Various investigators have evaluated the percentage of moisture content of equine hoof walls, with reported values ranging from 16% to 36%.

One study involved use of various methods, including drying with potassium phosphate, freeze drying, drying at room temperature, vacuum drying, and oven drying at a range of temperatures to determine the repeatability of hoof moisture content assessment. Depending on the technique used, moisture content of identical samples in that study varied from 22% to 36%, which might explain the large range of values reported in the literature.

This variation in percentages has fuelled speculation that hoof moisture content, an important factor affecting the mechanical properties of the hoof wall, may differ substantially according to the breed and environmental conditions of a given horse.

Hoof wall moisture is believed to be important for the health and function of hooves, and some investigators recommend that horses living in dry environments have their hooves regularly bathed in water or treated with various moisture-replenishment products to supplement moisture content. However, the hydration mechanism of the hoof wall is not fully understood, and the effect of topical application of moisture to the hoof has not been definitively established. Some evidence exists to suggest the hoof regulates hoof wall moisture from within and that topical application of moisture does not affect hoof moisture content. Because horses and other equine species are adapted to semiarid environments, any biological need for an external moisture application to maintain hoof health might appear to be a flaw in the phylogeny of the equine hoof capsule.

The purpose of the study reported here was to investigate the effects of 3 environments (arid, temperate, and wet) on hoof wall hydration to further understand the mechanisms of equine hoof hydration. A secondary aim was to determine whether there would be any beneficial effect of foot soaking on equine hooves.

**Materials and Methods**

**Horses and environments**—This study involved 2 parts. In the first part, which was designed to measure the degree of hydration in hoof walls, the left forefeet from 40 feral horses from 3 Australian and New Zealand regions with different environmental conditions were used. The horses had been culled as part of feral horse control programs unrelated to the study. Evaluation of dentition revealed all horses were >5 years of age.

Ten of the feral horses were from the Kaimanawa Range of central North Island of New Zealand. Horses...
from this region are small (adult height at the top of the shoulders [withers], 133 to 151 cm). Results of genetic analysis suggest they are closely related to domestic Thoroughbreds and local station hacks. The horses occupy 200 km² of land consisting of upland plateaux, steep hills, and river basins and valleys. Minimum temperatures in this region range from −10° to 7°C, and maximum temperatures range from 12° to 32°C throughout the year. Rainfall ranges from 75 to 180 mm/mo (mean, 100 mm/mo). At the time of sample collection, the entire location was wet and boggy. Degrees of rainfall and snowfall in the previous 3 months had been typical for that area.

Twenty of the feral horses were from Palparara, which is a vast location referred to as Channel Country, in the southwest corner of Queensland, Australia. The region is an arid to semiarid desert fringe with an annual rainfall of 200 mm. However, the area is inundated with flood water at approximately 10-year intervals, and this phenomenon occurred 3 months before the study began. During the flood period, horses are regularly flood bound and must cross flood waters to access dry land and feed. In the 3 months before the study began, the horses used would have grazed on dry sand hills and rock-covered hills and drank and fed at long boggy lagoon stretches. Therefore, their hooves would have been intermittently soaked. Horses in this area have a Thoroughbred and Australian Stockhorse lineage and have been intermittently soaked. Horses in this area have a Thoroughbred and Australian Stockhorse lineage and are generally considered the progeny of drovers’ stock and station horses that had been released (or escaped) there between the 1880s and 1960s. The breed origins of these horses are similar to those of the Palparara group, with influence from early Thoroughbred, Arabian, and station hack horses. Horses in this area feed on sparsely covered sand hills and rough rock-covered plains and hills. Water was limited to 1 permanent water hole in the area for 3 months before the study began, and horses were forced to walk long distances on sandy trails over the dry desert from water to feed. Horses in this habitat drink water every 2 to 4 days, and this time is the only opportunity for the hooves to contact external moisture.

For the second part of the study, which involved evaluation of the effect of short-term (2-hour) immersion on hoof wall and sole moisture status, 6 domestic horses were used. The horses were mature (age range, 5 to 14 years) Quarter Horses of both sexes (2 geldings and 4 mares). They were housed in paddocks and were maintained unshod. All feet appeared healthy, and the hooves were not trimmed for at least 6 weeks before the study began. The study protocol was approved by the University of Queensland Animal Ethics Committee and complied with the Australian Animal Welfare Act of 2001 and the Australian Code of Practice for the care and use of animals for scientific purposes.

Measurement of hoof wall hydration—Methods

Full-thickness samples of the dorsal midaspect of the hoof wall opposite the midpoint of the distal phalanx were obtained from feral horses within 15 minutes after death. A bandsaw powered by a portable generator was used to grossly dissect the hooves. A 15-mm-wide block was cut out of the dorsal aspect of the hoof wall by use of a bandsaw. The stratum medium in this block was then cut away from the stratum lamellatum by use of a scalpel, and a 20-mm-long, full-thickness hoof wall block was cut. The block was then immediately wrapped in 3 layers of self-sealing, moldable, flexible film and placed in a plastic zipper storage bag on ice until transferred to a freezer (−20°C) on the same day.

Hoof wall blocks remained frozen until processed at the laboratory within 2 weeks. Hoof wall samples prepared in this way and stored at 4°C for 3 months reportedly lose only 0.55% of hoof moisture content. Processing at the laboratory involved further dissection of hoof wall blocks with a scalpel to achieve smaller full-thickness blocks (10 mm² each). Each block was cut into five 2-mm slices, and all 5 slices were immediately weighed by use of an electronic scale that was accurate to the nearest 0.1 g to obtain the original sample mass.

Each sample was weighed within 2 minutes after removal from the sealing film. Samples were placed in a desiccator over a layer of phosphorus pentoxide as recommended. Processing in this manner reportedly yields a constant mass in hoof wall samples following 3 days of phosphorus pentoxide drying. However, because of the large size of the samples, they were left in the desiccator for 10 days. Constant mass was recorded for 2 consecutive days before it was determined that full drying was complete. Samples were then removed from the desiccator and reweighed to determine the mass of the dried samples. The total percentage of hoof wall moisture content was calculated by use of the following formula:

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\text{Percentage of moisture content} = \left(\frac{\text{dried mass}}{\text{original mass}}\right) \times 100
\]

Measurement of the effect of foot soaking in live horses—Live horses were restrained in stocks and had free access to hay for the duration of the soaking experiment. Both forefeet were cleaned with a hoof pick and brush. The left forefoot was placed in a custom-made rubber cylinder boot, which was filled with tap water to the level of the carpus. The right forefoot was placed in a loose-fitting dry commercial rubber boot to maintain an even limb length and to protect the sole of the foot from any moisture that may have spilled from the water immersion boot. Following water immersion (2 hours), the left forefoot was removed from the soaking cylinder and the foot patted dry with a towel. The circumference from medial quarter to lateral quarter of the hoof was immediately trimmed with nippers to remove the hoof horn tissue distal to the sole plane. Any areas of cracked hoof were removed from the sample of hoof horn so that only healthy horn remained. Col-
lected samples of healthy hoof horn tissue were cut with a sharp knife into 10-mm blocks, and all blocks were immediately weighed together as 1 sample. After samples were weighed, each was immediately placed in a desiccator for drying.

Immediately after hoof wall trimming, a sharp hoof knife was used to remove a section of sole horn from the ground surface of the foot toward the toe. A section measuring approximately 60 mm long, 30 mm wide, and 3 mm deep was then trimmed with a knife to remove any tissue peripheral to the junction of the sole and the white line so that only sole horn tissue remained in the sole horn sample. This sample was weighed and placed in the desiccator to dry. The interval from removal from the water immersion boot to weighing was < 3 minutes for all samples. The process was repeated for the right forefoot in the dry boot.

**Statistical analysis**—Statistical analyses were performed with the aid of computer software.1 Mean hoof moisture content was compared among the 3 groups of feral horses by means of ANOVA. Pairwise comparisons within the 3 groups were analyzed by use of the Tukey honestly significant difference test. The effect of water immersion percentage moisture content in the hoof wall and sole in live domestic horses was compared by use of a paired t test. The moisture content of the sole was compared with that of the hoof wall both before and after immersion by use of a Welch t test. All data are reported as mean ± SD. Values of P < 0.05 were considered significant for all analyses.

**Results**

Percentage of hoof wall moisture content in feral horses—The mean ± SD percentage moisture content in hoof wall samples from feral horse carcasses was 29.6 ± 5.1%, 29.5 ± 5.8%, and 29.3 ± 2.9% for the horses from the differing climates of Kaimanawa, Palparara, and Kings Canyon, respectively. Moisture content did not differ between the 3 groups, nor was there a significant difference between any pair of feral horse groups.

**Effect of soaking on hooves in live horses**—The mean percentage moisture content was lower in the hoof wall distal to the sole horn (23.8 ± 4.2%; 12 non-feral horse samples) than in the center of the dorsal wall (29.5 ± 5.1%; 40 cadaveric feral horse samples). A paired t test revealed that water immersion for 2 hours did not result in a significant increase in the degree of hoof wall hydration in the hoof wall distal to the sole horn. However, soaking in water for 2 hours resulted in a significant increase in the degree of sole hydration (Figure 1). In addition, the Welch t test revealed that the moisture content of the sole was significantly greater than that of the hoof wall in both the dry and soaked samples.

**Discussion**

Findings in the present study suggested that the degree of hydration in the hoof wall of feral horses from 3 environments, ranging from bogs to desert, was similar. It would be reasonable to expect that if environmental moisture affected internal hoof wall moisture content, then we would have detected a difference among the 3 groups. Methods used in our study also revealed similar hoof wall hydration in horses (30 ± 1%) in another study.1 Differences from the hoof wall moisture content in previous studies (eg, 22.7%3 and 36.3%13) are most likely due to differences in methods used and may not accurately reflect the actual moisture content of horse hoof wall in vivo. For example, moisture loss of 21% has been reported following removal of hoof wall samples from live donkeys,4 and this postcollection moisture loss may have accounted in part for the low moisture found in one of the aforementioned studies.3 Several other factors can affect measurement accuracy, including sample preparation time and method, storage method, and drying method.1 The present study was designed to minimize these potential influences.

If the hoof wall horn moisture content does not differ among horses in different environments, then application of moisture to the outside of a horse’s hoof may have no effect on the internal hoof wall moisture content. Findings in the present study supported this reasoning. After hooves of Quarter Horses were soaked in water for 2 hours, no difference in hoof wall moisture content was evident. The outer layer of the stratum medium and stratum externum of the hoof wall appears to be sufficiently impermeable to prevent water uptake from the environment and limit moisture loss from within.

Desert-dwelling horses in Australia reportedly drink at 2- to 4-day intervals from
water sources in which foot immersion is not always possible.\textsuperscript{12} Furthermore, the feet of horses from similar environments appear healthy and robust.\textsuperscript{13} Moisture penetration in dried outer hoof wall samples was minimal (3 to 5 cell layers deep) in 1 study,\textsuperscript{6} even following soaking in water for 14 days. Some investigators have hypothesized that application of topical agents containing proteins would not benefit the hoof because of the impermeability of the cell membranes in the stratum medium of the hoof wall.\textsuperscript{13} Others confirmed that the moisture gradient in the hoof was due to the proximity of the various layers to the underlying dermis and its vascular supply, which is the source of the moisture.\textsuperscript{14}

In the study reported here, the mean percentage moisture content was lower in the hoof wall distal to the sole horn in live horses than in the center of the dorsal wall in the feral horse samples. The hoof wall distal to the white line should have lower moisture content than more proximal samples because with growth, it has moved distally beyond contact with the lamellar corium. Furthermore, the hoof wall distal to the sole horn has no protection from the environment on its axial surface and is therefore more susceptible to moisture loss than is hoof wall still in contact with the dermis or sole horn.

An interesting finding was that the moisture content of the sole horn tissue in our study (29.8 ± 1.1\%) was similar to that in samples obtained from the dorsal aspect of the hoof wall. This is not surprising given that the sole architecture is similar to that of the hoof wall and its moisture content is influenced by the sole corium. The percentage moisture increase in sole tissue following soaking indicates a different hydration mechanism in the sole than in the hoof wall. Although the horn tubule architecture of the 2 structures is similar, the sole appears to be more porous and thus affected by the moist external environment. In our experience, the sole responds to the amount of moisture in the environment, leaving the foot vulnerable to bruising in wet conditions and allowing easier access during trimming with the hoof knife. Our findings support the use of moist sole poultices by veterinarians and farriers for softening the sole tissue to access bruising and abscesses for drainage.

Findings of ours and other studies discussed here provide good evidence that soaking horses’ feet regularly in water would be unlikely to change the degree of hydration in the hoof wall. Indeed, this often-recommended practice might yield little benefit for horses. The sole, on the other hand, may be influenced by external sources of hydration. Because the sole is prone to bruising and damage when weakened by excessive moisture, soaking feet regularly may in fact be detrimental to horses.

References