the 160 km ('100 miles in one day') Tevis Cup from Nevada to California, first run in 1955. On the original course (ridden between 1955 and 2011) the fastest winning speed was 15 km/h in 1981. Australia holds the second oldest tradition of modern endurance competition, having run the 160 km Tom Quilty Gold Cup since 1966. Spain and Portugal have held endurance rides since the 1950s. The European Long Distance Rides Conference (ELDRIC) was formed in 1979 and played an important role in integrating North American, Australian and South African rules and organised international competitions. Endurance became a Fédération Equestre Internationale (FEI) discipline in 1982, and since then international rides have been run under FEI regulations.

The FEI Rules for Endurance Events describe the sport as a test of 'the competitor's ability to safely manage the stamina and fitness of the horse over an endurance course in a competition against the track, the distance, the climate, the terrain and the clock'.[1] At FEI endurance events there are classes with specific criteria, such as distance (80–160 km) and whether only young riders (riders aged ⩽21 years) can participate. The distance is divided into phases of 20–40 km. In modern endurance, most rides are organised around a central area (Vet Gate) from where horses start and return to after each loop. However, there are still some competitions with a continuous track, where officials move along the track to check horses at certain points. After each phase, there is a compulsory halt for veterinary inspection, followed by a compulsory rest period

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[1] See: http://www.fei.org/disciplines/endurance/rules (Accessed 18 April 2012).

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(usually 30–50 min) where the horse has to qualify to start on the next loop.

The terrain of endurance competitions varies widely between countries and regions and may consist of rocky mountain trails, sandy deserts tracks or undulating forestry paths. Weather conditions also vary from cold and dry (e.g., South Africa in winter) to hot and humid (e.g., Malaysia).

Different rules may apply to national rides, depending on the country. In national rides, distances vary from 20–160 km and the spectrum of injuries may be different to those seen at international rides. Low-level national competitions can raise welfare issues that are less likely to be seen at higher level events, e.g., considerably overweight or unfit, unsuitable horses. A minimum weight (70 or 75 kg, depending on the level of the competition) applies at international competitions for senior riders. In some countries there is no weight requirement at national rides. Most horses are ridden in saddles specifically developed for long-distance riding. In theory these should be very comfortable for both horse and rider in order to cope with the long hours. In reality the results of ill-fitting saddles are commonly seen. Some riders need to carry extra weight (often in the form of lead weights attached to the saddle) to meet the minimum weight criteria. Other riders may be well over the minimum weight, which raises some concerns when considering the low weight (often 350–420 kg) and size (average 150 cm height at the withers) of endurance horses.

At international competitions Arabian and Arabian cross horses dominate. The appearance and size of Arabian horses vary somewhat depending on their origins. However, even the taller varieties (e.g., Shagya Arab) cannot be considered big horses; their height is approximately 155–160 cm, while some smaller Arabians are approximately 145–150 cm tall. At lower level rides (mostly with recreational riders) a great variety of breeds are seen, from ponies through cobs, Thoroughbreds, Sports Horse breeds to Shires.

Veterinarians at an endurance ride

At international competitions under FEI Rules the Veterinary Commission consists of a President, a Foreign Veterinary Delegate, members and treating veterinarians. The number of veterinarians required is determined by the number of entered horses and the level of the event (FEI Rules for Endurance Events[2]). The President and the Foreign Veterinary Delegate oversee the work of other members of the panel, advise if needed, provide second opinions and form the panel for voting (see later). Both must be experienced endurance veterinarians.

The objectivity of veterinary decisions has come under increasing pressure in recent years because of the high financial stakes, owners' prestige and cultural diversity of participants. In an ongoing attempt to minimise the subjectivity of veterinary opinion on the field of play, the FEI is pursuing all efforts to achieve the greatest possible consistency in clinical veterinary decision making. Anonymous voting by three veterinarians to adjudicate lameness assessments, and for the final examination on gait, has been used in the Middle East since the early 2000s and was introduced to the FEI Endurance Rules in 2009. The purpose of voting is to improve the consistency and objectivity and remove doubts about fairness of veterinary decisions. It also reduces the likelihood of abuse of a veterinarian by an eliminated rider.

There is a compulsory education and qualification system for FEI veterinarians.[3] Veterinarians must officiate at a prescribed number of rides within a specific time period. It is also mandatory to attend FEI courses at regular intervals, to ensure that FEI veterinarians are up to date with the regulations and that they are aware of any changes in the discipline. At most courses, case discussions are also involved, which facilitate consistency in veterinary decision making.

Veterinary control at endurance rides

Before the start, and after each phase, horses are examined by veterinarians. Horses are eliminated from the ride if veterinarians consider the metabolic status or orthopaedic condition are not adequate to enable them to continue the ride ('fit to continue'). They may also be eliminated for other reasons that compromise their welfare (e.g., sore back, sore in the mouth, wounds). Horses can be eliminated before or during the ride, and also at the final veterinary examination after completing the ride (this is unique to the endurance discipline).

The FEI Rules for Endurance Events define when a horse should be eliminated for lameness ('irregularity of gait'): 'At the first or the final inspection or any inspection during the course, a horse with an irregularity of gait, which must be consistently observable at trot, or an equivalent gait; and is observable through evaluation by trotting the horse on a loose lead in hand straight out and back, without prior flexion or deep palpation; which must be observed to cause pain, or threaten the immediate ability of the horse to safely perform athletically; will be removed from competition and will fail to have qualified for the next phase'. This definition serves as a principle, but the final decision depends on individual veterinarians' and the panel's experience and judgement.

Very low-grade hindlimb lameness may be obvious to an experienced orthopaedic clinician, but probably not to every member of the Veterinary Commission. Even if lameness is consistent, it may be very subtle, and can therefore in such a case be considered unlikely to compromise the horse's welfare; as a result, such horses may be allowed to continue. Some horses do not show consistently irregular gait, but take moderately lame steps as they slow down. In the author's (AN) experience the welfare of these horses is a potentially serious concern, because some stress-related bone injuries result in lameness of this pattern. This type of lameness can be grounds for elimination, even if the horse does not show a gait abnormality at every step.

Horses are eliminated for metabolic reasons if the examining veterinarian considers that the horse's metabolic status is compromised, based on general impression, heart rate, cardiac recovery index (Ridgway, 1994), colour and moisture of mucous membranes, capillary refill time, the time it takes for a pinched skin fold over the point of the shoulder to flatten (skin tent) and the presence and intensity of gut sounds, and that the horse's health would be at risk if it continued the ride. Elimination for metabolic reasons can also occur solely due to a heart rate higher than defined in the ride schedule (usually >64 beats per min). According to the FEI Rules, horses can only be retired from the competition if they pass the veterinary inspection, otherwise they are eliminated.

Epidemiological studies on causes of eliminations during endurance rides

The popularity of endurance riding has been growing, accompanied by increasing numbers of competitors at international level. The number of FEI endurance events has grown from 16 in 1994 to 276 in 2011.[4] If the number of events is considered, endurance riding is the fastest growing FEI discipline and the second most popular FEI discipline after show-jumping.

The high elimination rate from endurance rides has been regu-

[2] See: http://www.fei.org/disciplines/endurance/rules (Accessed 18 April 2012).
[3] See: http://www.fei.org/disciplines/endurance/officials (Accessed 31 May 2012).
[4] See: http://www.fei.org/media/publications/annual-report (Accessed 18 April 2012).

larly discussed in professional and public forums. The first study investigating elimination rates from endurance rides was by Burger and Dollinger (1998), who conducted a descriptive study using a database from the ELDRIC and also described results of some rides in the Middle East. They used data on 7,117 horse starts from 308 ELDRIC rides of 80–160 km, between 1990 and 1996. Inclusion criteria of rides were not defined. Lower distances had higher completion rates (62.6% for 80–110 km, 46.2% for 160 km). Of all eliminated horses, 62.7% were eliminated for lameness, 24% for metabolic reasons, 0.3% for other reasons; in 13% of eliminations the reason was not recorded.

The first study of FEI endurance rides was by Marlin et al. (2008), but the only publication resulting from the study was an abstract. The number of eliminations and horses treated at the ride was assessed in eight global regions from 2005 to 2007. Marlin et al. (2008) used the FEI database and selected two rides of 120 km and two rides of 160 km randomly from each region, assessing a total of 1651 horse starts. The number of horses that were eliminated for lameness increased in the study period, but the number of eliminations due to metabolic reasons remained unchanged. Risks factors for elimination were not assessed.

A larger study on eliminations from FEI endurance rides by Nagy et al. (2010) assessed 4326 horse starts in nine countries in 2008. Countries were selected based on their anecdotally high number of starters in endurance rides, or their tradition in endurance riding, and to represent all five continents. Rides in Australia, France, Italy, South Africa, Spain, United Arab Emirates (UAE), United Kingdom (UK), the United States of America (USA) and Uruguay were assessed. All the countries included ran ⩾5 FEI rides of ⩾100 km distance in the study year. In 2008 46% (1991/4326) of horses that started an FEI ride of ⩾100 km distance, completed the ride. Lameness was the most common cause of elimination in all countries, followed by elimination for metabolic reasons (69.2% and 23.5%, respectively, of all eliminations and 31.8% and 10.8%, respectively, of all started horses). These figures are similar to those of Burger and Dollinger (1998), despite the probable different level of rides included and the dates of the studies.

A recent study investigated risk factors for elimination from endurance competitions in the USA (Fielding et al., 2011). The number of international (FEI) rides was not specified, but it is assumed that the majority of data were collected from rides run under the rules of the American Endurance Ride Conference and not the FEI. Rides of all distances, including <80 km were included. Records of 3493 horses competing in 2007 were analysed. An overall elimination rate of 18.9% was recorded; 8.9% of all started horses were eliminated for lameness and 4.2% for metabolic reasons. This is much lower than previously published results (Burger and Dollinger, 1998; Marlin et al., 2008; Nagy et al., 2010). The difference may reflect varying elimination rates between rides of different distances and organised under different rules and different aims of the riders (e.g., to compete for fun, or to qualify for a subsequent competition rather than to get the best possible placing). It is likely that there are considerably more riders riding for pleasure and not for competition (i.e., at lower speed) at low-level national competitions than at international endurance rides.

Risk factors for eliminations have been investigated by Nagy et al. (2010) and Fielding et al. (2011). In the international study (Nagy et al., 2010) the country where the ride was held and the number of entries were associated with risk of elimination for lameness and metabolic reasons. Faster winning speeds were not associated with increased risk of elimination, but it is possible that the combination of course and environmental factors (e.g., terrain and weather) and faster speeds may be associated with an increased risk of elimination. Such data are not yet available, but there is an ongoing study assessing detailed risk factors for elimination, including terrain and weather conditions (A. Nagy et al., unpublished data).

In the study by Fielding et al. (2011) certain breeds were associated with increased risk of elimination for lameness and metabolic reasons. These results are unlikely to be applicable globally because many of the breeds were native North American horses (e.g., Quarter Horse, Tennessee Walking Horse and Rocky Mountain Horse) that are probably not used for endurance riding elsewhere. The length of the ride was also associated with both lameness and metabolic eliminations, which was not seen in the study by Nagy et al. (2010). Deteriorating parameters that indicated the metabolic status of the horse (attitude, heart rate, capillary refill time, gut sounds) were associated with increased risk of elimination for lameness, which is not surprising. Pain over the back or withers was associated with increased risk of elimination for lameness. Hindlimb lameness can result in secondary muscle pain, which may explain this finding, but lame limb identification data were unavailable.

The increasing speed of endurance competitions has been a constant source of concern. Since the 1990s in some countries horses competed faster and faster year by year. World records were continuously broken. Currently, the world record for 120 km is 29.5 km/h (2010, UAE) and for 160 km 27.8 km/h (2010, UAE). These are average speeds and horses may gallop at over 35 km/h in the last loop, which is often 15–20 km long. It appears that in 2011 no world records were broken. Although undoubtedly training methods have evolved, resulting in fitter horses able to compete faster, these high speeds raise a concern for the welfare of horses. Anecdotal information suggests that the types of injuries have changed and increased in severity. This information is supported to some extent by Misheff et al. (2010) who documented fractures previously only seen in racehorses, some of which were catastrophic. However, more detailed evidence-based data is required to draw conclusions. It is interesting to note that European and World Championships between 2009 and 2011 have been won with speeds of 19.6 km/h, 21.1 km/h and 18.5 km/h, respectively. This suggests that slower average speeds can potentially be achieved by creating more technically difficult courses.

Veterinary problems in endurance horses

Orthopaedic problems

Limited information exists about the type of orthopaedic injuries in endurance horses. In a study of 12 Arab horses undergoing progressive endurance training over 90 days after a 4 month layoff, working at speeds up to 15 km/h, the response to palpation of the forelimb suspensory ligaments and superficial digital flexor tendons and various muscle groups was assessed every 10 days (Gomide et al., 2006). The sensitivity of the suspensory ligaments increased most. Chapters in lameness textbooks describe commonly seen causes of lameness, but these are based on personal experience and not on evidence-based data (Misheff, 2010; Holbrook, 2011). Alternatively they describe diagnoses achieved at a brief examination at the Vet Gate, without diagnostic analgesia, or other diagnostic techniques (Holbrook, 2011). Misheff (2010) documented that proximal metacarpal pain is the most common cause of lameness, followed by foot pain and fetlock region pain, based on personal observations and communications made in a country where horses compete at speeds exceeding an average of 20 km/h on variable sand surfaces. This therefore may not apply to other geographical regions. However, similar injuries are also seen in Europe in horses competing at lower speeds.

Records of the American Endurance Riding Conference showed that during the 2007–2008 season the most common cause of lameness resulting in elimination was hindlimb muscle pain, followed by forelimb suspensory ligament and foot pain (Holbrook, 2011). These diagnoses were based on a brief examination at the Vet Gate and therefore should be interpreted with care. Scientific evidence is needed to establish the incidence of different injuries in different parts of the world.

A recent publication described racehorse-type fractures in endurance horses and speculated that they may be related to increasing speed (Misheff et al., 2010). A fractures rate of 2–3 per 100 horse-starts has been anecdotally reported at endurance events with winning speeds >25 km/h, but unfortunately this has not been reported in an official manner, or published in a scientific journal.

Lameness in endurance horses is often transient; riders and veterinarians are often faced with the situation that a horse eliminated for lameness does not show overt lameness when examined by the treating veterinarian some time later. It is speculated that apart from some obvious causes (e.g., a stone in the foot, subsequently removed), some horses may have transient muscle spasm/pain that resolves quickly. This hypothesis could be investigated by a detailed veterinary examination at the time of elimination, but it is not possible in the limited time veterinarians have at the Vet Gate.

The challenges of lameness investigation in endurance horses is beyond the scope of this paper, but it has to be noted that, similar to racehorses, stress-related bone injuries often result in rapidly improving lameness. Therefore veterinarians should promote prompt veterinary examination following elimination for lameness, particularly in high-level endurance horses.

Back pain is commonly seen at endurance events and ranges from mild to severe and can be grounds for elimination. It is often assumed that muscle pain caused by an ill-fitting saddle or a heavy/unbalanced rider is the primary cause of back pain. Although this is possible, underlying osseous abnormalities are frequently diagnosed in sports horses (Denoix and Dyson, 2010) and should be borne in mind when examining endurance horses. Hindlimb lameness can result in alteration of the gait and secondary muscle pain in the thoracolumbar region. If lameness is subtle or bilateral, it may be difficult to notice, especially at an endurance event.

Detailed description of orthopaedic injuries in endurance horses, their occurrence related to the stage of the ride and speed would provide very valuable information. The authors made every possible effort to conduct such a study of orthopaedic injuries, but failed because competitors were reluctant to provide information, despite reassurances about confidentiality.

Training regimes vary greatly between trainers and countries. The surfaces and terrain on which horses are trained depend on their geographical location. It is not uncommon prior to championships that horses are transported to be trained on terrain similar to that of the championship. The training programme depends on the local circumstances (terrain and facilities), the level and fitness of the horse, previous experience and trainers' preferences. Anecdotal information suggests that there is huge variation in training regimes for horses preparing for elite competitions, but to the authors' knowledge this information has not been published. It is assumed that different injuries are prevalent on various terrains and would also vary according to different training regimes, but to the best of our knowledge no scientific data exist on training-related injuries.

Some potentially transferable information can be gained from the human literature when endurance riding is compared to marathon and ultramarathon (longer than the marathon distance) running. Krabak et al. (2011) reported that 85% of 1173 ultramarathon runners required medical care during or after the race. Musculoskeletal problems accounted for 18% of all injuries and medical illnesses for 7.5%. Older runners and males were less likely to incur an injury than younger and female competitors. A study evaluating risk factors for lower extremity injuries among male marathon runners established that participating in more than six races in the previous 12 months and a history of running injuries were associated with increased risk of injury (Van Middelkoop et al., 2008). Anecdotal information and personal experience suggest that a frequent racing schedule can result in an increased risk of elimination from equine endurance rides, but no evidence-based data support this hypothesis. The FEI established compulsory rest periods between rides, i.e. a mandatory period of time after each competition before the horse can participate again in an FEI ride. The length of time depends on the distance completed, but it is based on consensus of opinions and not on evidence-based data.

Relationships between training or racing surface and performance or injuries have been investigated in racehorses (Cheney et al., 1973; Verheyen et al., 2006; Cheetham et al., 2010) and dressage horses (Murray et al., 2010). A study assessing risk factors for pelvic and tibial stress fractures in racehorses identified a particular sand-based all-weather surface to be related to increased risk of fracture (Verheyen et al., 2006). Racing performance was shown to be associated with track surfaces (Cheetham et al., 2010). Arenas that become deeper in wet conditions and sand-based arenas were associated with increased risk of lameness in dressage horses (Murray et al., 2010). Most authors warn that results relating lameness to competition or training surfaces should be interpreted with caution, because many factors (e.g., exact composition and maintenance) cannot, or were not assessed in the studies. To the authors' knowledge studies evaluating the effect of different surfaces have not been performed in endurance horses. Surprisingly, no information on the effect of different terrain (e.g., flat vs. hilly) on performance or injuries in marathon or fell runners was found in a literature search.

Metabolic problems

Metabolic problems in endurance horses are considered to be secondary to dehydration, electrolyte and acid–base abnormalities, heat accumulation and substrate depletion (Foreman, 1998). Horses that are taken past their level of fitness and are pushed to continue at that state can become physiologically exhausted (Whiting, 2009). Some horses are not fit enough for the demand of the competitions, but fit horses can also be pushed beyond their limits by inexperienced riders. Undertraining and over conditioning can both contribute to depletion of energy stores. Horses performing in excessive heat and humidity can develop clinical signs of exhaustion sooner than in more temperate climatic conditions (Whiting, 2009).

Factors contributing to the onset of exhaustion can include heat production incurred during exercise, water and electrolyte losses, lactic acid production, metabolic alkalosis, fluid and electrolyte shifting, mild lameness and previously undetected underlying problems (Whiting, 2009). There is a great range of clinical signs of exhaustion, depending on the severity and speed of onset of exhaustion and the physiological reserve of the horse. Initially horses may only show mild alteration in attitude and alertness and may develop changes in gait due to muscle soreness. More severely affected horses become depressed and symptoms may extend to marked neurological signs (e.g., ataxia, head pressing or seizures) or horses may exhibit severe muscle soreness, stiffness or cramps, which may progress to fulminant rhabdomyolysis and eventually recumbency (Whiting, 2009).

A study using data from 16 French national and international endurance rides in 2003 described metabolic problems occurring at endurance rides (Langlois and Robert, 2008). Of all started horses, 12.5% required treatment for metabolic problems. The most common symptoms (in >30% of treated horses) were fatigue, dehydration and colic. Other, less commonly observed symptoms (in 10–30% of treated horses) included difficulty in urinating, dark urine, lameness, cramping, stiffness, anorexia, depression and sweating. Certain factors appeared to be associated with elimination for metabolic problems, namely, if a mare was on heat, and older (>9 years) and taller horses. More horses needed treatment for metabolic problems at temperatures >22 °C than at cooler temperatures.

In the 2007–2008 racing season in the UAE, 435 (15%) of the 2832 starters (including national and FEI rides) received veterinary treatment at the venue (Alexander and Haines, 2012). Interestingly, this number is not greatly higher than the 12% recorded in France, despite the much hotter weather conditions in the UAE. Of the 435 treated horses, 47 had colic (11% of treated horses, 1.7% of starters), two of which required surgery (Alexander and Haines, 2012).

A study from the USA on 30 endurance horses (eliminated for metabolic reasons and requiring emergency treatment) identified clinical reasons for metabolic disorders including colic, oesophageal obstruction, poor cardiovascular recovery, myopathy and synchronous diaphragmatic flutter (Fielding et al., 2009). A recent study documented colic in 36 endurance horses examined at referral centres within 48 h of an endurance ride. (Fielding and Dechant, 2011). A diagnosis of no specific known cause or ileus was made in 56% of horses. Enteritis related to Salmonella or another cause was recognised in 16% of horses. The authors concluded that endurance horses with colic typically responded well to medical treatment, but hospitalisation was prolonged for some animals. It is not clear from the study whether all horses had been eliminated from the ride prior to admission, or when the first colic signs were noted.

Colic occurring within 48 h of an endurance ride may be unrelated to the competition. Alexander and Haines (2012) described colic requiring surgical treatment in racing endurance horses sent directly from the venue to a referral hospital in the UAE. Between 2004 and 2011, 15 horses underwent colic surgery due to uncontrollable pain. In 13 horses (87%) a diagnosis of small intestinal volvulus was made; in two horses the small intestine was thickened, but not entrapped.

Synchronous diaphragmatic flutter (SDF) (diaphragmatic contractions at the same time as the heart beat) used to be a ground for elimination at FEI rides, but is no longer so. SDF is thought to occur due to electrolyte imbalances resulting in hyperexcitability of the phrenic nerve as it crosses the pericardium (Hinton et al., 1976). It has been seen in conjunction with clinical hypocalcaemia, hypokalaemia and metabolic alkalosis (Whiting, 2009), but in clinical situations not every horse with SDF has measurable electrolyte disturbances. In hot countries, SDF is sometimes seen in horses at the beginning of a ride and may be present throughout, despite the horse appearing fit and completing the ride with all other parameters acceptable.

It is reasonable to assume that horses in hot and humid condition have reduced performance and are more likely to develop metabolic disorders. However, relatively little information exists on the effect of weather on horses' performances. In an experimental study, unacclimatised horses tolerated cool and dry and hot and dry conditions, but had reduced performance in hot and humid conditions (Marlin et al., 1996). These results may apply to championship endurance rides, to which horses travel from different locations, but at the majority of endurance rides it is assumed that most horses are acclimatised to the conditions in which they compete.

Weather has been shown to have an impact on marathon-running performance (Ely et al., 2007; Vihma, 2010), with high temperature being the most important factor for reducing running speed. The effect of weather conditions on horses has been assessed in experimental and clinical studies (Marlin et al., 1999, 2001). In an experimental study, horses showed physiological adaptation to hot and humid conditions consistent with a humid heat acclimation response (Marlin et al., 1999). A study assessing recovery from transport and acclimatisation to hot and humid conditions concluded that horses exposed to hot and humid conditions after transport are able to accommodate these stresses without prior acclimatisation (Marlin et al., 2001). Hinchcliff et al. (2010) established that with an ambient temperature <20 °C there was an increased risk of exercise-induced pulmonary haemorrhage, compared with warmer temperatures. To the authors' knowledge association between environmental conditions and horses' performances in endurance events has not been assessed, but is a part of an on-going study (A. Nagy et al., unpublished data).

Link between orthopaedic and metabolic problems

Many endurance veterinarians agree that orthopaedic and metabolic problems are not distinct, but to date no studies have been carried out to support this hypothesis. However, it is reasonable to assume that a horse with subtle underlying gait abnormality (i.e., low grade pain) may fatigue earlier, resulting in metabolic disorders before an overt gait abnormality becomes apparent in a straight-line trot-up. It is also possible that a metabolically compromised horse is more prone to orthopaedic injuries due to muscle fatigue, leading to decreased support of joints, tendons and ligaments.

It has been proposed that mild or even subclinical lameness may contribute to the onset of exhaustion (Foreman, 1998). Lameness may alter the horse's gait resulting in excessive use of some normally used muscle groups, or in the use of muscle groups different to those used normally. This can lead to focal or more diffuse exertional myopathy (Foreman, 1998). Exertional myopathy tends to occur early in the ride or towards the finish. Myopathy can result in elimination for either lameness or metabolic reasons, often depending on the stage of the disease. Some horses coming back from a loop show hindlimb lameness and potentially stiff or sore muscles in the hindquarters, but their metabolic parameters have not deteriorated enough to provide a reason for elimination. In some of these horses muscle soreness is only noted after rest. Other horses show signs of severe metabolic compromise by the time they are presented to the veterinary panel, and are sometimes unable to trot or even walk.

Lameness also results in increased endogenous catecholamine and cortisol levels, leading to peripheral vasoconstriction and subsequently to poor blood flow to the periphery (Foreman, 1998). This may result in exacerbation of laminitic effects that can accompany exhaustion and hypovolaemic shock. In some metabolically compromised endurance horses laminitis develops within hours of elimination, but in other horses signs only appear the following day, or even some days later.

Poor and reduced performance

The potential causes of poor performance have been widely investigated in racehorses (Allen et al., 2006; Jose-Cunilleras et al., 2006), but there is little information available for endurance horses. Fraipont et al. (2011) identified respiratory problems to be the main reason for poor performance in a group of 29 endurance horses competing in rides of 20–160 km, followed by musculoskeletal and cardiac problems. However when interpreting the results of this study it must be borne in mind that an average riding horse can complete 20 km, whilst only few elite endurance horses are capable of completing 160 km.

Other than elimination from an endurance ride for metabolic reasons, there was no objective definition of poor or intermediate performance (vague terms such as 'slow recovery', 'problems in training' and 'completed race at low speed' were used). Despite the high reported prevalence of gastric ulcers in high-level endurance horses during the racing season (Tamzali et al., 2011) the poor performance examination by Fraipont et al. (2011) did not include gastroscopy.

Conclusions

The constant changes in the endurance discipline have prompted veterinarians and regulatory bodies to adapt, to increase knowledge and to take measures when necessary to protect the horses' welfare. The high elimination rates should be interpreted in the light of the fact that endurance is the only discipline where there are compulsory veterinary examinations before, throughout and after the competition, and horses can be eliminated at any of these veterinary inspections. Moreover, the aim of elimination is to protect the horse and to avoid serious injuries. Clinical research is warranted in many areas related to the sport and the popularity and fast evolution of the discipline further increase the urgent need for evidence-based data. In particular, little information exists on orthopaedic injuries. Knowledge about the prevalence of specific injuries would enable us to improve our diagnostic skills and better manage the horses that are involved. Confidentiality issues have been obstacles to such studies, but hopefully in the future participating parties will recognise that the provision of anonymous data will lead to information that is useful for everyone involved, and can potentially improve the welfare of endurance horses.

Conflicts of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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