# 초지관리 및 방목형태에 따른 발굽질병의 발생

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# 초지관리 및 방목형태에 따른 발굽질병의 발생

## Equine Hoof- Anatomy, Physiology, Nutrition and Diseases, dependant on grazing conditions and pasture managements -

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## 요 약

말에서의 발굽은 육상선수에서와 마찬가지로 다른 어느 기관에 비하여 중요하며 결정적인 역할을 담당한다. 건강하며 강한 발굽을 가진 말을 육종 번식하려는 노력과 말의 발굽이 건강하도록 관리하려는 노력은 예로부터 지금까지 계속되고 있으며, 앞으로도 전문가들이 함께 정보를 공유하며 풀어야 할 과제이며, 말 산업 발전에 한 획을 그을 수 있는 중요한 명제이다. 건강한 말의 발굽을 유지하도록 하기 위하여는 그에 관계되는 말을 사육하고 훈련시키는 사육자, 육종학자, 초지학자, 장제사 그리고 발굽전문 수의사의 통합된 영역을 통하여만 이루어질 수 있는 것이다.

통계적을 말의 발굽질병은 소화기 질환인 산통 (colic) 다음으로 중요한 도태의 원인이며, 만성적인 퇴행성관절염, 근골격계 질환, 건염 등에 능력감퇴의 일차적인 원인이 발굽의 균형상실 (hoof imbalance)에 기인 한다는 점은 발굽의 중요성을 다시 한번 강조한 것이라 할 수 있다. 또한 말의 모든 다른 부위 중에서 발굽은 장제나 삭제 등을 통하여 정기적인 관리를 하여 주어야만 하며, 야생상태인 경우에도 바닥의 따른 차이를 나타내지만 이러한 관리가 꾸준히 이루어지고 있는 것을 관찰 할 수 있다.

발생학적으로 발굽은 다른동물의 손발톱과 마찬가지로 피부의 변형된 형태로 배아의 외배엽으로 부터 발생된다. 발굽은 셋째 발가락의 끝부분을 의미하며, 발굽끝은 발굽, 첫마디뼈 (제 1지골), 주상골 (sesambina), 중간마디뼈 (제 2지골)의 아래쪽 부분으로 구성되어 있으며 말의 움직임시 지면과 직접으로 접촉을 하는 부위이다. 감각신경을 갖고있지 않은 발굽은 발굽둘레 (periople), 발굽벽 (wall), 발굽빗장 (bars), 각질층, 발바닥 그리고 발굽볼록살로 구성되어 있다.

발굽은 발굽벽, 발굽둘레, 바닥 그리고 발굽쐐기로 구성되어 있다. 발굽벽은 정면과 측면에서 바라볼 수 있는 기관으로 굽앞을 포함한 앞벽, 옆벽 그리고 굽의 뒷부분의 볼록살로 이어지는 부분인 뒷벽인 발굽빗장으로 구성되어져 있다. 발굽둘레

는 발굽갓 근처에서 얇은 각질띠로 구성되며 얇고 광택이 나는 부위이다. 말이 오랫동안 수분이 있는 장소에 서있을 경우 수분을 흡수하여 불투명한 젤의 형태로 나타나게 된다. 이 층의 재질은 발굽볼록살을 덮는 가질소관과 소관사이각질로 구성되며 점점 넓어져서 발굽쐐기바닥과 합쳐진다. 발굽벽의 외층(Str. exterinum)을 형성하며 발굽의 수분의 량을 조절하는 기능을 담당한다.

발굽바닥은 발굽벽과 발굽쐐기사이 공간에 위치하며, 발굽쐐기를 통하여 볼록살과 연결된다. 바닥은 바닥을 향하여 오목한 형태를 취하므로 일부 벽주변만이 직접 바닥과 접촉을 한다. 발굽바닥과 벽이 만나는 지점에는 연속의 띠를 형성하는데, 이곳은 색소침착이 안되므로 백색의 연속선을 나타낸다. 이러한 백선은 두께와 연속성 등을 보고 과거의 발굽 질병의 여부를 판단하는 지표가 될 수 있다. 또한 이곳은 조직학적으로 밀폐된 공간이 아니므로 외부의 영향으로 인하여 이 물질이나 병원성 박테리아, 수분 등이 쉽게 침투할 수 있는 공간이므로 발굽질병을 유발하는 관문의 역할을 담당한다. 또한 백색띠(white line)는 장제시 못을 박는 위치를 결정하는 중요한 지표로 활용된다.

발굽쐐기 (frog)는 굽의 뒤꿈치 사이에 위치한 발굽볼록살이 있는 부위로 발굽앞쪽 중간부위까지 쐐기 모양으로 가늘어지며 뻗어있다. 발굽볼록살과 발굽쐐기는 발굽에서 가장 근접한 부분에서 지면과 접촉을 하며 탄력을 갖는 구조로 바닥상태를 직접 발굽에 전달을 하여 말의 균형과 발굽의 균형을 유지하는 중요한 부위이다. 그러므로 장삭제시 발굽쐐기의 높이를 잘 조정할 필요가 있을 것이다.

발굽의 각도는 말의 용도 및 품종에 따른 차이는 있지만 대체로 다음과 같이 구분할 수 있다. 측면에서 본 발굽각도는 앞다리의 경우 524, 뒷다리 534, 정면에서 앞다리의 본 외측면의 각도 754, 뒷다리는 765, 내측면의 각도는 각각 833, 764, 외측 뒤꿈치의 각도는 각각 1354, 1373, 내측면 뒤꿈치의 각도는 1354, 1383으로 정의하였다. 물론 제 2지골의 길이에 따라 이상적인 발굽의 각도는 다시 정의 되어져야 하지만 측면에서 관찰하여 발굽중심과 제 2, 3지골의 중심선이 선이 꺾이지 않는 발굽의 각도와 정면에서 관찰한 경우 발굽의 끝을 향하는 중심선과 제 2지골 그리고 손발등뼈와의 일직선을 이루는 경우가 이상적인 발굽의 자세인 것이다.

발굽에 필요한 영양분을 특별하게 따로 급여를 한다는 것은 아마 무척이나 어려운 일일 것이다. 하지만 발굽은 선행되어진 말의 일반적인 영양공급상태를 한눈에 알아 볼 수 있는 지표가 될 수 있다. 일반적으로 발굽은 망아지의 경우 일일 5mm 가량 다른 말의 경우에는 일일 2mm가량 자라는 것으로 알려져 있다. 말발굽의 성장에 영향을 주는 인자는 다양한 발굽질병과 발굽의 혈액을 공급하는 규칙적인 운동 그리고 영양분의 공급상태이다. 특히 황을 포함하는 아미노산 즉 시스틴, 메치오닌은 아미노산의 제한요소 일뿐만 아니라, 발굽벽의 각질화를 유도하는 중요한 영양인자로 작용을 한다. 바이타민 중에는 바이오틴이 이러한 기능을 수행하는 중요

한 인자로 널리 알려져 있다.

대표적인 발굽질병으로 제엽염 (lamiitis)을 소개하면, 제엽염은 일종의 감염성 혹은 대사성 질환으로 급성, 아급성, 만성으로 진행될 수 있는 발굽질환이다. 주요 발병원인은 운동량이 적은 말에 과도한 농후사료를 급여함으로써 발생된다는 것이 일반적인 이론이다 후자에 다시 상세히 언급하겠지만 "초지 제엽염"은 야생 상태의 말 뿐만 아니라, 초원에서 인위 방목하는 말에서도 흔히 발견되며, 갑작스런 죽음을 유발하는 중요한 질병으로 관심을 불러 일으키고 있다. 제엽염은 체중의 2/3을 지탱하는 양쪽 앞다리에 오는 경우가 대분분이며, 뒷다리를 포함한 모든 다리의 오는 경우도 종종 관찰할 수 있다. 소화기 장애인 산통의 경우 후유증으로 제엽염을 동반하는 경우가 많으므로 산통처치시 반드시 제엽염의 처리를 동시에 수행하는 것은 유럽 선진국에서는 수의사의 의무사항처럼 여겨진다. 제엽염의 발생기전을 간략히 서술하면, 목초나 건초에서 곰팡이에 감염된 사료를 섭취하는 경우, 특히 여름철에는 두과사료에서 흔히 관찰되는 아프라독소 등에 노출된 경우 이러한 독소성분이 혈액을 통해 발굽에 분포된 모세혈관을 파괴하여 발굽진피층에 방사형으로 분포된 모세혈관 베드를 손상시켜 부종을 유발시키며, 이러한 부종으로 인하여 통증을 유발시킴으로 기립불능의 상태를 유도하여 급성인 경우에는 이러한 내부독소 (endotoxins)에 의한 쇼크사를 일으키는 경우가 적지 않다. 적절한 조치가 이루어지지 않을 경우, 통증 및 교감부교감신경 부조화에 의한 2차적인 산통으로 인하여 죽음을 초래하는 경우도 종종 볼 수 있다. 이와 같이 제엽염은 단순히 제엽염자체뿐만 아니라 보행기관의 말단기관임으로써의 기능 때문에 다른 질병과의 상관성에 의한 2차적인 증상이 죽음을 초래하거나 후에 능력부진의 중요한 원인을 제공하는 경우가 많다. 다음으로 중요한 발굽질병은 부분적으로 나타나는 발굽바닥의 상처나 물리적 자극에 의한 염증성 질환이다. 앞에 설명한 제엽염처럼 발굽전체로 파급이나 죽음을 초래하는 급성, 아급성으로 진행되는 경우는 드물지만, 발생빈도 면에서는 가장 많은 발생빈도를 나타낸다. 특히 매달 반복되는 장삭제의 경우 숙련되지 않은 장제사의 경우에는 장제후 2 ~ 3일 간은 파행 때문에 말을 이용할 수 없는 불평을 자주 접하게 된다. 이러한 질환은 발굽압박장치 (hoof tester)나 작은 뾰족한 망치를 이용하여 쉽게 상처부위를 진단할 수 있으며, 심한 경우를 제외하고는 서있는 상태에서 처치를 할 수 있다. 그 외에 발굽의 벽면 일부가 파손되거나 발굽갓의 상처로 인한 발굽벽의 불균형적인 성장으로 인한 발굽의 균열 등은 때로는 심각한 능력감퇴의 원인을 제공하기도 하며, 귀중한 말의 조기도태의 원인을 제공하여 마주로 하여금 심한 경제적 손실을 초래하게 된다. 특히 이러한 발굽질환 등은 과도한 농후사료급여 및 알팔파건초의 무제한 급여 등으로 인한 질소함유 암모니아의 분뇨 배출을 증가시킴으로 인하여 그리고 대부분의 시간을 마방에서 이러한 암모니아 밀집환경에서 보내야하는 경우, 마방산성도가 증가함으로 곰팡이포자의 증가를 초래함으로 발병빈도가 높아질 수 있다.

오랫동안을 초지에서 방목하는 말의 경우에는 상대적으로 마방에서 사육되는 말에 비하여 발굽질환의 발생빈도는 적다는 것은 일반적으로 잘 알려진 사실이다. 발굽에 나타날 수 있는 변형 즉 정상적인 해부조직적인 상태에서의 모든 변형은 말의 능력을 최적화시키는 저해요인이 될 수 있다는 점에서 중요한 가치를 찾아야 할 것이다.

초지 방목중 발굽에서 나타날 수 있는 변화는 변형 (Deformation), 제염염 (laminitis), 발굽관리부족에 따른 질병, 물리적 자극에 의한 상처 그리고 과도한 일방적인 부하에 의한 발굽의 균열 등으로 나눌 수 있을 것이다. 방목지의 노면상태에 따른 가장 큰 변화는 발굽의 변형일 것이다. 국내에서라기보다는 호주나 미국 등의 방대한 초지를 보유하고 있는 선진국에서도 건기와 우기가 심한 년도에 따라 그에 상응하는 발굽의 변형으로 인한 경제적인 손실은 매우 큰 것으로 보고되고 있다. 특히 초기 발굽의 변형에 대한 대처부족으로 인한 관절의 변화에 의한 연골손상은 경주마의 경우에는 치명적인 능력감소 및 조기도태로 이어진다는 연구보고는 호주뉴질랜드 마필산업에 많은 충격을 던져주고 있는 듯하다.

본 논문에서 연구된 몽고 원조 말인 플레즈발스키 말 (Przewalski Horse)의 발생된 "Grass Laminitis"는 야생화된 말에서뿐만 아니라 잘못 관리된 초지에서 경주마나 일반승용마에서도 흔히 발견될 수 있다는 점에서 관심을 갖기에 충분하다. 물론 급작스런 죽음의 원인이 되는 급, 아급성의 초지제엽염도 문제가 될 수 있으나 만성적으로 진행되어 초기에는 임상적인 증상을 보이자 않던 훈련 경주마가 본 경주에 들어가기 전에 강도 높은 훈련을 이기지 못하여 급만성 파행을 나타내는 경우 경제적 시간적인 손실 뿐만 아니라, 마주와 트레이너, 기수 등 모든 사람에게 심리적인 부담감과 좌절감을 줄 수 있다는 사회심리적인 관점에서도 중요한 손실요인이 될 것이다. 이러한 야생화된 말에서 발생된 초지제엽염의 발생기전은 고온 다습한 외부조건에서 탄수화물을 다량 함유한 초지에서 방목된 말에서 집중적으로 발생함으로써 "carbohydrate overload laminitis" 혹은 "grass laminitis"라고 명하여졌다 (Eustace 1992, Houpt 1994). 특이한 외부적인 조건은 봄가을 찬 밤, 약간 얼은 듯한 초지, 그리고 따뜻한 햇빛이 쬐는 오후라는 계절적인 조건에서 초지에 fructans (수용성 과당 폴리머)의 농도가 증가되게 된다. 이러한 조건은 말의 맹장과 대장에서 발효에 의한 젖산성 산성증 (lactic acidosis)의 조건이 장내에 형성되며, 이것은 streptococcus bovis의 급진적인 증식을 유도한다. 이 세균은 말의 제엽염발병의 직접적으로 작용한다는 사실이 이미 밝혀져 있다. 여기에 가스 발생에 의한 산통 유발과 그에 따른 내독신 (endotoxin)의 작용이 제엽염의 발병을 촉진 시킨다. 이러한 발병의 원인을 설명할 수 있는 가설은 "내독신은 발굽내에 분포한 모세혈관의 수축을 유도하여 혈류의 속도를 낮추어 흐름을 방해하여, 그 결과 혈관벽과 진피층의 산소공급을 낮추므로 저산소증 괴사 (ischaemic necrosis)을 유도하며 결과적으로 주상골을 둘러싼 지지인대의 괴사를

유도하게 된다"는 이론과 상피와 진피층의 기저세포벽에 존재하는 MMP 2와 MMP 9는 주상골의 지지인대를 파괴할 수 있는 주요한 효소로 말의 맹장으로부터 분리한 Streptococcus bovis의 *in vitro*배양상층액을 분리하여 인위적으로 실험한 결과에 의하면, 이러한 상층배양액이 발굽의 MMP-2을 활성화시켜 실험실적으로 진피층판의 분리를 유도하는 것으로 미루어 제엽염의 발병에 직접적인 관여를 하는 것으로 추정될 수 있다.

반 야생상태에서 여름과 겨울의 발굽의 생성 및 마모속도, 발굽의 강도의 변화, 생화학적인 변화, 그리고 해부조직학적인 변화를 관찰하는 실험에서는 다음과 같은 결과를 돌출할 수 있었다. 여름과 겨울의 발굽의 성장은 생성과 마모속도의 차이에 의하여 나타나며, 초지 및 패독의지반상태 및 움직임의 가능여부에 의하여 결정되어지며 실질적으로 발굽의 질을 결정할 수 있는 cytokeratins와 keratinfilament의 해부조직학적인 검사나 gel electrophoresis 등 생화적인 유의차는 나타내지를 않는 것으로 결론을 지울 수 있다. 단지 영양분이 풍부한 여름에는 겨울에 비하여 발굽의 성장속도가 빠르며, 경도를 측정하는 도구를 이용하여 측정시 여름에는 낮은 값을 나타내었으며, 조직학적으로는 단위 당 각질층판의 숫자가 적은 것, 즉 밀도가 낮은 것을 알 수 있었다. 또한 Przewalski Horse와 일반 경주 혹은 승용말과의 비교실험에서는 전자의 발굽이 훨씬 많은 각질층판의 숫자를 보여주었으며, 백색의 넓이도 후자에 비하여 훨씬 좁은 것을 알 수가 있다. 즉 가축화된 말보다는 원시야생마에서는 발굽의 질이 높은 것을 알 수가 있었다.

결론적으로 방목지에서의 발굽의 변화는 초지의 초종배합, 바닥상태, 강수량, 토질 등에 의하여 대체로 서서히 일어나지만, 만성적인 변화를 막기 위해서는 초지의 관리 뿐만 아니라, 풀을 뜯는 시간 및 량을 결정하여야 할 것이다. 특히 밤낮의 기온차가 크고, 어린 풀이 많은 늦봄과 초여름에는 말을 초지로 보내기 전에 충분히 건초 및 사료의 섭취를 유도하여 과도하게 초지의 어린 풀을 섭취하지 않도록 유도를 하여야 할 것이다. 정기적으로 발굽의 상태를 점검하여 결정적인 변형(deformation)이 생기기전에 조치를 취하여, 2차적인 후유증이 생기지 않도록 사전에 예방을 하여야 할 것이다. 특히 체중의 증가가 심한 임신마의 경우에는 체중의 증가로 인한 발굽질병의 가능성이 높으며, 이로 인한 유산의 위험이 급증하므로 더욱 더 주의를 기울일 필요가 있을 것이다

# Equine Hoof- Anatomy, Physiology, Nutrition and Diseases, dependant on grazing conditions and pasture managements -

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## Part I : The structure and function of equine hoof

### 1. Introduction

We like to speak about the horse, especially the hoof. As horses are used in many different ways in these days there has taken place a development in their physical condition and in the structure of their legs, most the hoof. The hoof is the deepest part of the leg who has contact with the ground. This contact can be strong (eventing or show jumping) or soft (riding for hobby, dressage). Because of these different kind of using, the hoof is strained very hard. Today the illness of the hoof becomes very important. That is the reason why a new branch of occupation was built up: farrier. These people occupy with the special problems of the hoof.

### 2. Embryonic development

The hoof shows the same development like the phalanx distalis of other animals. The embryonal disposition comes from an ectodermal thickening. Soon this thickening gets a second growth on its dorsal side which is called plate of epidermis. In the first time, the plate of epidermis sits on a smooth Corium. In this stadium you can make a difference between the plate of epidermis and the sole. The bars can already be seen. In the third month of development the length of the hoof is 10 mm and the corpus of papillae starts to grow in shapes like leaves and papillae. First the papillae can be seen in the distal part of the coronary bulge, at the bars, at the frog and at the distal part of the sole. The leaves of corium of the hoof wall are completed in distal direction. The growth of the epidermis begins at the corona. At the same time the frog and the sole show a strong proliferation. Soft mass of epithelium arise at the platform

of the sole which look like skittles. These skittles give the hoof his typical form. These special proliferation are called Eponychium and it is built to save the chorion during parturition. The further development of the hoof is signed by changing the structure of the epidermis cells. In connection with the papillae the typical tubular horn is built. In the last period the cornification starts. Normally the cornification begins in the seventh month at the dorsal part of the hoof and it is finished at the time of birth. Only the soft cells of the Eponychium get received for a few days, when the hooves are used they are lost.

## 3. Macroscopic Structure

The hoof is the Phalanx distalis of the third toe. The whole toe consists of the Os compedale (Phalanx proximalis), Os coronale (Phalanx media), Sesamabina, Os sesamoidea distalis and the Os ungulare (Phalanx distalis). The hoof has a bony base that consists of the distal one-half of the Phalanx media, the entire Phalanx distalis and the Os seamoidea distalis. Covering the bone and some adjacent structures is a highly vascular modified dermis called the corium of the foot. The corium is regionally named according in the insensitive structures it underlies and includes the perioplic corium, coronary corium, laminar corium, corium of the sole and corium of the frog. The hoof is the insensitive cornificated layer of epidermis covering the distal end of the digit. Corresponding sensitive structures underlie all insensitive structures, and pigmentation of the sensitive layer determines the color of the hoof. Black hooves are much tougher and stronger than white hooves. The hoof horn quality depends on the water content. The soft horn (frog, bars, glaze layer) is elastic, soft and flexible and the hard horn (sole) gets his strength from the cornification. The insensitive structures of the hoof include the periople, wall, bars, laminae, sole and frog. Each is produced by a corresponding sensitive structure consisting of the germinating layer of epidermis closely applied to the underlying corium of the same name, which is well supplied with vessels and nerves. With the exception of the ribbon-like laminae, all sensitive structures present papillae that produce some type of insensitive horn tubules.

The hoof wall is the part of the foot that is visible when the horse is in a standing position. It is divided into a toe region in front, medial and lateral quarters on the

sides, and medial and lateral heels behind that turn sharply forward at the angles to be continued by the bars. The wall consists of three layers: the periople and tectorial layer superficially, the tubular layer making up the bulk of the wall, and the laminar layer that connects the hoof wall with the third phalanx.

The major portion of the wall consists of parallel horn tubules cemented together by intertubular horn (cornified material between two tubules). The tubules are produced by thousands of papillae on the convex surface of the coronary band, a crown-shaped cushion that fits into the coronary groove in the top of the hoof wall and marks the junction of the skin and hoof. The tubules extend distally from the coronary band surface of the hoof. The tectorial layer of the hoof wall is the dense cornified surface of the hoof. The proximal part of the tectorial layer is covered by periople.

The periople is a thin layer of thin horn that covers the horn for a variable distance distally from the coronet, usually about an inch. It turns milky white when the hoof is soaked in water. The periople is produced by the narrow perioplic band just above and concentric with the coronary band.

The lamina corium is adherent to the periosteum over the convex surface of the third phalanx. The primary sensitive laminae radiate from the laminar corium like vertical ribbons with one edge attached to the corium and the other touching the tubular part of the hoof wall. Each primary laminar has up to hundred secondary laminae that is also parallel to the wall tubules but are at right angles to the primary laminae. Alternating with the sensitive laminae an related to them are an equal number of insensitive laminae attached to the tubular wall. Weight or force applied to the third phalanx is transmitted by this system of interlocking leaves to the wall of the hoof, so that in a sense the weight of the horse is suspended from the hoof wall by the combination of sensitive and insensitive laminae. This arrangement also permits the hoof wall to slide (grow) distally in relation to the third phalanx without disrupting the attachment, because the insensitive laminae move with the wall and the sensitive laminae remain attached to the periosteum of the third phalanx.

The sole of the foot is a concave plate that attaches much of the volar surface of the third phalanx. It includes the whole ground surface of the foot not occupied by the wall or the frog. The angles of the sole project are caudally between the bars and heels of the wall. Normally, the concavity of the sole allows the wall and frog to bear most of the weight and wear. Most of the corium of the sole is attached to the periosteum on the volar side of the third phalanx. It is covered by papillae that produce a short

horn tubules to make up the insensitive sole. The sole covers all of the volar side of the foot between the wall (and bars) and the frog.

Where the outer margin of the sole meets the inner marching of the wall, a narrow white mark appears that is known as the white line. It is useful as a landmark for driving nails in shoeing. A properly directed nail started at or outside the white line will not touch any sensitive structures of the foot.

The sensitive frog is separated from the third phalanx, the navicular bone, and the insertion of the deep digital flexor tendon by the digital cushion, a thick wedge of fibrofatty subcutaneous tissue. Papillae of the sensitive frog from the insensitive frog, a thick triangular structure with the apex pointing cranial and the base located between the heels. Each side of the frog is flanked by a deep groove called the collateral sulcus that separates each side of the frog from the respective bar. The central sulcus of the frog is a sagittal groove in the middle of the volar side of the base of the frog. The frog stay is sagittal ridge on the dorsal surface of the insensitive frog above the central sulcus. It cannot be seen unless the entire frog is removed from the foot.

## 4. Microscopic structure

The tubules in the distal part of the wall are hollow respective their mark consists of dying or dead cells. These tubules have lost their function. The cortex of the horn tubules has to stand a mechanical use. It is built out of helical cell layers in which every single cell presents the high border to that side on which the biggest pressure is. Outside the cells no tonofibrils can be found. The cortex is divided into three different parts: a inner, a middle and an outer layer. In these layers zones with different cells can be found: some with steep tonofibrils and some with flat fibrils.

The mechanical significance of the horn tubules is shown in their different anatomic structure. When the horse is moving two pressure can be recognized: one from the body to the ground and one in the opposite direction. The whole pressure is distributed in the horn capsule. The intertubular horn is functional linked with the horn leaves and it transits the vertical pressure into a radial and axial pressure for the horn tubules. In addition to this the horn tubules are also bend when the horse moves.

## 5. Physiology

### 1) Corium

The corium is a part of the outer skin which produces horn instead of hair. Because of this the hoof is able to stand many different kinds of strain. The production of horn is achieved by the cornification of the top corium cells which build at last a hard and coherent horn capsule. This capsule has a special suspension because of the arrangement of the different parts of the hoof namely those of the back. The corium covers the phalanx distalis and its cartilago on their outer and ventral side. To realize the production of different kinds of horn the surface shows several types of special cells: villus (tubules) and leaves. Because of this arrangement the area of the cornifying surface increases. Each villus of horn produces a horn tubule, the cells between them produce the so called intertubular horn which links the single horn tubules. That is the reason why its also called cement horn. As these two kinds of horn are connected very strong they build a homogeneous mass of horn which grows in a regularly rhythm. The new horn is soft and wet meanwhile the older horn becomes drier. Each part of the horn is produced by that part of corium which it lies on except of the wall. The biggest part of the wall is built by the coronary corium and not by the corium of the wall. The descend of all parts of horn is regularly and continuous towards the area that takes the weight of the horse when it moves. Normally the growth of the horn wall amounts to 8 or 10 mm per month. The different parts of the horn wall show a different quickness in growing: the toe needs almost one year, the side nine months, the buttress of heel 6 month. There are 5 different parts of the corium the limbus, the corona, the wall, the sole and the frog. They produce the different parts of the horn capsule of the hoof.

### 2) Limbus of the corium

It represents the transition between the skin with hair and the corium, can be seen as a 5 mm wide, plane groove which transits to the corium of the frog near to the bulbs. The surface looks like velvet because there are villus with 2 mm length and they build the limbus of the hoof. This horn is growing in a thin layer with the wall of the hoof and it is called glaze layer.

### 3) Coronary corium

Under the limbus the coronary corium starts with 6 mm long villus which are more than three times longer and thicker than the limbus.

**4) Wall corium:**

This part of the corium fills the whole area under the horn capsule. The surface is divided into 600 fold leaves which remind at the underside of a fungus and which end at the edge of the sole. If one magnifies one leaf many fine crossbars can be found. They are called accessory leaves and go down from the limbus in a parallel line. The cross-section shows a feathery appearance. In these feathery gaps the corresponding horn leaves mesh. They consist of the connecting intertubular horn and build in their totality the horn leaves. The purpose of this structure is to increase the surface and to link the wall corium and the horn wall. Those horn leaves of the wall horn which get in contact with the sole horn have also special crossbars which are called terminal villus. The terminal leaves interlink in an ninety degree angle where the corium of the wall and the sole meet. This contact zone is called white line (zona alba). The corium of the wall only produces a small part of the wall horn. Its just a connecting layer for the wall horn which is produced of the coronary corium. The underside of the wall corium has a close contact to the phalanx distalis and the collateral cartilage. They are even linked with several fibre so that there is a strict connection between the corium and the bone which makes it able for the hoof to stand hard and long moving.

**5) Sole corium:**

The surface shows a big amount of fine villus which produce the hard horn of the sole. Thats why this layer of horn has got a very fine structure of horn tubules.

**6) Frog corium**

The horn of the frog is very soft, it is produced with the help of very thin villus.

## 6. Function

When the horse moves several mechanism are used to put the pressure in balance and have a shock absorber. The angled articulations absorb the body weight elastically with the help of the ribbons and the tendons. Meanwhile the bone and cartilage in the articulations support it in a passive way. The hoof itself is able to level out some uneven patches by changing the structure of the horn parts elastically. Normally the sole of the hoof levels off and the buttress of heel wide up when the horse moves. The

frog just works as a shock absorber and fills the free space. The most important base for this mechanism is the suspension of the phalanx distalis on the inner side of the horn capsule with help from the wall corium. The elastic change of anatomic structure is the base for the so called hoof mechanism. On hard ground (street p.e.) this mechanism workes stronger than on soft ground because there is not as much pressure on the leg as in the second example. In addition to this the hoof mechanism supports the blood circulation in the corium so that the horn production is guaranteed.

The hoof should have a special form to be sure of a save moving of the horse. The hoof of the foreleg must have an angle of 46-50 degree (front wall to ground) and the relation between front wall and the wall of the heels has to be 3:1 meanwhile the hoof of the hind leg has to show an angle of 50-55 degree and the announced relation has to be 2:1. The front half of the hoof of the foreleg has to be round, the furthest line of the hoof has to be behind the middle line and the sole is vaulted soft and regularly. The hoof of the hind leg has a form like an egg, the furthest line can be found between the middle and the back third, the sole is vaulted more, the frog is stronger and the heels drift apart from each other.

Concerning with hoof form of WISSDORF et al. (1987), we could let know the following physiologic scale of hoof angles by front and rear legs.

| | front hoof | rear hoof |
|---|---|---|
| angle of back-contact plate: | 52°± 4° | 53°± 4° |
| angle of lateral side contact plate | 75°± 4° | 76°± 5° |
| angle of medial side contact plate | 82°± 3° | 76°± 3° |
| angle of lateral heel contact plate | 135°± 4° | 137°± 3° |
| angle of medial heel contact plate | 135°± 4° | 138°± 3° |

# Part Ⅱ : Hoof Nutrition

## 1. Nutrition

Through the process known as cause and effect, specific cases have exhibited positive results in conjunction with nutritional support. Some are quite subtle, others rather dramatic. The bottom line is that, in many cases, a process of systemic recovery holds no claim other than the supplements themselves. This is not to infer that a magic bullet exists, for it probably doesn't. What it does indicate is that nutrition, particularly case-specific support, has been overlooked in treating chronic laminitis and white line disease. A number of testimonials have been collected which, although certainly not scientific, are nonetheless pertinent, particularly given the nature of a disease that has perplexed and confounded the best authorities available. Farrier Science Clinic developed, documented and sent out surveys on 285+ horses through ANVIL Magazine and at clinics nationwide. These were received from veterinarians, horse owners and farriers. All support the findings that the immune system is violated and supplementation can be used for treatment. This is being clinically proven by research projects now underway.

## 2. Horses need

**1) Water: it makes up over 50% of their body weight**

**2) Protein: made up of amino acids**

a. 23 total amino acids

b. 10 essential amino acids

c. DL-methionine is the most important amino acid for hoof growth. It helps prevent edema and various infections, and works with choline to fight against tumors.

**3) Fats :** an energy source for the horse. Fats have 2.25 x more energy per gram than proteins or carbohydrates.

**4) Minerals**

a. Calcium and phosphorus

b. Magnesium

c. Sodium, chloride and potassium

d. **Iodine** stops the spread of fungus and dreaded bacteria and viruses in the hoof and skin. Certain amounts work through the thyroid gland to produce helpful bacterial antibodies needed for good health. **Iodine** is a key trace mineral which is necessary for many biological processes. Iodine is utilized by the thyroid in the production of thyroid hormones. These hormones aid in regulating the horse's basal metabolic rate as well as affecting intracellular processes of oxidation (3). Ethylenediamine dihydriodide (EDDI), a source of iodine, has been supplemented in the diet of cattle to prevent foot rot (2). Not only has this treatment been proven on the farm, scientific research has supported EDDI's effectiveness. Studies in the late 70's and early 80's were conducted with cattle to test whether orally administered EDDI would aid in the prevention and treatment of hoof rot. EDDI was found to be effective as a nutritional therapy to assist the animal in the prevention and control of foot rot (1). Field study surveys have indicated the use of supplements containing controlled amounts of iodine are effective in the treatment and prevention of white line disease (3).

e. **Inositol** - Helps to properly utilize choline. Promotes healthy hair, hoof and bones.

f. Trace minerals.

- **zinc** is one of the most important. It helps promote tissue growth at a faster rate. Helps fight infections. Zinc is important in many of the horses tissues including skin , liver, bone and muscle. When a zinc deficiency persists the horse may have the following symptoms: hair loss, lethargy, diarrhea, decreased feed intake as well as decreased growth rate (10). Zinc deficiency along with copper, have been associated with the occurrence of metabolic bone disorders in young growing foals such as O.C.D., epophysitis and contracted tendons.
- **Selenium** - A mineral essential in promoting hoof growth and quality. It is also required for proper muscle function and endurance. Selenium possesses anti-fungal qualities.
- **Copper** is needed for bone, cartilage, elastan formation, utilization of iron, and improves pigmentation and the structure of the hair and the hoof. Iodine is most commonly associated with enlargement of the thyroid gland, known as goiter. The condition can be either a result of excess iodine in the diet or an iodine deficiency. Many fear the use of iodine for this very reason. However,

iodine toxicity is unlikely to occur under normal feeding conditions (4). The NRC has estimated that iodine is safe at levels up to 5 mg/kg of dry matter intake per day. Common equine feeds range from 0 to 2 mg/kg of iodine. These levels vary depending upon the iodine content in the soil. (5).

**5) Carbohydrates**

a. Starches
b. Sugars
c. Glycogen

**6) Vitamins**

a. Fat soluble: A, D, E, and K
   - Vitamin A promotes tissue growth, strong bones, hoof, healthy skin, hair, teeth and gums. Helps build resistance to disease.
   - Vitamin D helps properly utilize vitamin A, calcium, phosphorus. Necessary for strong bones, teeth and hoofs.
   - Vitamin E helps to retard cellular aging; an anti-oxidant. Supplies oxygen to the cells for better endurance. Helps fight fatigue, accelerates healing and growth.

b. Water soluble: Thiamine, riboflavin, niacin, vitamin C, pantothenic acid, pyridoxine and biotin.
   - Niacin helps increase circulation of blood to areas of the body for faster healing and growth.
   - DL-biotin is second most important nutrient in hoof growth and repair. Helps alleviate eczema and dermatitis through utilization of proteins.
   - Choline helps eliminate poisons from the system by aiding the liver; helps nerve response to aid the healing.

## 3. Hoof Growth

**1) Normal growth**

Foals : 5 mm per day - 150 mm in two months (and more, with increased work and/or exercise)

Older : .2 mm per day - 60 mm in 1 month (and more, with increased activity)

**2) Factors (aliments/diseases) that cause increased hoof growth**

a. Laminitis
b. Cracks
c. Abscess
d. White line/hoof disease
e. Trimmed too short
f. Hoof and leg imbalance

**3) Factors that affect rate of hoof growth**

a. Blood flow to coronary band (affected in part by exercise)
b. Nutritional factors: Controversial in the area of feeding a deficient diet vs. excess feeding

**4)** There are several nutritional factors which are important to normal hoof growth. The protein structure of the hoof is loaded with sulfur-containing amino acids, so elemental sulfur is important to normal hoof growth. The sulfur-containing amino acids methionine and cystine are two of the more important ones to horses. Methionine is known to be necessary for keratinization of the hoof wall. It helps increase the bond between the lamina and therefore used to treat foundered horses.

In addition to sulfur protein, calcium and the vitamin biotin are very important to normal hoof growth. Calcium, in the correct ration with phosphorus (1.5 : 1 to 2 : 1 calcium), is important for hoof quality. Biotin is known to improve hoof quality and rate of growth.

# Part Ⅲ : Diseases of the hoof

## 1. Laminitis

### 1) Definition

An extended inflammation of the wall corium which can be found at all four legs or especially at the forelegs.

### 2) Etiolgy

It can be a metabolic disease that selectively affects the feet. It is often caused by overfeeding with large amounts of grain to inactive horses. Ergot toxicosis resulting from poisoning by toxic fungi cause the problem on foot. Various stress factors; abnormal concussion or weight bearing, overwork for the level of conditioning, drinking cold water when hot, high fever for an extended period of time, toxic drugs (especially steroids) or poisonous feed stuffs, endotoxin, the high blood concentration of lactic acid have been known to cause laminitis

Often the process of the illness is very fast (a few hours), in this case clear symptoms can be seen. But sometimes a slow and insidious process takes place without clear paralysis. The horse shows an increased sweat secretion, tremor of the muscles, a stiff bearing and a kyphosis because of the aching. The fore legs are put in front of the body and the hind legs are pushed under the body. The horse doesn't use the whole volar side of the hoof but only the heels when it moves. Sometimes temperature, pulse and breathing increase. The hooves are warmer than normal and one can find a (strong) pulsation at the distal part of the leg. The hooves are aching when one manipulates them and the structure of the corona is changed (convex or concave). The process can be very different: the horse can get healthy in between four or fourteen days or the constitution can get worse. In some case the connection between the bone and the wall corium is lost so that the phalanx distalis may rotates or drops. It can be shown with the help of a radiograph on which you have to control the angles between the horn capsule and the bone and also this between the corona and the bottom of the hoof. At worst the phalanx distalis can break through the horn of the sole, the whole hoof can become deformed, a purulent inflammation can be found, the whole horn capsule can be

lost, a pneumonia or an infection of the body can arise so that the horse maybe dies. This illness can have many different reasons, for example the horse is overstrained on hard and dry ground, distance riding, standing on hard ground in the stable or a continual paralysis. In some cases too much feed or an intoxication can be the reason for the arise of the illness. At last it can be found as a sequel of an infection or an incarcerated placenta.

All details of the arise and the process of the laminitis are not known already but the main point is the circulatory disturbance and the damage of the smallest vessels of the corium. As sequel a bleeding and an inflammation of the corium can be found.

Treatment for laminitis has to take into consideration the developing stage of the disease. Several different methods of therapy can be used. First the horse has to get a box with soft and smooth bed. If the horse has got a hoof shoe, one can let it on the hoof but old nails of the toe have to be taken out. Wet and warm bandages from the first to the third day can be very useful, later dry bandages are a helpful advice. Blood-letting and reinfusion of plasma expander can be used to dilute the blood and to decrease the concentration of the total blood cells, so haemtocrit is lower. In addition to this an injection of heparin can be a help, if the radiograph is negative. Beside, special hoof shoes (with high heels) and dietetic measures have to be taken.

## 2, Hoof abscess; gravel; pus pocket

### 1) Definition

A circumscribed purulent inflammation on the surface of the corium.

### 2) Etiology: Spherophoruus necrophorus

Diagnostic method: location with a hoof tester

One can divide different kinds of inflammation: a deep and a superficial form. The superficial purulent form affected only the superficial layer of the corium (Stratum germinativum and corium). The purulent secretion product (thin, black-grew pus) accumulate in a antrum and its named pododermatitis purulenta or Hoof abscess. Because the pus cannot drain, high pressure begins and the inflammation spreads. The way with the fewest resistance is along the white line to the bars and sole or along the leaves of the wall corium to the corona. The ribbon of the limbus and the corium can soften and remove and the pus is eruption on the corona. Because of the growth horn at one part at the sole, a double sole exists.

The deep purulent form marks the liquefaction all layer of the corium. Because of the purulent inflammation in the subcutis abscess and phlegmons are build at the part of the sole and the bulbs. The eruption of the pus (thick, yellow-white) unlike the superficial forms in the skin of the corona and the bulbs. More complications are necrosis of the corium and the Os ungulare, infection of the hoof cartilage, the frog and bulbs padding and at least it could be seen a systemic infection and tetanus.

The main cause is because of a lesion at a part of the white line. Microorganism, which produce a pus, can reach, because of the capillary suction between thin horn ruptures, in deeper layers or with dirt in superficial parts. Some more cause are step into a nail, bruising of the sole, hollow wall, horn clefts and kick on the corona.

The important symptoms are lameness, pulsation the middle foot arteries and painfulness if the hoof is in percussion. After cutting the part of the affected hoof, pus of different color flows out. This is the first and best therapy. A wet warm bandage infusion with antiseptic solution (Rivanol, Entozon) for 1-3 day could find the place of the infection much easier. The suppuration must be at the part of the sole and the area on which the hoof is based on shunnel-shaped free operate because of the free pus. The undermined horn must be prepared until the part of the healthy horn, because the rest infection lead to a relapse. The defect has to be treated with iodine-ether-solution fill witch graze tampon and to be dried. A dry compression bandage prevent the prolaps of the corium and a regular building of the horn. After the horn is built we can use a Dallmer-hoof shoe ore a leather sole. After 2-6 weeks the sole horn is hard enough to be used without a hoof shoe or a sole.

Furthermore there are some other illnesses of the hoof, for example putrefaction of the frog because of permanent dirty and wet hoofs and lesions of the hoof because of trauma, stab or incision. Thrush is a common disease of the frog. Canker or hoof cancer is a chronic hypertrophy of the sensitive frog. Yeast infection by Candidia albicans is fairly common in the humid climate zone. Sandcrack is a vertical crack in the hoof wall. Keratoma or keraphyllocele is a rare tumor of the horny laminae. Contraction, hoof bound or atrophy of the hoof is a drawing togrther of the buttresses causing a constriction of the hoof. Corns start as bruises of the sensitive sole in the angle formed by the wall and bars. Sole bruises are red spots or "strawberries" in the sole or frog of variable size. Pedal osteitis is an inflammation of the coffin bone. Side bone or ossification of the lateral cartilage is a loss of flexibility of the foot cartilages. Quittor or necrosis of the lateral cartilages is an infection of the lateral cartilages. Sheared heels are the result of unequal weight bearing by the foot.

# Part Ⅳ : Laminitis in Przewalski horses kept in a semireserve

## 1. Introduction

The Przewalski horse (Equus ferus przewalskii) is the only surviving wild relative of the domestic horse. It can be regarded as a representative of a group of related species, which were once widely distributed over Europe and Asia and from which the domestic horse derived (NOBIS, 1971). The species was rediscovered by Przewalski and described scientifically by POLJAKOV in 1881. Przewalski horses have been extinct in their natural habitat since the late 1960s and are preserved in zoos from extinction. A population of about 1600 individuals are currently protected in zoos and reserves (VOLF, 1996). The challenge of reintroduction into its former habitat is ongoing (VAN DIERENDONCK et al., 1996). Semireserves were created by the European Conservation Project for scientific research in preparation for reintroduction. They are defined as enclosures large enough to carry a group of Przewalski horses throughout the year without any additional feeding. As far as possible, the horses are kept isolated from external influences, though intervention should be possible i.e. for veterinary care. Hence, the purpose of the semireserves is not limited to preparing animals for survival under natural conditions, but allows us to learn what factors are important with respect to reintroduction into the wild (ZIMMERMANN, 1997). The responsibility ofhumans for protecting animals from suffering extends to animals intended for reintroduction to the wild (SCHEIBE and RICHTER, 1999). Even if the environmental conditions and the organisation are optimal, animals may have problems with natural conditions due to a lack of experience, too short acclimatisation or the presence of disease. As one of the direct ancestors of the domestic horse (Equus caballus), the Przewalski horse offers a unique opportunity to investigate the genetic and environmental effects that modern breeding and selection have had upon the development of the horse.

Thus the semireserve offers diverse opportunities for significant scientific research. As part of a general screening program, the hoof development in a group of Przewalski horses in a semireserve was followed (PATAN, 2001). Since the foundation of this semireserve in 1992, veterinary treatment was not necessary with the exception of hoof trimming in two animals in 1993. However, major health problems were encountered in

the spring of 1999, when three other mares showed signs of laminitis. Laminitis is an aseptic disease of the hoof, the cause of which is multifactorial (MARKS, 1984; RIGGS and KNOTTENBELT, 1998). This disease is and will continue to be one of the most frustrating medical conditions facing the horse owner, farrier or veterinary practitioner (HOOD, 1978).

The symptomless developmental phase of laminitis merges into the acute phase with the onset of hoof pain and lameness. After the acute phase it can make an apparentcomplete recovery (as in the three cases described) or develop palmar/plantar displacement (rotation) of the coffin bone, a sign of chronic laminitis (POLLITT, 1999, Fig. 396). This process is connected to the destruction of the suspensory apparatus of the coffin bone (PELLMANN et al., 1997) which begins during the developmental phase (POLLITT, 1999), before the first clinical signs of foot pain are apparent. Laminitis is a disease of the suspensory apparatus of the coffin bone (BUDRAS, 1999). The suspensory apparatus consists of the lamellar bond between the hoof wall and the coffin bone. The body weight pressure is transformed into a traction force by the dermal and epidermal part of the suspensory apparatus of the coffin bone. In the hoof wall it is retransformed into a pressure loading the forces on the weight bearing margin of the hoof or horse shoe (BUDRAS and HUSKAMP, 1999).

Our studies aim to clarify the following:

1) What caused the development of laminitis?
2) What treatment is relevant and achievable under the management conditions of the reserve?
3) Are there predisposing factors leading to the establishment of laminitis and what prophylactive measures, if any, can be taken to prevent it?
4) Are the affected animals suitable to being returned to the wild?

## 2. Materials and Methods

### 1) The semireserve

The semireserve Schorfheide-Liebenthal was created in 1992. It is situated in north-eastern Germany, 70 km north of Berlin. It consists of a 0.42 $km^2$ enclosure, with a large meadow and some smaller plots of pine and oak woodland. It is largely surrounded by forest. A small fenced area, located in the northern part with the water

point and salt licks, is available to the animals. It measures 4125 $m^2$, with one third covered with grass, a further third with sand and the rest with pine trees with only sparse vegetation. A second smaller fenced area of 940 m2 is only covered with grass. The soil of the semireserve consists largely of sandy loam and some sandy plots.

The vegetation was analysed and the plant species determined(DIERSCHKE, 1994). The following composition was found (SIELING, 1998): Festucetum ovinae: 2.96%, Lolio-Cynosoretum: 10.36%, Festucae rubrae-Cynosoretum: 1.58%, Seeded grassland with Utrica - and Cirsium: 19.23%, Seeded grassland: 54.59%, Prunello-Ranunculucetum: 0.11%, Teesdalio-Arnoseridetum: 4.76%, Calamagrostietum epigeji: 0.255, Holco mollis-quercetum: 1.19%, Agrostio-Quercetum: 2.31%, Pine forest: 2.3%, resting places without vegetation: 0.36%.

**2) Horses**

Table 1. Horses in the semireserve Schorfheide

| Name | year of birth | in reserve from |
|---|---|---|
| Bulgania | 1991 | 1992-present |
| Ashnai | 1991 | 1992-1996 |
| Mida | 1991 | 1992-present |
| *Mada | 1991 | 1992-present |
| *Lulu | 1992 | 1993-present |
| *Sprille | 1990 | 1992-present |
| Barbarina | 1991 | 1992-1997 |
| Sirena | 1991 | 1992-1997 |
| Duma | 1992 | 1993-present |
| Spirre | 1991 | 1992-1996 |
| Alina | 1988 | 1992-present |
| Nomin | 1991 | 1992-1996 |
| Vicky | 1996 | 1997-present |
| Viola | 1996 | 1997-present |
| Virginia | 1996 | 1997-present |
| Medi | 1991 | 1997-present |
| Medina | 1994 | 1997-present |

x) *these mares showed signs of laminitis in the spring of 1999

The horses originated from several zoos in Germany. All were mares, since reduction and delay of reproduction was one of the aims of this special semireserve. The mares established a stable herd structure, led by the oldest mare (Alina). At the start of the observation period the herd consisted of 10 mares, with two more added after the first winter. In 1996, four mares were removed and two more in 1997. Later in 1997 five new mares were introduced.

**3) Data collection**

The body mass and the weather conditions were recorded because of their importance to grass laminitis (HOUPT, 1994).

**Body mass** was recorded from 1994 onwards by an electronic weighing machine connected to the water trough (IMF Technology, Frankfurt/O, SCHEIBE et al., 1998). The water trough had a narrow access stall which could only be used by one animal at a time. When an animal entered the stall, a system of light barriers was activated. The individual was identified at a transponder identification station by means of external collar-mounted transponders attached to the animal. When the mare stood alone and still in the stall, her weight was measured by an electronic weighing machine set into the floor of the stall. The mare's identification code, body weight and the amount of water consumed were recorded by a PC together with the time of day and date in monthly dBase format files.

Ambient air temperature was measured at hourly intervals (sensor: PT 100, shielded against radiation, 1m above ground) and was recorded by the same PC that was used for water recording.

Files were analysed for monthly mean body weigth of each of the animals and monthly mean air temperature. The mares were regularly observed (one day per week) and unusual behaviour was recorded.

## 3. Results

**1) Weather conditions** at the time of occurrence of laminitis in the three mares

The spring of 1999 (April-May) was dominated by a period of stable high air pressure. In the night, temperature fell to values between 4 and + 10℃, maximal temperatures during the day were between 16 and 33℃. During most days, temperature varied between a daily minimum of 3 to 5℃ and maximum of 20 to 23℃.

**2) Body weight**

To evaluate a potential long-term influence of body weight on the development of lameness, wecompared the body weight curves of the animals affected by the disease with those of healthy horses. For this, we selected those three animals for which body weight data were available in the whole observational period: Alina, Bulgania and Duma.

To each individual body weight curve a model was fitted consisting of a piecewise linear trend component and a cyclic component. In the trend components, a breakpoint was found at March 1996. The cyclic component was modelled by a sinus function with a cycle lenght of 12 months. The results of the measurements according to Table 2 and Figure 1:

(1) After spring 1996 body weight per time increased.

(2) The initial weights of the healthy animals were lower than those of the laminitic ones.

(3) There was a tendency of higher slopes in the trend curve after March 1996 for the sick horses.

(4) There was a trend to higher cycle amplitudes for the sick horses.

(5) The differences in the phase shifts were marginal.

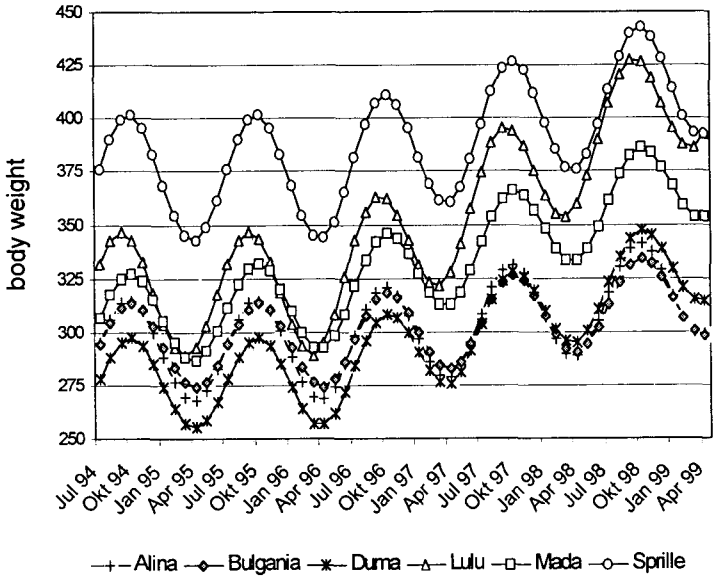


Fig. 1. Body weight.

Table 2. long-term body weight parameters of the horses affected by lameness (Lulu, Mada, Sprille) and three healthy horses (Alina, Bulgania, Duma). c1 = initial weight, b1 = body weight trend before march 1996, b2= body weight trend after march 1996, a = amplitude of annual cycle, p = phase shift of annual cycle.

| | c1 | b1 | b2 | A | p |
|---|---|---|---|---|---|
| Alina | 291.99 | 0.0 | 0.84 | 23.75 | 5.91 |
| Bulgania | 296.00 | 0.0 | 0.67 | 19.83 | 5.79 |
| Duma | 276.80 | 0.0 | 1.61 | 21.12 | 5.84 |
| Lulu | 316.61 | 0.0 | 2.69 | 28.78 | 6.27 |
| Mada | 305.17 | 0.38 | 1.68 | 21.43 | 5.86 |
| Sprille | 372.60 | 0.0 | 1.34 | 29.51 | 5.90 |
| Healthy | 285.61 | 0.0 | 1.17 | 22.57 | 5.84 |
| Sick | 336.46 | 0.0 | 1.90 | 26.31 | 5.92 |
| All | 311.09 | 0.0 | 1.52 | 23.01 | 5.86 |

We conclude that 1) after spring 1996 the increase of body weight per time was generally higher compared with the time before, 2) the initial weights of the healthy animals were lower than those of the sick ones, 3) there is a tendency of higher slopes in the trend curve after March 1996 for the sick horses, 4) there is a tendency of higher cycle amplitudes for the sick horses, 5) the differences in the phase shifts are marginal. Because of the low number of animals, the conclusions can not be statistically confirmed.

**3) Diagnosis:**

The **initial diagnosis** by the authors and the local veterinary surgeon of mid April 1999 based on observation of behaviour, gait, stance, walk and trot of three mares whose initial weights were higher than those of the healthy mares.

**Behaviour :** The diseased horses reduced their locomotion, moved slowly but grazed intensively. When we tried to approach them, they were shielded against us by the other (healthy) mares.

**Gait, stance :** All four hooves were placed forward putting pressure on the heels rather than on the front parts (toes) of the hoof, which are usually more severely affected. Thehind legs were placed well under the stomach (Fig. 2). The mares shifted their weight from one side to the other within few seconds in order to reduce the pain.

At **walk and trot**, the stride was shortened with the front limbs being lifted very high.

The final **diagnosis** was confirmed by palpation and the occurrence of very deep horn rings on all hooves and a laminitic horn ring on the right front hoof of one mare.

**Palpation** and physical contact are limited in wild horses in relation to their moods and sense of wellbeing. These mares showed signs of painful hooves and their "cooperation" was reduced. However, using patience and the horses' natural curiosity, we were able to examine the mares. All four hooves of the affected mares showed heat in the coronary band and a bounding digital pulse. The mares had palpable "laminitic"depressions just above the coronary band (below the hair line). Signs of improvement were seen two weeks after the occurrence of the laminitic symptoms. But one mare (Sprille) had shown a new (second) laminitic episode with the same laminitic symptoms.

Deep **hoof horn rings** were seen four weeks after the occurrence of the laminitic symptoms (Fig. 3). All three mares showed very distinct alimentary horn rings (AHR), whose distal edge was10 mm from the hair line. These AHR showed a proximodistal expansion (width) of 3 mm and were about 3 mm deep (Fig. 3 and 4). They were present on all hooves.

A typical laminitic horn ring also developed on the right front hoof of one mare only (Sprille). The unaffected mares showed neither distinct AHR nor laminitic rings. These distinct AHR, typical for acute laminitis, must be distinguished from the laminitic horn ring which is produced as a consequence of chronic laminitis due to the cessation of hoof horn production at the dorsal coronet. The laminitic horn rings diverge at the heel which is growing faster than the dorsal hoof wall (Fig. 3).

**4) Treatment and management**

An adequate laminitic therapy was not possible under the conditions of a semireserve, so that only management measures could be applied.

On April 22, 1999 it was decided to remove the three laminitic mares from the rich pasture in the main part of the semireserve and to confine them onto the poorer pasture of the separately fenced areain the northern part of the enclosure. The vegetation there was already much shorter than on the main pasture and soon became very sparse during the next days. Straw was offered additionally but rarely consumed. A water hole was offered for cooling of thehooves, but the animals did not use it. First signs of improvement were recorded two days later. On May 8, Lulu jumped over the 2 m high fence and re-entered the main enclosure. From May 14, Sprille and Mada showed

normal locomotion and were released back into the main enclosure on May 21. On 1 June, Sprille was observed again to be lame and was confined in the 4125 m2 fenced area on the next day. A new small fenced area of 940 m2 was prepared and Sprille was brought into it on June 16. Vegetation there was tall and dry and much poorer than on the main pasture. As vegetation on this enclosure soon became extremely short, additional feed was cut from the main pasture. It was taken from plots of dry and tall grass, lush grass and clover were avoided. Signs of improvement were seen from June 13, but the mare was not released until July 15, when she had been sound for about three weeks.

**5) Recovery**

Mada and Lulu had fully recovered from their laminitic condition by mid May and Sprille by mid July.

## 4. Discussion

Laminitis occurs rarely in Przewalski horses as this condition is probably a recent disease in the evolutionary timescale. This illness has a higher incidence in those equine breeds that have been domesticated most recently (HINCKLEY, 1997). Laminitis in Przewalski horses kept in a zoo was mentioned by KUNZE (1992) and HOUPT (1994). We are not aware of any publications concerning the occurrence of laminitis in Przewalski horses in close to natural conditions like a semireserve, thus justifying this communication of our results.

## 5. Pathogenesis

The probable cause of these bouts of laminitis in the three mares was the consumption of large amounts of carbohydrate rich feed, in the form of rich pasture, under certain climatic conditions. This condition is described as carbohydrate overload laminitis or specifically as grass laminitis (grass founder) (EUSTACE, 1992, HOUPT, 1994.). Protein overload, such as the white clover consumed by these mares, may also be a causative agent. This type of laminitis may be connected to the effect of certain climatic conditions on grass metabolism. Cold nights, frosty mornings and warm sunny

days result in the accumulation of high concentrations of fructans (water-soluble fructose polymers) in the grass, which may trigger hindgut fermentation and lactic acidosis in the horse. Grass fructans have been implicated in triggering the onset of grass laminitis (LONGLAND and CAIRNS, 1998). During conditions of carbohydrate overload, populations of Staphylococcus bovis have been shown to increase exponentially. Current investigations by POLLITT (1999) are trying to establish if Staphylococcus bovis is involved in the pathogenesis of laminitis, especially that caused by carbohydrate overload.

Two current theories concerning the pathogenesis of laminitis excist. Endotoxins play a vital part in both these theories by triggering laminitis directly (HOOD, 1978) or indirectly (POLLITT, 1999).

**1) Vasoconstriction theory**

Vasoconstriction and especially venoconstriction is triggered by endotoxins which act as vasoactive mediators (HOOD et al., 1978). Venoconstriction and high hydrostatic interstitial fluid pressure impede the flow of blood in the lamellar microcirculation. This can cause ischaemic necrosis of epidermal lamellae that leads to the destruction of the suspensory apparatus of the coffin bone.

**2) Metalloproteinases theory**

Metalloproteinase 2 and metalloproteinase 9 (MMP) are enzymes capable of destroying key components of the suspensory apparatus of the coffin bone i.e. the basement membrane between the dermal and epidermal lamellae. An endotoxic factor present in the supernatant of Streptococcus bovis cultures, isolated from the equine caecum, activates equine hoof MMP-2 and causes lamellar separation in vitro (POLLITT, 1999).

## 6. Treatment

Treatment was aimed at two goals:

**1)** To reduce endotoxin production and acidosis in the horses by reducing the ingestion of carbohydrate rich food. This also served to reduce their excess bodyweight.

**2)** To reduce the mares'level of activity by penning them in a small adjoining paddock to prevent tearing of the suspensory apparatus of the coffin bone. Trimming

was not necessary because after the alimentary and the laminitic horn rings had grown downwards the hoof was well-shaped.

## 7. Predisposing factors to laminitis

For an outbreak of laminitis to occur the following predisposing factors need to be met:

**1)** Seasonal factors play a part in the occurrence of grass laminitis (LONGLAND and CAIRNS, 1998). Lush spring pasture produced under certain climatic conditions is a predisposing factor of laminitis in these semiwild conditions, shown by the simultaneous occurrence of laminitis in these three mares without previous history of this condition. Frozen grass and high concentrations of fructans in spring are perceived to be one of the main causative factors in grass laminitis. As fructan concentration decreases with plant maturity in summer and autumn, the risk of grass laminitis decreases. Clover consumption also falls due to the increasingly bitter taste throughout the season, thus lowering the risk of laminitis.

**2)** Excessive body weight must be a factor as the three heaviest mares were affected. These mares had been gaining weight in the preceding three years at a greater rate than the remaining unaffected mares and had lost very little condition during the winter before the occurrence of laminitis. This was contrary to the normal annual cycle of variation in bodyweight described by MAYES and DUNCAN, 1986.

**3)** Age is a factor in the development of laminitis especially when linked to lower levels of activity and corresponding weight gain. Laminitis rarely occurs in foals (BUDRAS and HUSKAMP, 1999).

## 8. Prevention

**1)** Reduction in grass intake could be achieved by increasing the grazing pressure by an increase in stocking rate of the horses or mixed grazing with another species such as sheep. Alternatively, a part of the grazing could be removed by making hay.

**2)** A longer term solution to the problem may well be to sow specific varieties of grass with lower concentrations of water soluble carbohydrate, for example ryegrass (LONGLAND and CAIRNS, 1998).

**3)** Rigorous observation of the herd, especially at times of increased pasture availability, is important to detect early disease symptoms.

## 9. Selection of individuals for reintroduction into the wild

For the successful release of zoo animals into the wild it is useful to introduce a middle step of a semiwild reserve. This allows the animals to be monitored with respect to their adaptation to the less intensive management conditions of the semireserve when compared with those prevailing in zoos. In the semireserve, the animals are free to show annual variations in behaviour patterns, feed and water intake and reproduction (SCHEIBE et al., 1998). A seasonal influence on horn production rate, horn abrasion and horn quality in the hoof wall occurs under the conditions of the semireserve (PATAN, 2001). The relative success or failure of the animals to adapt to changing conditions allows a selection of those suitable for release into the wild.

On the basis of their weight, relative old age and susceptibility to laminitis, the three mares which succumbed to laminitis should not be chosen for release into the wild.

## Summary

Semireserves were created by the European Conservation Project for scientific research in preparation for reintroduction in the wilderness. They are defined as enclosures large enough to carry a group of Przewalski horses throughout the year without any additional feeding. The semireserve offers diverse opportunities for significant scientific research. As part of a general screening program, the hoof development in a group of Przewalski horses was investigated in the semireserve Schorfheide near Berlin. Since the foundation of this semireserve in 1992, veterinary treatment was not necessary with the exception of hoof trimming in two animals in 1993. However, major health problems were encounteredin the spring of 1999, when three other mares showed signs of

laminitis. The initial diagnosis by the authors and the local veterinary surgeon based on observation of behaviour, gait, stance, walk and trot of three mares whose initial weights were higher than those of the healthy mares. The initial diagnosis was confirmed by palpation and the occurrence of very deep horn rings on all hooves and a laminitic horn ring on the right front hoof of one mare. An adequate laminitic therapy was not possible under the conditions of a semireserve. The applied management aimed at two goals: 1. To reduce endotoxin production and acidosis in the horses by reducing the ingestion of carbohydrate rich food. 2. To reduce the mares'level of activity and to prevent tearing ofthe suspensory apparatus of the coffin bone. To achieve these two goals it was decided to remove the three laminitic mares from the rich pasture in the main part of the semireserve and to confine them onto the poorer pasture of the small separately fenced area. All three affected mares had fully recovered from their laminitic condition. Prevention of grass laminitis can be achieved by the following measures: 1. Reduction in grass intake could be achieved by increasing the grazing pressure by an increase instocking rate of the horses or mixed grazing with another species such as sheep. 2. A longer term solution to the problem may well be to sow specific varieties of grass with lower concentrations of water soluble carbohydrate. It is essential to determine the exact horn quality, to judge the result of prophylactic and therapeutic actions objectively. Poor horn quality can lead to very painful hoof diseases and diminish the utitility of a horse. The importance and clinical significance of hoof horn quality is shown in an American study by Slater and Hood, 1997, stating that 28% of all horses suffer from problems with the hoof wall. The quailty of the coronary horn, the monthly hoof horn production and the horn loss in the dorsal part of the hoof capsule of Przewalski horses in comparison to domestic horses were examined. For this purpose we would like to offer suitable methods for horn testing.

The aim of our study is to clarify the question if seasonal influences on horn production rate, horn loss and horn quality occur.

In order to demonstrate alterations induced by domestication, the results of this study were then compared to our related data on the hooves of domestic horses. In doing so, we compare the ancestors and their descendants. Overgrowth of the hoof due to insufficient horn abrasion can be seen in Przewalski horses held in captivity. The goal of this study is also to examine whether hoof trimming with inevitable anesthetization of the wild horse is necessary or if there is a self regulating mechanism to limit the hoof length.

The annual variations of the horn production rate are significant. In summer the horn production rate is two times higher than in winter.

Similar variations were observed in horn abrasion. The peaks are caused by broken and chipped out horn. I come back to this problem later.

In order to investigate a possible correlation between horn production rate and horn quality, we took samples from three different locations. The range of methods included material testing as well as light-microscopical, scanning and transmission electron microscopical techniques.

For mechanical-technical testing of horn hardness we used the Shore-C equipment. In external coronary winter horn we measured 92 Shore-C units, in summer horn only 90 Shore-C units.

The maximum of horn hardness is 100 Shore-C units. To explain the structural factors of horn quality we compare the horny masses with brickworks. The architecture of coronary horn tubules is comparable to that of factory chimneys.The bricks represent the horny cells and the motar is comparable to intercellular cementum.

We compared different portions of identical horn tubules, numbered 1-8, to analyze the hornarchitecture according to the time of horn production. The portions produced in winter time are characterized by more densely packed horn tubules, by a smaller medullar and a larger cortex of horn tubules. All three parameters are typical for hard horn according to the literature. This statement was confirmed by our results of material testing. In summer horn it was vice versa. There is a less number of horn tubules per unit area and this is typical for a lower hardness of the horny mass.

The intracellular factors of horn quality cytokeratins and keratinfilament associated proteins show no seasonal difference between winter and summer horn, neither in electron microscopy nor in gel-electrophoresis.

The intercellular factor relates to the intercellar cementum of the intercellular cleft. In winter horn the narrow intercellular cleft is completely filled with intercellular cementum that causes sufficient adhesion between the horny cells. In summer horn it is just the opposite case. Microcracks occur between horny cells that decrease the firmness of the summer horn.

In comparison to domestic horses we found a better horn quality in Przewalski horses. This was characterized by a higher hardness of the external coronary horn, a higher water storing capacityand higher seasonal alterations in horn production rate, horn loss and horn quality.

In conclusion, the seasonal variations of horn quality and horn production rate contribute to the seasonal variations of horn loss. A considerable overgrowth of the hoofcould be observed in the spring months. According to THOMASON, 1998, this causes enormous stress in the hoof wall including the suspensory apparatus of the coffin bone. The consequences are vertical and horizontal horn cracks located distally to the coffin bone, followed by the occurrence of broken and chipped out horn from the weight bearing margin of the hoof. This process starts on the hoof dorsum (on the toe) in May.

Our structural investigatons and material testings proved that the broken border of the horizontal horn cracks were made up by summer horn and the weight bearing margin consisted of winter horn. The differences in horn quality and horn cracks cause broken and chipped out horn acting as an additional self regulating mechanism of horn loss and hoof length. This mechanism comprises the whole weight bearing margin including the heels. It terminates in August. After abrasion of the unevenness the hoof is properly shaped in autumn and winter. Therefore, hoof trimming of Przewalski horses kept in semi-reservations is often unnecessary. This is of great interest, as such procedures require immobilisation involving great risks for each animal and also brings great excitement and stress to the herd. This self regulating mechanism of horn loss causes no lameness and decreases the stress in the hoof wall and the suspensory apparatus of the coffin bone. It diminishes the risk of laminits, the main disease of the suspensory apparatus of the coffin bone.

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