Pferdeheilkunde 28 (2012) 6 (November/Dezember) 657-664

Relationship between the incidence of fractures of the first phalanx in horses and ambient air temperature

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Summary

In 2005 and 2006, there appeared to be an increase in the number of horses referred to the Equine Clinic of the Zurich University Veterinary Hospital because of fracture of the first phalangeal bone (P1). It was speculated that the cold snap that occurred during the winter of 2005/2006 was a possible reason for this increase. The main goal of this study was to examine the relationship between the incidence of P1 fractures and air temperature. From 2000 to 2010, 100 horses with a P1 fracture and 88 horses with a splint bone fracture were referred to our clinic. For each case, the temperature measured at the nearest weather station on the day of the fracture as well as the mean temperature of the yearly quarter during which the fracture occurred were recorded. There were significantly more P1 fractures in yearly quarters with low temperatures compared with quarters with higher temperatures. This suggests that the ground reaction forces acting on the equine limbs are greater when temperatures are lower, possibly because of an increased incidence of stress related microfractures suffered by horses exercising on frozen ground. By contrast, splint bone fractures were more common during warm weather.

Keywords: Fracture aetiology / first phalanx fracture / splint bone fracture / relationship between temperature and first phalanx fracture incidence / ground reaction forces / orthopedics / horse

Zusammenhang zwischen dem Auftreten von Fesselbeinfrakturen und der Umgebungstemperatur

In den Jahren 2005 und 2006 wurden gehäuft Pferde mit Fesselbeinfrakturen an die Pferdklinik des Tierspitals der Universität Zürich überwiesen. Eine mögliche Ursache für diese Häufung von Fesselbeinfrakturen könnte die besonders tiefe Durchschnittstemperatur im betreffenden Winter sein. Hauptziel dieser Studie war, den Zusammenhang zwischen dem Vorkommen von Fesselbeinfrakturen und der Außentemperatur zu untersuchen. Zum Vergleich wurde ebenfalls das Auftreten von Griffelbeinfrakturen in Bezug auf die Außentemperatur untersucht. Von 2000 bis 2010 wurden 100 Pferde mit einer Fesselbeinfraktur und 88 Pferde mit einer Griffelbeinfraktur am Tierspital Zürich vorgestellt. Für jeden dieser Fälle wurde die Außentemperatur am Tag des Ereignisses bestimmt und ein Quartalsdurchschnitt berechnet. Es zeigte sich, dass in Quartalen mit tiefer Durchschnittstemperatur signifikant mehr Fesselbeinfrakturen entstanden als in Quartalen mit höheren Durchschnittstemperaturen. Dies lässt vermuten, dass die auf den Fuß des Pferdes einwirkenden Kräfte größer sind bei niedrigeren Temperaturen, und dass es durch Bewegung auf gefrorenem Untergrund zu einer Anhäufung von stressbedingten Mikrofrakturen kommen kann. Im Gegensatz zu Fesselbeinfrakturen treten Griffelbeinfrakturen, die häufig durch Schlagverletzungen entstehen, vermehrt während Warmwetterperioden auf, was vermutlich in Zusammenhang mit dem häufigeren Weidegang der Pferde bei warmen Temperaturen steht. Die Heilung von Mikrofrakturen, die vor allem bei der Arbeit auf hartem Untergrund auftreten, kann Monate dauern. Pferde sollten deshalb bei sehr tiefen Außentemperaturen keiner ermüdenden Arbeit unterzogen werden, zumindest nicht bei hohen Geschwindigkeiten. Um festzustellen, ob das Risiko für eine Fesselbeinfraktur durch limitiertes Bewegen der Pferde auf gefrorenem und unebenem Boden vermindert werden kann, braucht es weitere Studien.

Schlüsselwörter: Frakturentstehung / Fesselbeinfraktur / Griffelbeinfraktur / Temperaturabhängigkeit von Fesselbeinfrakturen / Bodenreaktionskraft / Orthopädie / Pferd

Introduction

Bone fractures can be divided into three categories: traumatic fractures caused by a transient overload, pathological fractures and fatigue fractures caused by repeated stress to the bone (*Riggs* 2002). Spontaneous fractures, which are common in racehorses during intensive training, are believed to be fatigue fractures (*Nunamaker* et al. 1990, *Verheyen* and *Wood* 2004).

Fractures of the first phalangeal bone (P1) in horses can be broadly divided into two groups: proximal intraarticular osseochondral and diaphyseal (*Auer* and *Stick* 2005). Intraarticular fractures involving the dorsoproximal edge of P1 (chip fractures) result from hyperextension of the metacarpophalangeal joint and are common in racehorses. Of 659 dorsoproximal P1 chip fractures in 461 Thoroughbred racehorses, 583 (88 %) occurred in the forelimbs (*Colón* et al. 2000). Torsional fractures of P1 involving the cortex result from the combined effects of compression and asynchronous rotation from lateral to medial of the cannon bone and P1. This may occur during the early weight-bearing phase when the foot contacts the ground and the articulation between cannon bone and P1 is unstable, or it may occur when the fetlock is bent prematurely and P1 rotates medially, causing joint instability (*Rooney* 1969). The latter may also lead to stumbling (*Stashak* et al. 1989).

Pathological fractures are less common but nevertheless worth mentioning. Intraosseous perfusion with gentamicin into P1 caused osteomyelitis and progressive osteonecrosis and ultimately a pathological fracture (*Parker* et al. 2010). Another report described a mare with disseminated Cryptococcus gatti infection, in which osteomyelitis and osteolysis in a hind limb resulted in a pathological fracture of P1 (*Lenard* et al. 2007).

Bone responds to a load by deformation. Within certain limits, the deformation is elastic and the bone returns to its original shape once the load has been terminated. If the load exceeds the capacity of the bone, it can lead to fracture in the absence of any preexisting damage (*Riggs* 2002). Fractures that are caused by overload are preceded by microfractures, which function to compensate the forces acting on the bone before a fracture occurs (*Martin* et al. 1996). The occurrence and the type of microfractures depend on the nature of the force; experimental studies using the equine radius have shown that tractional forces cause shorter microfractures (shorter than 100 mm) than compression forces (up to several 100 mm) (*Reilly* and *Currey* 1999). Furthermore, forces that typically act upon the bones of the extremities in the horse have a variety of microfracture patterns (*Martin* et al. 1996).

Under normal conditions, microfractures heal via bone remodelling involving break-down of bone by osteoclasts and formation of bone by osteoblasts, and these processes affect the development of fractures (*Stover* 2003). Bone remodelling has also been used as an indicator of microfractures in MRI studies (*Ramzan* and *Powell* 2010). The duration of the osteoclast activity is days to weeks, whereas the duration of the osteoblast activity is several months. During this time the bone structure is weakened and susceptible to fracture if high loads continue (*Stover* 2003, *White* and *Moore* 1998). Bone remodelling has a greater effect on the occurrence of fractures than does the mere presence of stress-related microfractures (*Martin* et al. 1996).

The relationship between the cannon bone parameters in the horse and the development of microfractures was examined in an in-vitro study (*Davies* 2001). The hypothesis was that mature racehorses have stronger cannon bones than young untrained horses because of the cumulative cycles of stress and bone remodelling in the former, and that a standard load causes fewer microfractures in the cannon bone of an older racehorse compared with an untrained horse. However, the hypothesis was rejected because bone size, the relationship between dorsal and palmar cortical thickness and the relationship between cortical thickness and medullary diameter were not significantly related to the development of microfractures.

Fractures of P1 in horses are more common in the forelimbs than in the hind limbs. A possible reason for this is that the first phalangeal bone of the forelimb undergoes greater vertical loads than the same bone in the hind limb (*Gustås* et al. 2004). Similarly, in tölting Icelandic horses, the forelimbs undergo greater maximum ground reaction forces than the hindlimbs at various speeds and are therefore exposed to greater stress levels (*Biknevicius* et al. 2004).

Effect of ground surface on the occurrence of limb fractures

It appears logical to assume that a soft ground surface reduces the ground reaction forces that act on the bones of the extremities, and vice versa. *Chateau* and co-workers (2010) examined the forces acting on the hooves in harness trotter horses running on different surfaces on a sand beach and on asphalt. Different degrees of sand firmness were selected by varying the distance from the water. On soft ground, there was a decrease in the vertical ground reaction force during impact; the force was about 95% lower on soft sand than on asphalt (Table 1). There was also a decrease in stride length and an increase in stride frequency. A softer landing of the foot on soft ground was evidenced by a decrease in vertical deceleration, which translates into a lower strain on the extremities and lower susceptibility for stress and microfractures. In a similar study, *Setterbo* and co-workers (2009) investigated hoof acceleration and ground reaction forces of racehorses on dirt, synthetic and turf track surfaces and found significant differences among the different surfaces. The forces were measured using a dynamometric horseshoe during a trot and canter at a racetrack. The synthetic surface was superior and generally associated with the lowest peak ground reaction forces and lowest vibrations. The authors proposed that an optimal ground surface had a positive effect on the prevention of the fracture risk, in view of the multifactorial aetiology of fractures in racehorses and the occurrence of stress fractures.

Effect of temperature on the occurrence of limb fractures

The winter of 2005/2006 was the coldest winter in 21 years and the temperatures from December to February were considerably below the seasonal average in Switzerland. The last time the winter months (December to February) were colder was in 1984/1985 (*Balmer* 2006).

From 2000 to 2010, 100 horses were referred to our clinic because of a P1 fracture. Interestingly, the cases were not evenly distributed during this time period; a disproportional increase was noted in the years 2005 and 2006. The goals of this study were to investigate whether the winter of 2005/2006 was statistically the coldest winter from 2000 to 2010, and whether P1 fractures that occurred during this period were more common in yearly quarters with low temperatures. For comparison, the occurrence of splint bone fractures was also investigated in relation to temperature.

Materials and Methods

The database of the medical records of horses admitted to our clinic from 2000 to 2010 because of a fracture of P1 or a splint bone were analysed with respect to time of year of the fracture, place of residence of the owner (assuming that

Table 1 Comparison of the vertical acceleration and ground reaction forces on the fore limbs of four trotters running on hard and soft surfaces. Means ± standard deviations are shown. Note that the ground reaction force on asphalt is higher than on sand (*Chateau* et al. 2010). / *Vergleich der einwirkenden Kraft auf den Fuß des Pferdes in Abhängigkeit des Untergrundes. Durchschnittswerte (Standardabweichung) von 4 Trabern, die in 3 Durchgängen am Strand und auf Asphalt getrabt wurden. Auf Asphalt ist die wirkende Kraft größer als auf trockenem Sand, was sehr schön den Einfluss des Untergrundes aufzeigt (*Chateau *et al. 2010).*

Surface	Speed [m/s]	Vertical acceleration [m/s^2]	Ground reaction force [N]
Deep dry sand	4.64 (0.47)	-338 (274)	1040 (385)
Asphalt	4.25 (0.30)	-7353 (5234)	2971 (870)

owner and horse were located in close proximity) and type of fracture (P1 versus splint bone fracture). There were 100 horses with a P1 fracture (Table 4) and 88 horses with a splint bone fracture (Table 5).

Ambient air temperatures were obtained electronically from MeteoSchweiz, Zurich and entered into the databases. A total of 320,367 temperature measurements, recorded daily 50 cm above ground level at 17:40 at 102 weather stations throughout Switzerland, were available. The mean monthly temperatures for the years 2000 to 2010 were also available (Table 2).

The geographic coordinates (latitudes and longitudes) of all weather stations were obtained from MeteoSchweiz and also entered into the database. The same was done for communities in Switzerland to facilitate the allocation of the location of the horse to the nearest weather station. If a temperature recording from a certain weather station was missing, the recording from the nearest station was used.
To determine whether 2005/2006 was the coldest winter of the 2000/2010 period, the mean temperature for the period from October 2005 to March 2006 was compared with the respective temperatures of the other years using a one-sample t-test. A one-sided P value <0.05 was considered significant. Each fracture event was assigned a temperature using the residential community of the owner of the horse and the date the horse was presented to the clinic. The fracture dates were grouped into yearly quarters, and a mean temperature by using the evaluated temperatures was calculated for each quarter. The software program IBM SPSS (version 19) was used to calculate the Pearson correlation coefficients. A one-sided P value <0.05 was considered significant.

Results

The mean temperature from October 2005 to March 2006 was significantly lower than the mean temperatures during the same periods in other years (Table 3) ($P<0.002$).

There was a positive correlation ($r=0.17$; $P=0.135$) between the mean quarterly temperature recorded at the time of the fractures and the number of fractures per yearly quarter.

Table 2 Mean monthly temperatures for the years 2000-2010 measured at the weather station Church Fluntern, Zurich (MeteoSwiss, Zurich). *Durchschnittstemperaturen pro Monat der Jahre 2000-2010. Temperaturmessungen der Messstation "Kirche Fluntern, Zürich" von MeteoSchweiz, Zürich.*

Month	2000 [°C]	2001 [°C]	2002 [°C]	2003 [°C]	2004 [°C]	2005 [°C]	2006 [°C]	2007 [°C]	2008 [°C]	2009 [°C]	2010 [°C]
Jan	0.10	1.70	0.80	0.20	0.90	0.50	-2.20	4.50	3.10	-1.90	-1.90
Feb	4.20	3.60	5.70	-1.80	2.10	-1.10	0.00	4.80	3.90	0.40	0.90
Mar	6.20	6.90	7.20	7.60	4.40	5.60	3.10	5.70	4.70	4.20	4.60
Apr	10.40	7.00	9.10	9.40	9.60	9.30	8.80	13.90	7.90	12.00	10.10
May	15.20	15.50	13.00	14.80	11.90	13.70	13.30	14.60	15.40	15.40	11.50
June	18.00	15.20	19.30	22.50	16.40	18.30	17.70	17.20	17.30	16.50	16.90
July	15.90	18.70	18.20	19.80	17.80	18.30	22.50	17.60	18.40	18.60	20.00
Aug	19.00	19.20	17.70	22.70	18.70	16.30	14.70	17.00	17.70	19.90	17.20
Sept	15.10	11.70	13.00	14.50	15.20	15.60	16.90	13.00	12.30	15.40	13.20
Oct	10.40	13.30	10.10	6.40	11.40	11.00	12.70	9.30	10.00	9.60	8.70
Nov	6.00	2.90	6.70	5.40	4.30	3.90	7.00	2.90	4.30	7.20	5.90
Dec	3.90	-0.10	3.90	1.20	0.70	-0.40	2.50	0.60	0.50	1.10	1.80

Table 3 Mean temperatures of the two quarters of the winters (October to March) from 2000 to 2010, mean local quarterly temperatures at the time of the fractures and number of fractures recorded during the winter. / *Durchschnittstemperaturen des letzten Quartals des Vorjahres und des ersten Quartals des Folgejahres. Der Testwert „Oktober 2005 – März 2006" zeigt, dass dieser Winter kälter als die Winter der Vergleichsjahre war (p=0.002).*

Time period	Mean quarterly temperature [°C]	Mean quarterly temperature at the time of the fracture [°C]	Number of fractures
October 2000 - March 2001	5.42	0.23	4.00
October 2001 - March 2002	4.97	10.30	2.00
October 2002 - March 2003	4.45	2.37	6.00
October 2003 - March 2004	3.40	-2.80	1.00
October 2004 - March 2005	3.57	1.70	4.00
October 2005 - March 2006	2.57	2.42	12.00
October 2006 - March 2007	6.20	4.65	2.00
October 2007 - March 2008	4.08	3.12	6.00
October 2008 - March 2009	2.92	2.68	5.00
October 2009 - March 2010	3.58	0.22	5.00

Table 4 Date, postal code of owner, identification of weather station and temperature at the time of the P1 fracture. / *Fesselbeinfrakturen, sortiert nach Datum der Patienteneinweisung mit der dazugehörigen Tagestemperatur*

Date	Postal code of owner	Weather station	Temperature [°C]
30.04.2000	4585	GRE	2.4
05.05.2000	8312	KLO	13.9
31.07.2000	1817	MLS	12
17.11.2000	6027	LUZ	1.1
27.11.2000	8846	WAE	5.6
16.01.2001	8307	SMA	-1.8
17.01.2001	8405	TAE	-4
13.06.2001	6315	CHZ	2.4
17.10.2001	8224	SHA	12.5
03.12.2001	8700	SMA	8.1
15.05.2002	8314	TAE	19.4
17.06.2002	8914	CHZ	2.4
29.06.2002	4654	GOE	2.4
14.07.2002	9475	VAD	18.5
10.10.2002	6343	DIS	12.9
31.10.2002	9444	ARH	2.4
20.01.2003	9402	STG	2.4
01.02.2003	8574	GUT	-7.8
24.02.2003	8599	GUT	-1.5
18.03.2003	9315	STG	5.8
08.04.2003	9607	EBK	2.4
26.04.2003	8104	LAE	8.3
05.06.2003	6043	LUZ	24.4
31.07.2003	9230	BIZ	2.4
25.08.2003	8808	WAE	25
09.12.2003	8865	GLA	-2.8
12.04.2004	8630	HOE	3.3
16.05.2004	8706	WAE	16.2
18.08.2004	8497	HOE	22.4
20.09.2004	6037	CHZ	17.2
22.09.2004	8228	SHA	12.8
25.09.2004	8166	LAE	6.8
05.01.2005	5621	REH	5.5
11.03.2005	1817	MLS	-4.3
12.03.2005	8107	LAE	-2.6
22.03.2005	9244	HOE	8.2
10.05.2005	9011	STG	6.2
12.05.2005	1619	MLS	5.5
08.06.2005	8554	HAI	2.4
20.08.2005	8702	SMA	14.1
04.10.2005	8835	WAE	11.1
08.10.2005	9533	HOE	11.4
04.11.2005	9463	STG	11.9
02.01.2006	9240	BIZ	2.4
06.01.2006	8127	SMA	-4.3
18.01.2006	8192	KLO	2.8
27.01.2006	8105	REH	-2.8
27.01.2006	8702	SMA	-3.6
28.01.2006	8162	LAE	-1
30.01.2006	8045	SMA	-0.8
31.01.2006	4310	MOE	2.4
04.03.2006	8133	WAE	-0.5
02.06.2006	7304	VAD	9.6
03.06.2006	9467	SAE	-3.4
24.07.2006	8488	TAE	29.8
03.08.2006	8733	EBK	2.4
10.12.2006	6983	LUG	6.9
26.03.2007	9246	BIZ	2.4
09.04.2007	8913	CHZ	16.8
23.04.2007	8806	WAE	21.5
03.05.2007	5634	CHZ	16.1
12.05.2007	3114	BER	19.7
14.05.2007	8477	SHA	12.2
23.05.2007	1434	MAH	22.9
25.07.2007	8477	SHA	21.7
07.10.2007	9502	BIZ	2.4
21.10.2007	8172	KLO	4.1
31.10.2007	8472	TAE	3.2
07.11.2007	8370	TAE	5.9
23.11.2007	8910	CHZ	7.9
25.12.2007	8239	SHA	-4.8
03.05.2008	7012	CHU	18.5
04.06.2008	5712	BUS	14.2
08.06.2008	5525	LAE	13.5
12.07.2008	8953	LAE	12.8
16.07.2008	4052	BAS	24.5
11.08.2008	8425	KLO	18.4
08.10.2008	5443	LAE	13.1
25.11.2008	8216	SHA	-0.4
26.11.2008	8627	WAE	-1.8
19.12.2008	7214	CHU	1
05.02.2009	4713	WYN	1.5
08.04.2009	8135	CHZ	15.8
30.05.2009	8305	SMA	17.8
15.06.2009	3360	WYN	20.2
17.07.2009	8627	WAE	14
01.09.2009	2720	CHA	12.7
07.12.2009	8575	BIZ	2.4
21.12.2009	5106	BUS	0.8
22.01.2010	7524	SAM	-12.6
21.02.2010	8157	LAE	3.5
23.02.2010	8472	TAE	7
13.04.2010	6102	PIL	-4.2
19.04.2010	3073	GRE	17.8
26.04.2010	2533	CHA	7.2

29.04.2010	3714	ABO	15.7
15.07.2010	3132	PLF	20.9
23.07.2010	9444	ARH	16.2
02.08.2010	8718	EBK	15.5
05.08.2010	1220	GVE	16.1

Table 5 Date, postal code of owner, identification of weather station and temperature at the time of the splint-bone fracture. / *Griffelbeinfrakturen, sortiert nach Datum der Patienteneinweisung mit der dazugehörigen Tagestemperatur*

Date	Postal code of owner	Weather station	Temperature [°C]
22.06.2000	8344	HOE	15
24.07.2000	8218	SHA	18.5
29.07.2000	8590	GUT	14.2
22.09.2000	7165	CMA	2.4
11.10.2000	4665	GOE	2.4
05.05.2001	8714	WAE	12
16.08.2001	9463	STG	21.2
19.08.2001	8632	HOE	18.7
27.08.2001	7503	COV	5.6
06.10.2001	8580	BIZ	2.4
04.02.2002	9055	STG	4.1
23.03.2002	8907	SMA	3.4
08.07.2002	8805	WAE	27.6
16.07.2002	8708	WAE	18.7
12.08.2002	5630	CHZ	2.4
16.08.2002	6005	LUZ	23.2
06.02.2003	6312	CHZ	2.4
24.02.2003	2533	CHA	0.5
05.04.2003	8123	SMA	10.4
21.04.2003	5024	BUS	12.4
23.06.2003	8234	SHA	31.2
18.08.2003	9246	BIZ	2.4
20.08.2003	8600	SMA	24.1
05.01.2004	8182	KLO	-0.2
06.03.2004	8008	SMA	3.9
25.03.2004	8484	TAE	1.9
26.03.2004	8645	WAE	0.6
05.04.2004	6216	EGO	2.4
05.05.2004	8164	LAE	2.4
09.06.2004	8164	LAE	24.7
21.07.2004	8248	SHA	25.8
26.07.2004	8868	GLA	16.1
10.10.2004	8752	GLA	10.7
22.04.2005	6006	LUZ	14.3
02.05.2005	8484	TAE	21.2
17.08.2005	8836	WAE	21.4
12.09.2005	8303	SMA	15.8
12.10.2005	8497	HOE	11.1
08.11.2005	8307	SMA	5.5
27.03.2006	8200	SHA	17.6
11.05.2006	8608	WAE	19.6
16.06.2006	8238	SHA	23.6
20.06.2006	8615	SMA	25.5
24.07.2006	8637	HOE	23.8
27.08.2006	8854	WAE	15.8
30.11.2006	8566	GUT	7.9
13.12.2006	1580	PAY	0.1
15.01.2007	8630	HOE	3.8
20.01.2007	3412	BER	10.1
19.02.2007	8706	WAE	8.6
21.03.2007	8633	WAE	1.3
27.03.2007	8182	KLO	11.4
16.04.2007	8856	EBK	2.4
18.04.2007	7550	SCU	11.2
21.04.2007	7137	CMA	3.9
27.06.2007	8184	KLO	13.3
03.07.2007	8627	WAE	13.3
28.08.2007	2875	CHA	14.2
07.09.2007	4623	WYN	14.2
24.09.2007	8548	TAE	18.3
16.10.2007	8636	HOE	12.2
05.03.2008	4802	GOE	2.4
23.04.2008	5637	CHZ	10.1
16.05.2008	8340	HOE	14.1
28.05.2008	8475	SHA	24.3
04.07.2008	8722	EBK	2.4
12.07.2008	8603	SMA	14.9
17.09.2008	7206	CHU	10.5
11.11.2008	1142	BIE	2.4
24.11.2008	9462	ARH	3.1
08.03.2009	8127	SMA	6.4
07.05.2009	8172	KLO	23
07.05.2009	8196	SHA	21.5
06.07.2009	9493	VAD	21.6
12.09.2009	8153	REH	17.6
17.10.2009	7304	VAD	3.9
19.10.2009	8022	SMA	3.3
20.10.2009	8600	SMA	5.8
20.10.2009	8564	HAI	2.4
06.11.2009	8108	LAE	4.7
09.02.2010	1630	MLS	-4.7
19.02.2010	8047	SMA	1.5
17.03.2010	1441	FRE	6.3
26.05.2010	7143	CMA	3.5
08.06.2010	9122	EBK	2.4
12.07.2010	9122	EBK	21.4
25.07.2010	6030	LUZ	19.6
21.08.2010	8309	KLO	25.8

During the 11-year study period, fractures of P1 were more common during warm weather, but the association was not significant (Fig. 3). For the years 2005 and 2006, which included the winter of 2005/2006, there was a significant (P=0.045) negative (r= -0.638) correlation between the number of fractures per yearly quarter and the mean quarterly temperature recorded at the time of the fractures (Fig. 4). During these two years there was an increased overall incidence of P1 fractures (Table 3), and the fractures were more common at colder temperatures (Fig. 2).

During the overall study period from 2000 to 2010 (Fig. 3) as well as during the years 2005 and 2006 (Fig. 4), there were significant positive correlations between the number of splint bone fractures per yearly quarter and the mean quarterly temperature at the time of the fractures (r=0.36, P=0.008 and r=0.628, P=0.048, respectively). Therefo-

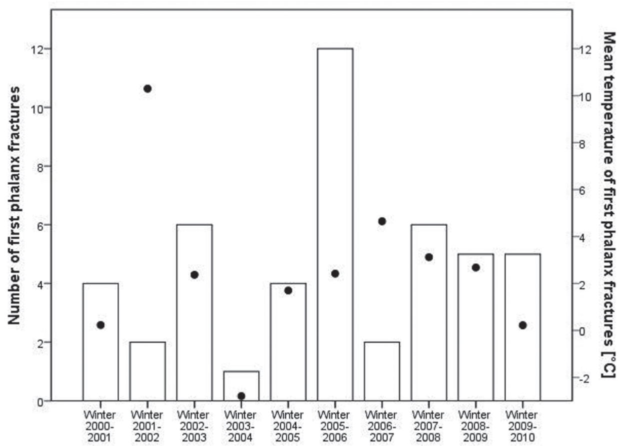

Fig. 1 Number of fractures and mean local temperatures at the time and place of the fracture during the months October until March of the years 2000 to 2010. Bars indicate the number of fractures and points indicate the mean temperature at the time of the fractures.
Frakturanzahl und Durchschnittstemperatur der Tage an denen die Frakturpatienten an der Klinik vorgestellt wurden der Monate Oktober-März der Jahre 2000-2010. Balken zeigen die Anzahl Frakturen, Punkte zeigen die Durchschnittstemperatur.

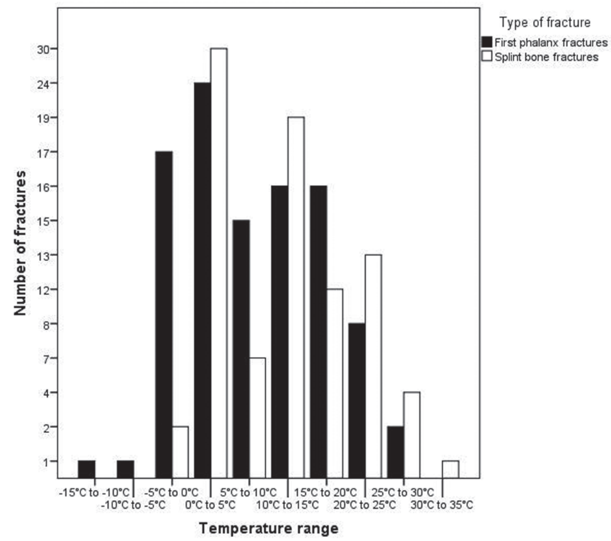

Fig. 2 First phalangeal and splint bone fractures during the years 2000 to 2010 relative to ambient temperature.
Fessel- und Griffelbeinfrakturen der Jahre 2000-2010 gruppiert nach Temperatur

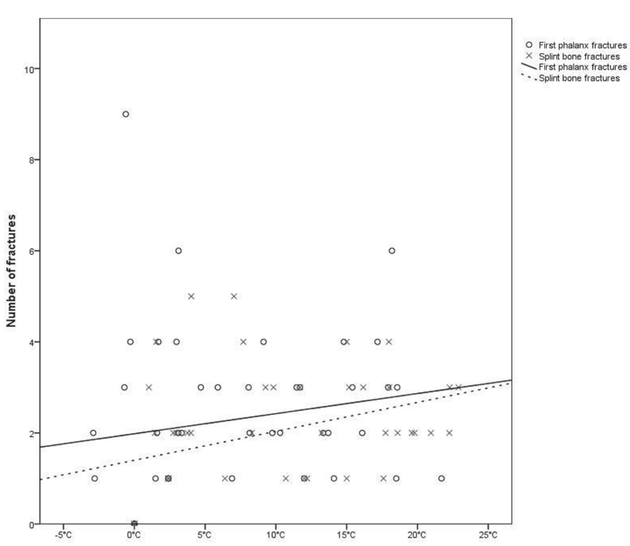

Fig. 3 Relationship between the number of P1 and splint bone fractures per yearly quarter and the mean quarterly local temperature at the time of the fractures for the years 2000 to 2010. The regression lines and correlation equations are shown for the fractures that occurred in the 44 quarters.
Fessel- und Griffelbeinfrakturen pro Quartal der Jahre 2000-2010. Dargestellt sind 44 Quartale aus 11 Jahren für Fessel- und Griffelbeinfrakturen und die Korrelationen der Anzahl der Frakturen pro Quartal und Durchschnittstemperatur am Tag der Frakturentstehung pro Quartal als Linien.

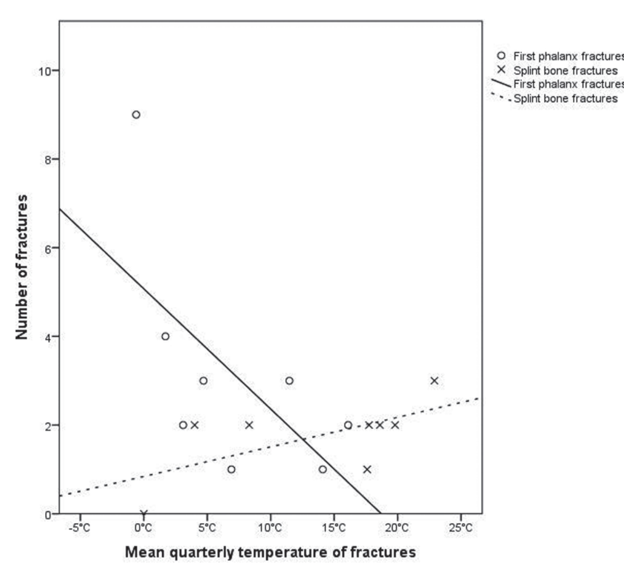

Fig. 4 Relationship between the number of P1 and splint bone fractures per quarter and the mean quarterly local temperature at the time of the fractures for the years 2005 and 2006. The regression lines and correlation equations are shown for the fractures that occurred in the eight quarters.
Fessel- und Griffelbeinfrakturen pro Quartal der Jahre 2005-2006. Dargestellt sind 8 Quartale aus 2 Jahren für Fessel- und Griffelbeinfrakturen und die Korrelationen der Anzahl der Frakturen pro Quartal und Durchschnittstemperatur am Tag der Frakturentstehung pro Quartal als Linien.

re, the hypothesis was accepted that splint bone fractures, unlike P1 fractures, occur more frequently at higher temperatures.

Discussion

During the cold snap of the two yearly quarters of the winter of 2005/2006, more P1 fractures occurred per yearly quarter compared with other quarters of the study period (Table 4). The two quarters during the winter of 2005/2006 were colder than other quarters during the study period (Table 3) and fractures occurred more commonly at colder temperatures (Fig. 2). Based on the analysis of fracture frequency and temperature at the time of the fracture, the hypothesis that splint bone fractures occur more commonly at higher temperatures (Table 5) was accepted. Splint bone fractures are common kick injuries in horses at pasture, and some horse owners may prefer to pasture horses during the warmer seasons for better pasture management, thus increasing the risk of a kick injury.

Horses on hard ground surfaces suffer more microfractures because the forces acting on the limbs are not absorbed as well as on soft ground. Horses are exposed to a wide range of surfaces varying from hard asphalt to synthetic surfaces at the track. The changes that take place in a surface at freezing temperatures are critical for the occurrence of microfractures; the characteristics of asphalt do not change appreciably at low temperatures, whereas surfaces with a high water content freeze and become hard and often lack the even surface of asphalt. Our study was based on temperatures that were recorded in the late afternoon, and it can be assumed that many of the actual temperatures at the time of the fracture on the same day were lower than the temperature recorded for that day. This means that some of the fractures that were associated with a low temperature above the freezing point likely occurred at freezing temperatures. Horses that are exercised in indoor arenas during the winter are not necessarily immune from the negative impact of hard surfaces because also short exposures to frozen pastures or paddocks can lead to microfractures.

It should be remembered that healing of microfractures may take months. This means that microfractures cannot be prevented by scheduling periods of rest between episodes of work. Instead, horses should not undergo strenuous work during very cold temperatures, at least not at high speed. Ground reaction forces increase very significantly at high speed (*Dutto* et al. 2004). Whether the fracture risk can be reduced by limiting exposure of horses to frozen and uneven ground surfaces during winter needs further study. The prognosis of limb fractures, particularly compound P1 fractures, in horses is generally poor and thus prophylaxis is crucial.

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