From the Department of Large Animal Surgery and Orthopedics

University of Veterinary Medicine Vienna

(Department Spokesperson: Prof. Dr. O. Univ. Dr. H. H. F. Buchner)

Box: Orthopedics

CORRELATION BETWEEN THERMOGRAPHICAL CHANGES AND ORTHOPEDIC DISEASES IN HORSES

INAUGURAL-DISSERTATION

to obtain the dignity of a

DOCTORA MEDICINAE VETERINARIAE

University of Veterinary Medicine Vienna

presented by

Graduate veterinarian **Ayse KOCABIYIK**

Vienna, in April 2012

SUPERVISOR

O. Univ.-Prof. Dr. med. vet. **Christian STANEK**

Clinic for Horses, Large Animal Surgery and Orthopedics

REVIEWER

Ao. Univ.-**Prof. Dr. Günther SCHAUBERGER**

Institute of Physiology, Pathophysiology, and Biophysics

Dedicated to my brother Ismail KOCABIYIK

Table of Contents

IV. Results

List of abbreviations

ΔR	Absolute temperature differences of the respectively symmetric regions
ΔRMax	Absolute differences of the regional maximum temperatures of the respectively symmetric regions
ΔRMean	Absolute differences of the regional mean temperatures of the respectively symmetric regions
ΔRMin	Absolute differences of the regional minimum temperatures of the respectively symmetric regions
ATF	Additional thermographic findings, thermal pattern changes in the areas that were not related with the injuried region
B1	Thoracic region
B2	Lumbar region
B3	Sacral region (in top line view)
BST	Barium strontium titanate
C1	Right shoulder region
C2	Left shoulder region
CD	Clinic diagnosis
CDR	Clinically diagnosed regions
Croup 1C	Sacroiliac region, caudal view
Croup 1L	Sacroiliac region, lateral view
Croup 2C	Hip region, caudal view
Croup 2L	Hip region, lateral view
FC	Fore limb, cranial view
FD	Fore limb, dorsal view
FLM	Fore limb, lateromedial view
FP	Forelimb, palmar view
G	Group
G1	Group 1 (Horses with hoof injuries)
G2	Group 2 (Horses with joint injuries)
G3	Group 3 (Horses with tendon/ligament injuries)
G4	Group 4 (Horses with bone injuries)
G5	Group 5 (Horses with other diseases)
G6	Group 6 (Horses with no diagnosis)
HC	Hind limb, caudal view
HCI	Hydrochloride
IRT	Infrared Thermography
HD	Hind limb, dorsal view
HML	Hind limb, mediolateral view
HP	Hind limb, plantar view
K	Kelvin

MC3	Os metacarpale 3
MC4	Os metacarpale 4
MT3	Os metatarsale 3
n	The number of the recorded values
N	The number of the horses
N1	From the atlas to distal end of the axis
N2	From the second to fifth cervical vertebrae
N3	From the fifth cervical vertebrae to seventh cervical vertebrae
nCDR	Number of the clinically diagnosed regions
nTSR	Number of the thermographically suspected regions
^{o}C	Celsius
OCD	Osteochondrosis dissecans
R1	Hoof region
R2	Pastern region
R3	Fetlock region
R4	Canon bone region
R5	Carpal/ tarsal region
R6	Radial/ tibial region
R7	Elbow/stifle region
RMax	Regional maximum temperature
RMean	Regional mean temperature
Rmin	Regional minimum temperature
RST	Regional surface temperature values, RMean, Rmin , Rmax, ΔRMean, ΔRmin, ΔRmax
TF	Thermographic findings, thermal pattern changes in the areas that were related with the injured region
TSR	Thermographically suspected regions

CHAPTER I:

I. INTRODUCTION

Temperature has been used as a diagnostic aid since ancient times. Hippocrates, considered the pioneer of medicine, used to place a thin layer of wet mud over the bodies of his patients and observed the drying patterns (RING, 2007; WALDSMITH, 1992). The observation of the variation in drying times enabled him to localize the suspected regions of inflammation. Another significant advance in temperature measuring was the invention of the thermoscope, which is a crude version of the actual thermometer, by Galileo in 1597. The first clinical thermometer, which is still universally used as a diagnostic tool in physical examinations, was developed by Dr. Carl Wunderlich in 1868 (DELCHAR, 1997; RING, 2007).

In the early 1800's, using solar radiation, John Herschel obtained the first thermal image which he called a 'thermogram' (RING, 2007). The first electronic sensors for infrared radiation, and consequently thermocouple-temperature measuring devices, were first developed in 1940`s (WALDSMITH, 1992; RING, 2007). These equipments were designed primarily for industrial and military applications and were introduced to the medical community in 1959, followed by the introduction of color images in 1960. The first application of these devices in veterinary medicine was reported in 1965 by Delahanty and Georgy, which utilized computers for the analysis, processing and storage of the images. The first practical application of thermography was introduced to the medical veterinary community in 1975 by Nelson and Osheim.

Thermography in medicine is a non-invasive, non-contact, non radioactive physiological imaging technique which is capable of detecting surface heat emitted from a target surface in the form of infrared radiation (TURNER et al. 1986; PUROHIT, 2004; MCCAFFERTY, 2007).

IRT (Infrared Thermography) has recently gained popularity and is now considered as a useful tool for the detection of lesions that can potentially result in lameness. As the surface of the skin is a highly efficient radiator and IRT provides us with the possibility of detecting infrared emissions, a thermal map of the temperature distribution of the skin can be created (TURNER et al., 2001). Compared to healthy tissue, injured or diseased tissue has an altered temperature. The determination of local temperature changes between two regions within an image, variations and deviations can be used to detect regions of inflammation (BOUE et al., 2007) and possible indicators of lameness. Therefore, it is desirable to display the cardinal signs of the inflammation as graphical and numerical data (WALDSMITH, 1992; TURNER, 1998; DYSON et al., 2001).

Humans can manually detect temperature differences on patient skin with a sensitivity of 2°C (at best), while current thermographic instrumentation can detect temperature differences of 0.1°C (TURNER, 2001) and increases in regional heat can be noted two weeks prior to the occurrence of any clinical symptoms (TURNER et al., 2001).

As can be understood from these facts, since 1960s, thermography is considered a useful tool for diagnosing orthopedic diseases in veterinary science. Yet, there are relatively few publications on the usage of thermography in routine clinic examinations. Therefore, this study in general aims to analyze the availability of thermography in routine clinical use in equine lameness cases.

Specifically, thermographical findings at the beginning of the examination of orthopedic diseases in horses have been recorded and the results were compared to the actual clinical diagnoses. The correlation between these results will be presented. The hypothesis to be argued is that, the evaluation of the thermographical status at the beginning of the orthopedic examination allows an accurate localization of inflammatory and degenerative conditions of the equine locomotor system. Special emphasis is given on the questionable possibility of differentiating disorders within a certain region as joint, tendon or similar.

CHAPTER II:

LITERATURE REVIEW

II.1. Infrared Energy

Heat loss from an animal to its environment takes place in the following ways: non-evaporative and evaporative heat loss. Evaporation occurs in the mucous membrane in the respiratory system and on the skin, either actively by sweating, or passively through insensible evaporation. The rate at which evaporative heat loss takes place depends on the difference of vapor pressure between the skin and the environment. Non-evaporative heat loss happens through convection, conduction and radiation, and the rate at which it takes place is proportional to the temperature difference between the surface of the animal and its environment (MORGAN et al., 1997). Heat loss from the body is distributed among the heat loss mechanisms as follows: 3% through conduction to objects, 12% through conduction to air, 25% through evaporation, and 60% through radiation. Radiation is the type of heat loss which can be detected by thermography (PROUDFOOT, 2009).

Conduction refers to the transfer of energy between two solid bodies that are in direct contact. Heat can also be conducted within the same body when there is a difference in temperature between regions. The second mechanism is convection, which is the transfer of energy via the displacement of a fluid, such as water or air. Finally, radiation refers to the transfer of heat by the electromagnetic energy that an object emits regardless of the medium (object, atmosphere or vacuum) (HODGSON et al., 1994; EDDY et al., 2001). All objects, having a temperature greater than absolute zero (0 K, -273 ^{o}C) (BORNKLAV, 2004; CARLOMANGO et al., 2010), emit infrared energy to the atmosphere proportional to their temperature (PUROHIT, 1980; EDDY et al., 2001; VOLLMER et al., 2010).

The term infrared radiation refers to the radiation of waves with wavelengths between 0.78 – 1000 μm within the electromagnetic spectrum. They have a higher frequency than radio waves and microwaves but a lower frequency than visible light, ultraviolet waves, x-ray and gamma rays (BORNKLAV, 2004; VOLLMER et al., 2010, KOUPELIS, 2011). Figure 1 illustrates the electromagnetic spectrum.

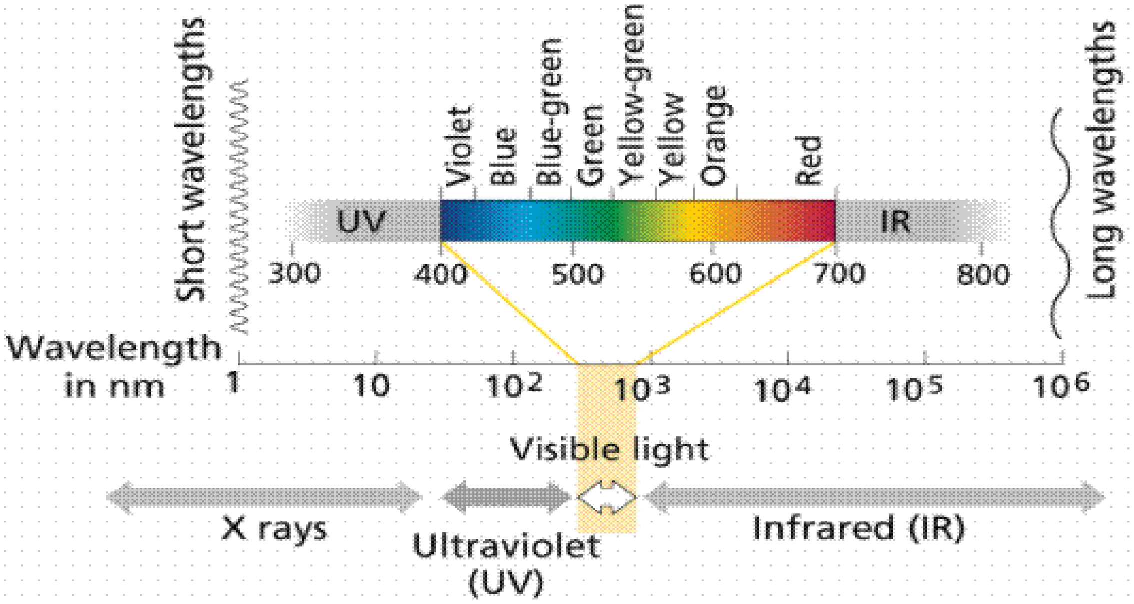


Image from Purves, et al: The Science of Biology, 5th Edition, 1997

Fig 1: Electromagnetic spectrum

Radiant existence, the total amount of the flux emitted by a point on a surface into all directions above the surface, depends not only on the temperature, but also on the emissivity value. Emissivity defines the portion of radiation emitted by an object measured, in comparison to that emitted by a perfect radiator black body (GAUSSORGUES, 1994; VOLLMER et al., 2010). The black body is the hypothetical object that emits the greatest amount of radiation at a given temperature without reflecting any of it (CARLOMANGO et al., 2010; KASTBERGER et al., 2003). The emissivity of a perfect black body is defined as 1 while the emissivity of a perfect white body is defined as 0. Practically the emissivity of the body of humans and animals are considered as equal and has a value of 0.98 which is very close to a perfect black body (GAUSSORGUES, 1994).

Infrared energy is emitted in the form of photons which move at the speed of light and are subjected to the laws of optics (KASTBERGER et al., 2003). Similar to visible light, infrared radiation can be optically focused, deflected, reflected and converted to electronic signals via detector arrays (BORNKLAV, 2004; EDDY, 2001).

II.2. Types of Thermography

II.2.1. Liquid Crystal Thermography

Liquid crystals deployed in temperature sensors have been in use since the 1960s (RING, 2007). Liquid crystal thermography uses liquid crystals which are in deformable base and reflect polarized light within a narrow frequency spectrum. The crystals change their shape according to the temperature of the surface of contact. For the medical applications of this technology, the liquid crystals are embedded into a flexible and durable latex sheet. When placed in direct contact with the skin, the crystals change shape, reflect a specific colored light and form a colored thermal picture of the heat patterns of the skin.

This equipment is relatively easy to use. It is durable and provides immediate results, and a permanent record can be made of the thermogram. The greatest disadvantage of this equipment is that it requires direct contact to the skin with a possible immediate change of hemoperfusion due to the contact. Direct skin contact may produce false readings because the latex sheets could either cause heating or cooling of the skin via heat conduction through the material. This is particularly true of cold sheets falsely cooling the warm skin (TURNER, 2001).

II.2.2. Microwave thermography

Temperature distribution in the body can be measured by the means of its own microwave radiation emission, through a technique called microwave thermography (MACDONALD et al., 1994).Waves with lengths of 1 m to 1 mm are represented by microwave bands. Microwave thermography uses an antenna designed to receive radiation, which, in order to maintain the reflective loss at the air-tissue interface to a minimum, can be placed either in direct contact with the integument, or in immediate vicinity to it. The signal that is then received needs to be amplified before sampling. These systems have a sensitivity as high as tenths of degrees Celsius (von SCHULTHESS et al., 1998).

II.2.3. Infrared Thermography

Infrared thermography refers to the technique of producing a visible image of the heat emitted by the objects which is normally not visible to the human eye. The image from an infrared camera is created by converting radiant heat energy radiation into a signal that is displayable on a monitor (DELCHAR, 1997; GREEN, 1999). IRT detects the thermal radiation on the surface of an object and displays the heat pattern as an image, with different colorings and shadings representing a different temperature. It is similar to a digital camera, with the difference that the thermographer needs to evaluate emissivity, reflected temperature, focus and other factors and their influence to the recording accuracy (JHONSON et al., 2011). The camera contains detectors with complex arrays composed of temperature sensitive barium strontium titanate (BST). These detectors are pyroelectric, meaning that they generate a certain amount of voltage depending on the temperature and infrared radiation generated by an object. In the case of a temperature variation in the BST, a pyroelectric signal is received by the intricate circuit within the detector, interpreted and a corresponding electronic signal is generated. With the help of specialized hardware and software, the signal is transformed to a video signal which, with varying colors, represents the differences in the heat emissions generated from the object (EDDY et al., 2001).

The thermal image, which is called a thermogram, displays the temperature differences in a spectrum of colors (RING et al, 2000; MCCAFFERTY 2007).

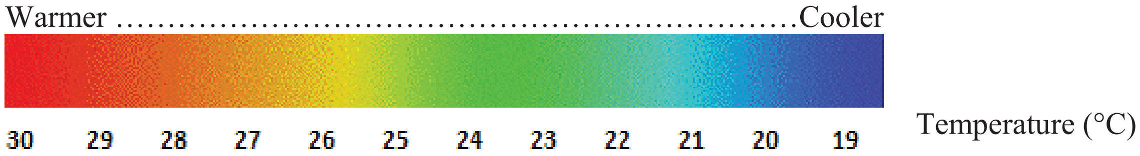


Fig 2: Colored scale of the thermogram

The hierarchy of colors used to represent the relative temperature differences are illustrated in Fig. 2. Higher temperatures result in more energy being emitted (PUROHIT et al., 1980 a). The IRT assigns the color black to the lowest temperature in an image, the color white to the highest temperatures, and graduating shades of grey for the temperatures in between. This image can also be colored, to obtain different colors for portraying different temperatures (MCCAFFERTY, 2007).

The spectral range is the most important factor. The electromagnetic spectrum from 0.7 to 14µm is useful for IR measuring purposes – particularly, the mid-wave (3-5 µm) and long-wave (8-14 µm) bands (KASTBERGER et al., 2003) and short-wave bands 0.9 to 1.7 µm (VOLLMER et al, 2010). For medical application, the range from 8 to 14 µm is ideal, because the skin has peak emissivity, and less environmental artifacts are encountered at this range (TURNER, 2001). Infrared cameras which operate in long-wave infrared region are less affected by sunlight compared to the mid and short waves (EDDY et al., 2001)

The various types of the detectors in thermographic cameras can be divided into two categories; cooled and uncooled. Cooled detectors are cryogenically cooled and typically contained in a vacuum-sealed case. This provides greater sensitivity since they have much lower temperatures compared to the objects of which temperature and radiation they are measuring. Cooling temperatures typically range from 4 K to 110 K, but 80 K is the most commonly used. Without the cooling, these sensors would have been 'blinded' or ‘flooded’ by their own radiation. The drawbacks of cooled infrared cameras are the relatively high production and running costs. The cooling process and the disposal of cooling gases are power- and time-consuming. Several minutes of time are necessary for the cooling of the camera before it can be used. Despite the bulky and expensive components to lower pressure and temperature, images produced by cooled infrared cameras have superior quality compared to the images from uncooled cameras (PUROHIT, 1980). The sensitivity of cooled IR cameras, which in this case refers to the smallest amount of temperature change that can be detected, generally lies in the range of 0.01°C (TURNER et al., 2001; TURNER, 2001).

The sensors deployed in uncooled thermal cameras operate either at ambient temperatures or temperatures close to the ambient by utilizing small temperature control elements. The state of the art uncooled detectors all use sensors that demonstrate a change in resistance, voltage or current when exposed to infrared radiation. These changes are then detected, measured and compared against the values at the original operating temperature of the sensor. For noise reduction purposes in the images, uncooled infrared sensors can be stabilized to a fixed operating temperature, but cooling to low temperatures and therefore bulky, expensive cryogenic coolers are not required. This enables infrared cameras to have more reasonable sizes and costs. However, their resolution and image quality are not as high as cooled detectors. This is due to the limits in the currently available technology for their fabrication processes (PUROHIT et al., 1980 a). Uncooled IR cameras have sensitivities generally lying in the range of 0.1°C. For most medical applications, thermograms having a sensitivity within 0.3°C are considered sufficient for thermal scanning (TURNER et al., 2001).

There are two types of thermography; real-time thermography and still thermography, of which real-time thermography is preferable due to its elimination of the problems with motion. Also, real time thermography provides faster imaging (TURNER, 2001). Still thermography produces a thermogram over a period from 19 seconds to 6 minutes (TURNER, 1996 a). Due to the dynamic nature of the real time thermography, the operator can immediately observe change in a real-time manner (TURNER, 2001).

II.2.4. Applications of Thermography

The use of IR imaging has a wide range, being useful in any situation where a medical condition or even a problem of entirely different matters might induce a thermal difference to surface, even the military, which is one of the most important beneficiaries of this technique (BATHE, 2007).

Infrared imaging is a developing field in human and veterinary medicine. Thermography has been used sporadically in human medicine for a multitude of conditions. Although there are reports from the 1960s and 1970s of it's use in early detection of breast cancer (AWERBUCH, 1991 b), certain ophthalmic conditions have also been studied with thermography. Other examples of use in human medicine include localization of biopsy sites, post surgical assessment of tissue healing, post operative mapping of blood flow in cutaneous flaps, identification of tumors causing exophthalmia, evaluation of vascular disorders, and assessment of certain neurological conditions, such as naturopathic facial pain (GREEN, 1999).

It has advantages over other imaging techniques in that it is non-invasive and with the current technology it is very rapid (LAI et al., 1998; SCHAEFER, 2004). It does not expose the patient to x-rays (HILDEBRANDT et al., 2010; KOLD et al., 1998). It can be performed without sedation or restraint and, in some instances, from the distance which is the one great advantage of thermography, since thermographic examination can be performed either at close range (< 1 m) or at large distance (>1000 m) without touching and disturbing the animal, depending on the instrument type and application. Even though thermal imaging was initially mainly used in the military and medical domain, it has been also of benefit in the study of insects, reptiles, birds and mammals (MCCAFFERTY, 2007).

This technique is ideal as a first screening test, it is non invasive and portable, allowing thus an easy comparison between individuals of the same species. The images provided are in real time, therefore permitting its use on animals in motion, and the cases are easily followed up in time as the data recorded is documented (PROUDFOOT, 2009).

Probably the most important advantage of thermography is it's extremely sensitivity to changes in heat and its ability to detect pathologic conditions in asymptomatic patients (PUROHIT et al., 1980 a; VADEN et al., 1980; EDDY et al., 2001; TURNER et al., 2001).

II.3. Thermography in Equine Medicine

The uses of thermography in veterinary medicine are contributed to four aspects;

- IRT as a diagnostic tool,
- IRT as an enhancement to physiological examination,
- IRT as a preventive tool,
- IRT as a follow-up tool

II.3.1. Thermography as a Diagnostic Tool

Diagnostic imaging techniques are broadly divided in two categories as anatomical and physiological imaging (HEAD et al., 2001; OTILIA et al., 2006; PROUDFOOT, 2009). Anatomical imaging, which includes radiography, ultrasonography, computed tomography and magnetic resonance imaging, produces high quality, high detail images of the tissues with the help of modern equipment and digitalization (HEAD et al., 2001) With anatomic imaging, changes that have already occurred in tissues can be determined, like a fractured bone, or a tear in a structure such as a tendon (X rays and ultrasound). On the other hand, physiologic imaging is a function of metabolic action (OTILIA et al., 2006), like nuclear scintigraphy, which enables the operator to 'see' the activity within specific tissues (STRODEL, 2001; HEAD et al., 2001).

When it comes to physiologic imaging, the principle lies in the fact that images obtained by these techniques can show a difference before a specific anatomic lesion becomes evident.

Thermography is also a physiologic imaging technique, which through the possibility of a graphical description of inflammation, will allow for an accurate and rapid detection of appearance and its progression or regression (HEAD et al., 2001; STRODEL, 2001; OTILIA et al., 2006).

The technique mentioned above seems so attractive due to the fact that thermography becomes a picture of physiology and the images produced by it are of use in the diagnosis of different conditions in a practical setting (WALDSMITH, 1992; HEAD et al., 2001). Thermographic examination provides whole horse view which can be taken at each examination and provokes further investigations at all regions that are thermographically abnormal (TURNER, 1996 b; von SCHWEINITZ, 1998).

Although thermographic images measure only skin temperature, they also reflect alterations of the circulation in deeper tissues. Mostly, injuries associate with blood flow variations, thus alterations of the local skin temperature might occur (TURNER, 1998). Inflammation leads to hyperthermia and is associated with thermographic hot spots (TURNER, 1998; VAN HOOGMOED et al. 2000). Whereas degeneration reduced muscular activity, soft tissue trauma or poor perfusion like vascular infarcts may decrease local blood flow and cause a hypothermic pattern (HILDEBRANDT et al., 2010; DYSON et al., 2001; TURNER, 1998). Marked swelling and the presence of dense scar tissue may also be a reason for thermographic cold spots (TURNER, 1998).

The hot spots mentioned above are actually thermographically identified lesions that express themselves as a focal area of increased heat, which will, by progression, spread and become more diffuse (GREEN, 1999).

There are a number of studies reported for specific conditions in which thermographic imaging was very useful in localizing the area of injury, such as: sub-solar abscesses, laminitis (PUROHIT, 1980; TURNER, 2001; EDDY et al., 2001), serous arthritis (KOLD et al., 1998; PUROHIT, 1980; VADEN et al., 1980; TURNER, 2001; EDDY et al., 2001), tendon and ligament problems (PUROHIT, 1980; TURNER, 2001; EDDY et al., 2001; WALDSMITH, 1992; MARR, 1992; WEIL et al., 1998), heel pain, dorsal metacarpal disease (TURNER et al., 2001; TURNER, 2001), splints (TURNER, 2001), muscle injuries (WALDSMITH, 1992; TURNER et al., 2001; TURNER, 2001), hind limb lameness (KOLD et al., 1998; TURNER, 1996 c; TURNER, 1998; EDDY et al., 2001) bursitis, navicular disease (WALDSMITH, 1992; TURNER et al., 1983; WEIL et al., 1998; TURNER, 2001-b; EDDY, 2001), stress fracture (PUROHIT, 1980), hairline fracture (GREEN, 1999), vertebral spine injuries (KOLD et al., 1998; WALDSMITH, 1992; PUROHIT et al., 1980 a; TURNER, 2001), nerve injuries (WALDSMITH, 1992; EDDY et al., 2001; PUROHIT, 2004), Horner` syndrome (PUROHIT et al., 1980 a; GHAFIR et al., 1996), back pain (EDDY et al., 2001; PUROHIT et al., 1980 a; FONSECA et al., 2006).

II.3.2. Thermography as an Enhancement to Physiologic Examination

The human sensory can manually detect temperature differences on patient skin with a sensitivity of 2°C (WALDSMITH, 1992). Modern infrared imaging techniques can detect surface temperature changes by the help of sensitivity at least ten times more accurate than the one of the human hand (TURNER, 2001; TURNER, 2003; SIMON et al., 2006). Current thermographic instrumentation can detect temperature differences of 0.1°C (TURNER, 2001).

IRT helps increase diagnosis accuracy, since it provides objective data while evaluating suspicious areas, which might need more investigation (ultrasonography, muscle biopsies, x-ray) in the immediate future, or actually confirms the suspected existence of inflammation in already evaluated painful areas (KOLD et al., 1998). Increases in regional heat can be noted two weeks prior to the occurrence of any clinical symptoms (TURNER et al., 2001). Also, thermographic imaging can be an aid in the evaluation of compensatory lesions that result from a primary insult or prevent the omission altogether of a lesion, which is something that appears often during lameness examination, where the detection of one lesion leads to its treatment and monitoring such as to avoid stressful additional testing (GREEN, 1999).

II.3.3. Thermography as a Preventive Tool

IRT, as described, is a tool which is able to detect blood flow alterations on the body surface that are caused by pathological situations. Metabolic activity is a real time function which precedes anatomic alterations. Thus, this technique can detect pathological conditions prior to their clinical detection (PROUDFOOT, 2009).

In the athletic equine, early abnormality and trauma detection are important (GREEN, 1999) therefore the onset of these lesions can be monitored by IRT during training periods (BOWMAN et al., 1983). Training programs can be therefore adjusted to reduce inflammation in detected and localized area, reducing the risk of serious injury (WALDSMITH, 1992; TURNER, 2001). STROMBERG (1971) performed a study in which he showed that young thoroughbreds with thermographic evidence of inflamed tendons would eventually “break down” if allowed to continue training

VADEN et al. (1980) detected abnormal thermal changes in four horses with no radiographic evidence of inflammation in the corresponding body part. Even though clinically healthy, their performance was poor. VADEN et al. (1980) and STROMBERG (1973) demonstrated that thermography was able to identify joint and tendon injuries two weeks prior to clinical manifestation. TURNER et al. (2001) supports these findings and it appears that they are not limited only to joint and tendon problems. Thermography was able to detect dorsal metacarpal disease, splints, hoof and muscle injuries before the problem became apparent to the naked eye.

It has been demonstrated that thermographic findings can be used for the prevention of subsequent breakdown of body structures through early remedial therapy that can be started on time (VADEN et al., 1980; TURNER et al., 2001).

This may prove to be the most valuable application of thermography to equine orthopedics, which means that it can ascertain whether physical activity gradually increases the temperature contrast in the asymptomatic patient, in which case the exercise or treatment is placing an objectionable strain on the healing process. This way, thermography produces objective assessments instead of subjective ones (KOLD et al., 1998).

II.3.4. IRT as a Follow-up Tool in the Healing Process

Thermography has also proven itself to be an imaging technique which can detect cast-induced complications and may therefore be used by surgeons to monitor casts for their appearance (LEVET et al., 2009).

In areas in which damage has been recorded, this technique can provide quantitative images as to assess the degree of inflammation and can be then used to record the resolution rate (BOWMAN et al., 1983; WALDSMITH, 1992; COLLES et al., 1997; GREEN, 1999).

II.4.1. Reliable Use of the Thermography in Equine Medicine

Thermography can find a vast application area in equine veterinary medicine, which is only bounded by the veterinary surgeons' understanding of physiology and practical technological constraints.

Changes in blood flow at the skin surface can be the indicator of many inflammatory and neuromuscular abnormalities. When all artifacts affecting skin-surface temperature have been eliminated, the thermal imaging can serve as a direct graph of blood flow on the skin (WALDSMITH, 1992).

Thermal images should be obtained in standardized conditions (RING et al, 2000). For producing reliable thermographic images, artifacts that may interfere with the interpretation of infrared imaging should be determined, understood and avoided if possible (STROMBERG, 1971; TURNER, 2001; LINDA et al., 2002; SIMON et al., 2006; YANMAZ et al., 2007).

To avoid the negative effects of motion, the patient should be immobilized, because motion causes false temperature elevations via increased peripheral circulation (YANMAZ et al., 2007).

To eliminate the effect of motion, the horse can be held in stocks or a specific handler can be used (EDDY et al., 2001; AUTIO et al., 2007). Real-time thermography is more preferable than still thermography because of these motion considerations (TURNER, 2001).

The use of chemical restraining agents like sedatives and tranquilizers to prevent the horse from moving should be avoided. These agents may alter thermal pattern and temperature gradients due to their affects on peripheral circulation, and cardiovascular system (TURNER, 2001; STROMBERG, 1971; TURNER 1996 a; EDDY et al., 2001; PUROHIT, 2007).

It has been suggested by WALDSMITH (1992) and WALDSMITH et al. (1994) that regional nerve anesthesia could have adverse effects on IRT by causing a thermal blush, secondary to vasodilatation from sympathetic blockage.

In this field the study from HOLMES et al. (2003) indicates that IRT imaging can be performed after administration of perineural anesthesia with mepivacaine hydrochloride (HCI) without creating artifactual changes to the limb surface temperature. The influence of local anesthetic agents on local vascular activity is variable. Mepivacaine HCI results in less vasodilatory activity compared to lidocaine HCI. This could explain why no effects were observed in the thermographic images obtained in this study.

We have to also make sure that no physical therapy within 24 hours of the examination should be applied and acupuncture in the region of the thermographic scan during the previous week should be avoided. The use of topical agents prior to the scan should be avoided and any residues should be carefully washed off the previous day (EDDY et al., 2001).

TURNER (1986) suggested that bandages and liniments should be kept off the horses' leg for at least 2 hours before the thermographic imaging. Although this recommendation remains still valid, it is indicated by TURNER et al., (2001) that thermography can also be accurately assessed with the use of those. They emphasized that this is of major practical significance at a racetrack, where thermographic examination will not be interfering with the daily routine of the horse.

As mentioned before successful thermographic imaging can only be performed in a controlled environment. To decrease the effects of extraneous radiant energy, thermography should be performed in a closed surgical room with uniform air flow (WEBBON, 1978; PUROHIT et al., 1980 a; TURNER, 2001; LEVET et al., 2009). Thermal cameras are not affected by the intensity or quantity of light in the scene. The important relevant measure is heat, not light (EDDY et al., 2001).

The ideal temperature of the room which is prepared for thermography should be around 20 °C for inflamatoric lesions (RING et al, 2000; TURNER, 2001; EDDY et al., 2001; SIMON et al., 2006; BOWERS et al., 2009) although thermography can be performed in any temperature less than 30°C. In temperatures higher than 30 °C, effects of heat loss due to sweating should be taken into consideration (TURNER, 2001).

Excess moisture increases the local heat loss to the environment or to the dryer areas of the coat (STEWART et al., 2005). After taking the horse to the thermal imaging room, the horse should be allowed 10 to 20 minutes to acclimate to the environment (PUROHIT, 2004; TURNER, 2001; EDDY et al., 2001; SIMON et al., 2006).

In a study of TUNLEY et al. (2004) about the factors that effect the quality and the interpretation of the thermographic image, the effects of the size of the horse, the color, the hair length and the temperature difference between the horses original environment and the thermal imaging room on the duration of the acclimatization before the imaging have been investigated. In the study, it has been shown, with 95% confidence, that none of these factors had a significant effect except the following: the temperature difference between the horse's actual environment and the thermal imaging room and hair length. In terms of these two major factors, the study has proved that they have no significant effect on the time that is spent to reach the plateau temperature in lateral thorax and gluteal areas, unlike in the metacarpal region. As a result, the recommended period required for a horse to equilibrate fully to its environment is between 39 and 60 minutes.

In addition, the authors found that only 19% of sites (lateral thorax, gluteal areas and metacarpal region.) acclimatized within the previously recommended time scale of 10-20 minutes, in which that 25% of horses were equilibrated within 21-38 minutes and in 56% it took more than 39 minutes. Likewise, during the equilibration, the thermographic pattern obtained did not change even when assessed over a 7 day period.

The skin should always be checked for alterations in hair length, since these may lead to false hot spots in the thermogram (TURNER, 1996 a). Quantification of temperature variations is important solely because the thermographer needs to differentiate whether symmetrical areas have matching temperatures. Hair and hair length are important, since when the thermographist is assessing a thermal image, an asymmetry of 1°C or more is significant and indicates possible pathology (TURNER, 1996 c).

Hair could also have an insulating effect by blocking heat emission from the skin, but as long as hair is short and uniform in length, the thermal image produced is correct (TURNER, 2001; TURNER, 1996 a). Furthermore, it should not be forgotten that imaging a clipped horse would not affect the overall pattern of the image but it would only reduce the length of the time that is needed for the horse to equilibrate (TURNER, 1996 a; TUNLEY et al., 2004; AUTIO et al., 2006).

A study conducted with the aim of determining the effect of clipping the coat on the thermographic pattern and skin temperature in dogs argues that clipped limbs were warmer than unclipped limbs. The results suggested that clipping the coat in healthy dogs increased the measured skin temperature but did not change the thermal pattern. Although there were differences in mean temperature values between clipped and unclipped regions, significant differences between the corresponding thermographic patterns were not observed. The thermal imaging patterns can be consistently obtained with a waiting time of 15 minutes after clipping (LOUGHIN et al., 2007).

Therefore the horse must be clean, with dry hair coat and dry skin and it should not be groomed within 2 hours before the scan (TURNER, 2001; EDDY et al., 2001). Equally important, the horse should be kept free from drafts. Dirt on the horse affects the heat emission and heat conductivity.

There is another factor which mentioned that understanding of exercise and the influence of exertion on thermographic images is important for the reliable use of thermography .To clarify, SIMON et al., 2006 performed a study on six adult Thoroughbred horses without any clinical signs of lameness or musculoskeletal injury. Equally all of them were preconditioned to high speed treadmill work and all were considered fit and routinely exercised.

Consequently, the study indicates that surface temperature of all muscled region and MT3/MC3 were significantly increased after exercise in comparison with the recorded surface temperature of the horses before exercise. Due to this study, it was shown that there is no detectable significant difference in surface temperature between thermograms that were obtained before exercise and those which were obtained 45 min. after exercise across all regions.

Another important point that was declared during the same study (SIMON et al., 2006) was the difference in reduction of the temperature or cooling of muscled after exercise. For instance, the study showed that muscular regions appeared to cool more rapidly rather than non-muscled region. In other word, the surface temperature of those parts that have more muscle became lower in shorter time than those parts that were non- muscled. The reason for this is that the heat which was generated in muscled area during exercise, creating higher emitted surface temperature after exercise than non-muscled regions, so emitted temperature could decrease rapidly after exercise is stopped.

Although TURNER (2001) indicated that at least 2 hours should lapse after maximal exercise before thermographic examination, SIMON et al. (2006) state that thermographic images can be performed at least 45 minutes after high-speed treadmill exercise without risk of artifacts.

The horse should be also examined for conditions that could interfere with the interpretation of the thermographic images like body clipping; surface contour and should be noted (GREEN, 1999).

The reliability of diagnostic interpretation is enhanced by repeating thermal scans several times during the same examination (TURNER, 1996 b; TURNER, 1991). An actual lesion should be present in each replicate examination whereas an artefactual lesion will not be reproduced consistently. Circumferential examinations should be performed on extremities (GREEN, 1999; TURNER, 1986). In order to evaluate whether a hot spot is systematically present, the area in question needs to be monitored multiple times from minimum two directions, while the thermographic images should have a roughly 90^o angle in between 1 to 2 m range (TURNER, 2001; TURNER et al., 2001). The distance from where the imaging is taking place is not an important issue for the obtaining of a good thermogram, with the exception of the obvious safety considerations for the clinician, but a closer presence to the animal will lead to better details in images (WALDSMITH, 1992; TURNER, 1996 a).

II.4.2. Evaluating the Thermogram

Owing to the fact that thermography records heat emitted from the skin surface and presenting the heat pattern in a graphical image (CLARK, et.al., 1977), it is important to understand what affects skin surface temperature. Temperature of the skin is influenced by many factors, including the tissue metabolism, vascular activity of the skin and below its surface and heat transfer from the body core to the skin and to the environment (LOVE, 1980; ZETTERMAN et.al., 1998)

Thermal energy generated by the body is dissipated from the skin to the surrounding environment by radiation, convection, conduction and evaporation (TURNER, 2001). Evaporation is low under balanced conditions (LOVE, 1980).

In a controlled environment, the main influences on skin temperature are tissue metabolism and local vascularization (LOVE, 1980; HEAD et al., 2001; TURNER, 2001; LINDA et al., 2002). The metabolism in sound tissue is mostly constant, therefore it can be assumed that changes in skin temperature appear due to corresponding changes in local tissue perfusion (HEAD et al., 2001; TURNER, 2001; TURNER et al., 1986). The skin has a normal thermal pattern, which can be sketched out taking into account the surface contour and vascularization (TURNER, 2001; TURNER, 1996; PUROHIT et al., 1980 a). It is important that underneath the skin, muscle activity may also contribute to increase in skin temperature (TURNER, 2001).

The practitioner must remember two main principles, when evaluating a thermogram:

- The thermal emission model is symmetrical in a healthy animal
- Any change of 1°C over 25% of the corresponding anatomic region has a clinical significance (STROMBERG, 1971; WEBBON, 1978; PALMER 1983; PUROHIT et al., 1985; WALDSMITH, 1992; MARR, 1992; TURNER, 1996 a; TURNER et al., 1998; CETINKAYA et al., 2011).

In addition to these principles, when evaluating a thermogram some generalizations also should be kept in mind;

1- Midline of the back and chest, between the hind legs and along the ventral line are generally warmer (TURNER, 1991). The areas with warmer temperature tend to follow or coincide with the major vascular patterns (PUROHIT et al., 1980 a; STASHAK, 2002; KOLD et al, 1999).

2- The heat that emits from the limbs usually takes the routes of the cephalic vein in the front limb and of the saphenous vein in the hind limb, the veins are generally warmer than arteries because they are draining metabolically active areas (TURNER et al., 2001).

3- The area that is warmest in the distal part of the limb is around the arterial-venous coronary and laminar corium plexus, which is rich in vessels and is found proximally on the hoof wall.

4- Both, the cannon area (metacarpus/tarsus), as well as the area of the pastern joint, are usually cooler (KOLD et al., 1998; TURNER, 2001), because the image recording is farther from the main blood source (TURNER, 2001). Generally, pastern joint temperature is 3 to 5 degrees lower, while fetlock joint temperatures are 2 to 4 degree lower than the coronary band (PUROHIT et al., 1980 a).

5- There is a warmer line between the flexor tendons and the third metacarpus, by the route of the median palmar vein in the front limb and the metatarsal vein in the hind limb (TURNER, 2001).

6- In the hoof area, the warmest area relates to the coronary band (PUROHIT, 1980; TURNER, 2001; BATHE, 2007), while the hoof temperature gradually decreases by bands of degree (PUROHIT et al., 1980 a).

7- From the palmar and plantar aspect; tendons tend to have lower temperatures and the warmest area is located between the bulbs of the heel. The area between the bulbs of the heel is 1 to 2 degrees warmer than the other structures (PUROHIT et al., 1980 a; TURNER, 2001).

8- From the lateral and medial aspects; above the tarsus and carpus, the medial part is warmer than the coronary band while the lateral part is 2 to 3 degrees cooler than the coronary band (PUROHIT et al., 1980 a).

In the tarsus, the lateral part is cooler in the dorsal and plantar aspects, with an increase of heat of 1 to 3 degrees in the midline. This manifestation is partial to two underlying vessels: a branch of the caudal tibial artery, which is the caudal lateral malleolar artery, and the cranial tibial artery (dorsal pedal artery later), which branches then as perforating tarsal and dorsal metatarsal III arteries (VADEN et al., 1980).

II.4.3. Specific Applications of Thermography

II.4.3.1. Injuries of the Foot

Thermography provides more sensitive measurements in foot temperature than palpation (DYSON et al., 2003) and has been used for diagnosis and evaluation of the foot injuries (PUROHIT et al., 1980 a; TURNER, 1991; GREEN, 1999; TURNER, 2001; HOLMES et al., 2003; YANMAZ et al., 2007). The thermographic evaluation is useful when it is performed in early or hidden conditions where traditional examination (physical, x-ray) isn't particularly useful (TURNER, 2001).

When analysing feet through thermography, care needs to be given to the comparison of the front feet, the front and hind feet, as well as the region between the heel bulbs (TURNER et al., 1986; TURNER, 1991; TURNER, 1996 b; TURNER, 2001). Any difference that exceeds 1°C while comparing these body regions is significant. Thermographic examination of the normal foot shows that, compared to other areas of the foot and limb, the coronary band, due to its rich blood supply, is warmer (GREEN, 1999; TURNER, 2001; HOLMES et al., 2003). This phenomenon makes detection of inflammation in this region very difficult (TURNER, 2001; HOLMES et al., 2003). However, when comparing all coronary bands, elevated warmth in one of them indicates that there is some pathology going on (GREEN, 1999).

Traumatic lesions such as distal phalanx fractures or bruises on the horn, as well as local sepsis, all produce thermographically detectable hot spots, (GREEN, 1999; TURNER, 2001).

Navicular syndrome is a condition associated with singular characteristics that can be of use in thermographic evaluation, since the syndrome is dominated by a decrease in normal blood flow of the foot to its caudal regions, in contradiction to most other foot conditions, where inflammation leads the clinical expression (TURNER, 2001; MARR, 1992). After exercise, normal horses exhibit a 0.5 °C increase in foot temperature, whereas navicular syndrome diagnosed horse do not exhibit the same pattern, because of the low blood flow (TURNER et al., 1983; TURNER, 2001; TURNER, 2003).

Among the inflammatory conditions of the hoof, laminitis is one of the conditions, where, through the inflammation of the hoof laminae, a change appears in the normal thermal model of the hoof. As noted, the coronary band is 1-2 °C warmer than the rest of the hoof, so when the rest of the hoof begins to level to the coronary band temperature, an inflammatory condition might be the cause of this themperature increase (TURNER, 2001).

II.4.3.2. Joint Disease

Thermographic patterns can have a special model in joint inflammation with osseous structure or soft tissue, or both tissues involvement, since it is known that these joint patterns start changing two weeks before the clinical manifestation, e.g. lameness appears (STROMBERG, 1973; VADEN et al., 1980; TURNER et al., 1986; TURNER et al., 2001). Joints with a normal thermal pattern are cooler compared to the other structures around them, being best evaluated from a dorsal view (STROMBERG, 1973; TURNER et al., 1986, KOLD et al., 1998). The only exception is the hock, due to the fact that this region has a vertical hot spot along the medial aspect, which matches the position of the saphenous vein.

When joints become inflamed, the thermographic model alters in the shape of an oval area, with a heightened temperature, positioned over the joint, with its widest area horizontally medial to lateral. The exception here is represented by the pastern joint, where the model associated with inflammation here has a circular shape. While the center of the joint is usually cooler, joint capsule attachment regions have the tendency to be warmer, probably due to joint swelling or pressure, which in turn will lead to the loss of microcirculation (TURNER, 2001).

Joint temperature may relate to the following factors: condition stage (chronic conditions radiate less heat), synovial involvement, cartilage damage percentage, osteochondral fragments absence or presence etc. All these factors affect joint temperature due to interactions which lead to alterations in the inflammatory response (GREEN, 1999)

II.4.3.3. Long Bone Injuries

When it comes to long bone conditions, IRT looses value in the diagnosis. Due to the fact that through this technique one evaluates skin temperatures and the fact that most bones do not lie in contact or near the skin, temperature is not affected by these problems (TURNER, 1991).

Therefore, deeply set and muscle covered bones are wrong examples for a thermographic assessment. Dorsal metacarpal disease is one of the few equine long bone conditions which can be evaluated by thermography.

The so called “bucked shin complex”, or dorsal metacarpal disease, is an inflammatory condition of the dorsal cortex of cannon bones, categorized into three degrees (TURNER, 2001). The first degree implies a painful response to the palpation of the cannon bone, but no radiographic evidence of any pathology. The second degree, next to pain in the cannon bone, radiographic evidence of a subperiostal callus can be obtained. Lastly, the third degree disease will evidentiate cannon bone pain along with the appearance of a stress/fatigue fracture. Degrees two and three might not be easily indistinguishable; also the radiographic confirmation will not be possible for up to the first three weeks. The variations in temperature between the last two degrees could help distinguish the third degree condition earlier than conventional x-ray imaging. In the first and second degree stage of the condition, thermography evidentiates hot spots, generally 1 to 2°C warmer than the adjoining tissues, midshaft along the dorsal canon bone. When it comes to the third degree, hot spots change their central position towards lateral and medial views, with the areas being up to 3 °C warmer than the adjoining tissues. The temperature changes precede x-ray imaging evidence by two weeks (TURNER, 1991).

II.4.3.4. Tendon Injuries

Thermographic models of the physiological flexor tendons are symmetric and comprise elliptical isothermic areas (TURNER, 1991). The cooler area is situated centrally over the palmar aspect of the tendons, whereas the warmer areas (up to 1°C) are located peripherally near the corpus and fetlock (TURNER, 1996 b).

The acute inflammation of the tendons is easily detected as a central area of increased heat in a normally elliptical isothermic region (STROMBERG, 1973). As the lesions heal, the model returns to its physiological shape, but overall temperature remains higher. Hot spots can be determined through thermography up to 14 days prior to clinical manifestation such as pain and swelling (CLARK et al., 1977; TURNER, 1991). This allows a rapid detection of possible lesions and allows the adjustment of training routines to the current situation (STROMBERG, 1973; CLARK et al., 1977; EDDY et al., 2001; TURNER et al.,2001).

As the healing process in the tendon proceeds, the thermographic model normalizes but still remains abnormally high compared to the physiologic tendon (STROMBERG, 1973). This happens because the tendon becomes neovascularized, so that the thermal model diffuses, which in turn means a hot spot no longer exists. Still, in the comparison of a healing tendon to a normal tendon, thermal emission from the healing one is overall increased.

Additionally, mechanical stress in the proximity of the damaged area can contribute to the strain and aggravate the lesion in the tendon. In the tendonitis of the superficial digital flexor tendon, stress can be alleviated through superior check desmotomy. Yet in most of clinical settings, evaluating the usefulness of desmotomy is challenging. Thermography is the technique which can assess these stress areas before their influence on the clinical response, so that it can be used in the decision making process referring to the therapeutic desmotomy needed (TURNER, 1996 b).

II.4.3.5. Ligament Injuries

Ligament pathology usually appears, from a thermographical point of view, similar to tendon injuries. Hot spots might probably appear over the area in question. The most useful utilization of thermography in the clinic lies in the correlation of heat to an irritable ligament, especially in the case of the suspensory or interosseous ligament. When palpating the ligament, a sensitivity response can be elicited. The significance of this response in the clinic is controversial, but through a thermographical examination, it is possible to evaluate whether inflammation is also involved, next to the elicited sensitivity. Splints, or metacarpal calluses may also cause suspensory desmitis, in which case thermography can be of aid in the detection of inflammatory processes linked to the suspensory ligament next to the splint. Of course, the above stated facts may also apply to any ligament (TURNER, 1996 b; TURNER, 2001).

II.4.3.6. Muscle injuries

Determining the sources of the problem in cases that the pain is located in the proximal hind limbs and is not related to synovial structures is often difficult. Back pain can be given as an example for this category of lesions (FONSECA et al., 2006).

Specific muscle damage is also difficult to evaluate and serum muscle enzyme increase only offers information towards general, non specific muscle damage. For the assessment of muscle injury, one can extract information on two aspects: the localization of the inflammation area in a muscle or muscle group, as well as atrophy illustration, long before there are any clinical signs (TURNER, 2001).

From the point of thermographic examination, the best domain of application in clinical work of thermography lies in the evaluation of muscle injuries (STROMBERG, 1971; TURNER, 1996 c). Localizing the degree and severity of muscle strain or rhabdomyolysis may be assisted by infrared thermography (VALBERG, 2006). When it comes to the upper limb, the temperature differences can be identified as hot or cold spots, where temperature elevations might appear due to inflammation and the according vasodilatation and temperature decreases appear due to more advance manifestations of inflammation, such as local swelling- edema or vascular stasis, as well as chronic conditions with reduced circulation, such as scars (STROMBERG, 1971; HEAD et al., 2001; TURNER, 2001).

When muscle needs to be evaluated, samples will be paired and left and right sides compared (TURNER, 1986). The images obtained need to be as similar as possible. Alterations that are consistent from side to side are indicators of muscle damage, either in the cold or hot spot (TURNER, 2001). Hot spots occur in the cases of supraspinosus and interspinosus desmitis and muscular lesions (FONSECA et al., 2006).

Myositis can be usually identified through the thermographic camera, as a hot spot in the skin overlying the tissue in question (STROMBERG, 1971).

Muscle strain is the most common cause of myositis. Human medicine, especially athlete medicine has elaborated a classification of the injury degrees (grade one, two and three), which can also be used in the horse. The foreleg seems to be relatively free of muscle strain, the most common conditions being pectoralis and shoulder extensor myopathies, whereas the back and hind muscles are much more affected (STROMBERG, 1971) and named croup and caudal thigh myopaties. The first category comprises the strains on the longissimus muscle, the origin or body of the gluteus medius, or the insertion of the gluteal grater trochanter and the third femoral trochanter, whereas the second category consists of biceps femoris and semimembranosus muscle injuries which usually occur midbody, as well as injuries of the semitendinosus muscle, which appear in the musculotendinous junction (TURNER, 2001). Myositis can be usually identified through the thermographic camera, as a hot spot in the skin overlying the tissue in question (STROMBERG, 1971).

II.4.3.7. Injuries of the Vertebral Column

Horses with back and spine pathology may also benefit widely from the use of thermography as means to detection of abnormal body surface temperature (TUNLEY et al., 2004). The physiological thermographic pattern of the thoracolumbar region shows that the hottest point is the midline, with a decrease of temperature up to 3°C on either side of it (TUNLEY et al., 2004).

Injuries of the vertebral spine can be identified by the means of thermography, such as luxations, subluxations and fractures (STROMBERG, 1974), supraspinosus desmitis, interspinosus desmitis, dorsal intervertebral osteoarthritis (FONSECA et al., 2006).

Diagnostic radiography of the vertebral column is difficult, requiring general anesthesia, therefore the identification of these problems may be ignored completely or it can happen at a later point. This is why thermography might be of aid, offering an erect position while examining, and being able to be used as a screening test to determine whether anesthesia in order to perform an X-ray might be of use or not. Vertebral spine injuries are translated into thermography as hot or cold spots (TURNER, 2001).

When evaluating the spine for thermography, the points of view should be from above the animal (top line view), by examination of the thoracic, lumbar, and sacral vertebrae. When examining laterally, one uses the images for the assessment of the cervical vertebrae. The injuries usually appear on the midline, with a correspondence between injury and thermal area. As noted before, most areas associated with cold spots exhibit signs of chronic injury, but that has not been consistent in the case of the vertebral spine. These cold spots mostly correlate to severe pathology, accompanied by severe swelling, which might interfere with the autonomic nerve supply. Root signatures are linear increases in temperature that follow nerve roots from the spine, appearing due to irritation applied on the local sympathetic nerves, such as the case of Horner's syndrome, involving the entire trunk and causing heightened temperatures on a whole side (PUROHIT et al., 1980 a).

Thermal models can be specific to a disease, such as sacroiliac subluxation, where a pattern of a focal cold spot between the tuber sacrale is formed (TURNER, 2001). Findings associated with cold spots also occur in the cases of dorsal intervertebral osteoarthritis due to causing local pain without causing an inflammatory response at the location of lesion (FONSECA et al., 2006).

CHAPTER III

MATERIALS AND METHODS

III.I. Animals

The study was carried out between Mai 2010 and June 2011 in the Equine Clinic of the University of Veterinary Medicine Vienna. This study included 100 horses which were admitted to the Equine clinic. Anamnesis data, age, breed, gender, duration of clinical signs treatments and surface contour were documented for each horse. Horses aged between 1 to 21 years (9.4 ± 4.8 years), of both sex (28 mares, 62 geldings, 10 stallions) and mixed breeds. On every horse a thermographic examination was carried out independently and immediately before orthopedic examination. The orthopedic surgeon was not informed about any results of thermography.

Room temperature was recorded and did not exceed 30°C at any time during the measurements. Average temperature was 21.6 ± 1.7 °C (17.9 to 28.46 °C). The horse was allowed 10-20 minutes to equilibrate to the room where thermography was performed. This allowed animals to acclimate to controlled atmospheric conditions within the hospital in accordance with recognized thermographic guidelines. The patients were not sedated, clipped or exercised before the thermographical examination.

III.2. Experimental procedures

Multiple thermographical images were obtained using at least two directions with approximately 90° angle and a distance of 1 to 2 m. range. Minimum eight standard thermographic images were recorded for each horse. The protocol for obtaining the images were following positions: right and left side view of the whole body, croup, chest, neck from both sides and the back in top line view.

For obtaining the images a handheld infrared camera (Variocam, Infratec®, Dresden, Germany) was used. The thermal imagining system had a 12.5 mm focal length lens, for the spectral range of 7.5 -14 µm. It is featured with an uncooled microbolometer array and capable of distinguishing a temperature difference of 0.08°C. The emissivity was adjusted at 1.00 in all thermographic scannings. Images were saved within a flash memory card for further evaluation and review. Thermological images were analyzed with an analyzing software program IRBIS® software (Infratec®, Dresden, Germany).

The basis of the software program is matching the pixels in the thermographic picture with the temperature. The program has 6 opportunities for measuring the surface temperature of the interested area. First one is for point measurement. This function allows assigning the pixel's temperatures which matches the selected point on the thermogram. Second one is lineal measurement. The program gives the minimum, maximum and mean temperature values for the pixels that are involved in the drown line. Third one is the elliptic measurement which allows the operator to designate the region of interest with an elliptic shape and gives the minimum, maximum and mean temperature values for the pixels that are involved in the chosen elliptic area. The fifth one, the circular measurement, gives the opportunity to determinate the region of interest with a circular shape. The program calculates the minimum, maximum and mean temperature values for the pixels that are situated in the circle. The last one is polygonal measurement, which was used for the regional surface temperature evaluation in this research. This option allows the investigator to draw the region of interest, makes possible to measure the minimum and maximum temperatures and calculates the mean of the temperature of the pixels that are involved in to the manually drawn region.

The first two opportunities were not usable for comparing the regions because of the point and line measurement. It could not be possible to find the same point that matches the same pixel for symmetric regions every time. With the use of this polygonal measurement option to determine the border of the area of interest was easier and more realistic when compared with the others, the risk of the taking extra pixels from out of the border in to the interested region was lower.

For evaluating the RST (regional surface temperature values), polygonal measuring was used and the body was divided into manually drawn defined regions: for the extremities seven regions, for the croup two, for the neck three, for the back three and for the chest two regions were determined as seen in figure 3.

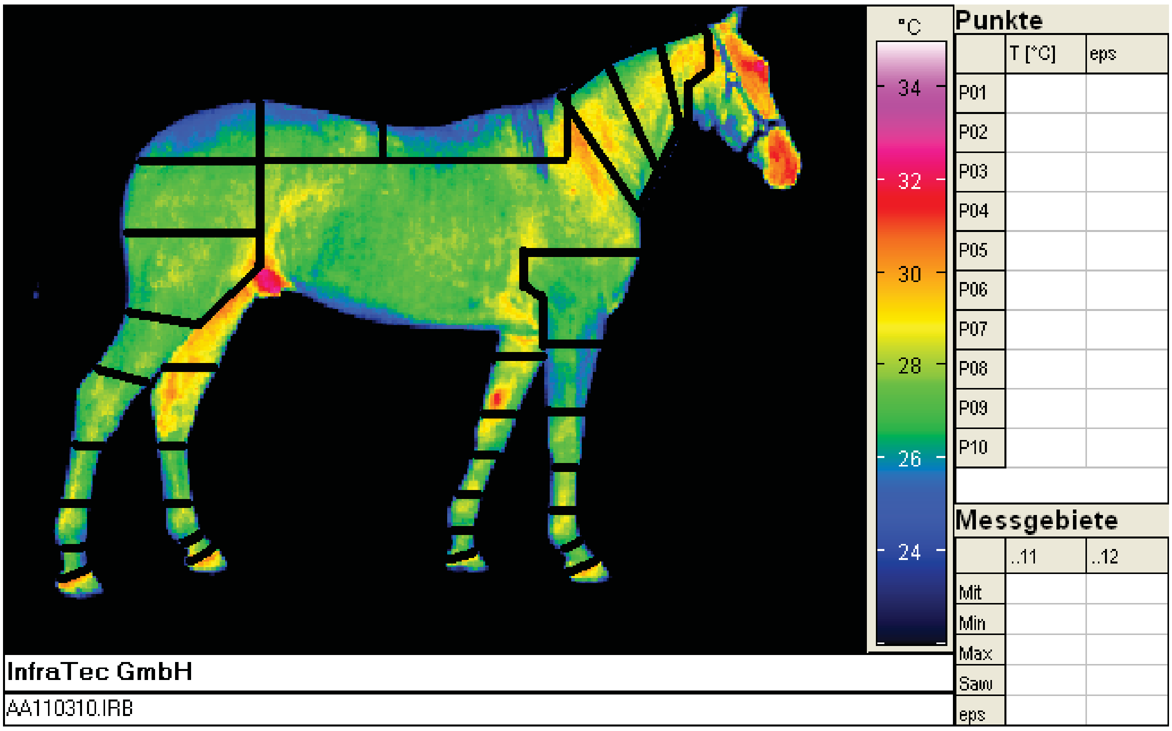


Fig 3: Illustration of the thermographical software screen and the defined regions from the right side view of the whole body

Scans of the distal part of forelimbs and hind limbs were made with obtaining the thermographical images from dorsal, lateral, medial and palmar/plantar views. For upper limbs lateral, cranial and caudal views were obtained.

The defined regions which were used in the evaluation of forelimbs and hind limbs were named as: R1= hoof (distal to the coronary band); R2= pastern region (from the distal end of the fetlock to the coronary band); R3= fetlock region (fetlock joint); R4= canon region (from the proximal end of the fetlock to the distal end of carpus/tasus) ; R5= carpal/ tarsal region (carpal/tarsal joint); R6= radial/ tibial region (from the proximal end of the carpus/tarsus to the distal end of shoulder/stifle); R7= elbow/stifle region (elbow and stifle joint). Figures 4, 5, 6 illustrate the defined regions for front limbs and the figures 7, 8, 9 illustrate the defined regions for hind limbs.

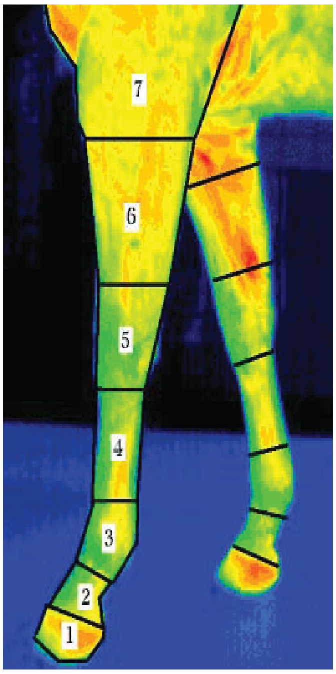


Fig 4

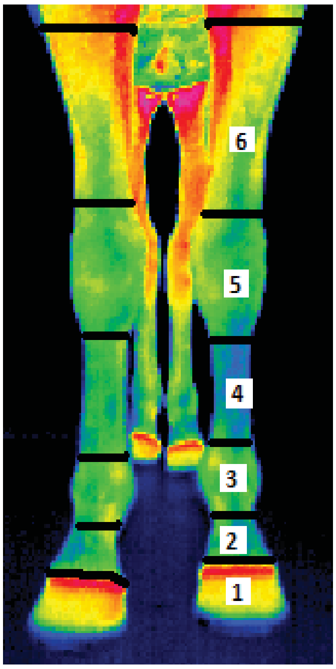


Fig 5

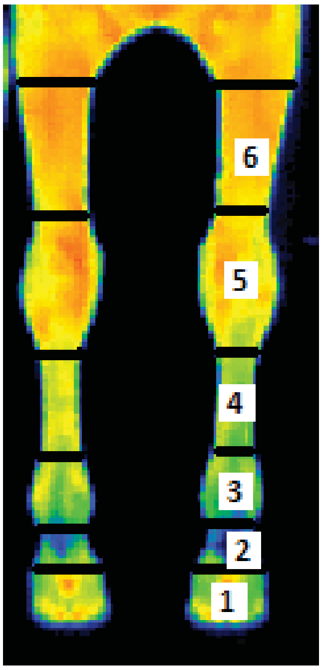


Fig 6

Fig 4: Illustration of the defined regions of a horse`s forelimbs observed in lateromedial view. (*1*), 1FLM (region 1, fore limb, lateromedial view). (*2*), 2FLM (region 2, fore limb, lateromedial view). (3), 3FLM (region 3, fore limb, lateromedial view). (*4*), 4FLM (region 4, fore limb, lateromedial view). (*5*), 5FLM (region 5, fore limb, lateromedial view). (*6*), 6FLM (region 6, fore limb, lateromedial view). (*7*), 7FLM (region 7, fore limb, lateral view).

Fig 5: Illustration of the defined regions of a horse`s forelimbs observed in dorsal view. (*1*), 1FD (region 1, fore limb, dorsal view). (*2*), 2FD (region 2, fore limb, dorsal view). (3), 3FD (region 3, fore limb, dorsal view). (*4*), 4FD (region 4, fore limb, dorsal view). (*5*), 5FD (region 5, fore limb, dorsal view). (*6*), 6FC (region 6, fore limb, cranial view).

Fig 6: Illustration of the defined regions of a horse`s forelimbs observed in palmar view. (*1*), 1FP (region 1, fore limb, palmar view). (*2*), 2FP (region 2, fore limb, palmar view). (3), 3FP (region 3, fore limb, palmar view). (*4*), 4FP (region 4, fore limb, palmar view). (*5*), 5FP (region 5, fore limb, right side, palmar view). (*6*), 6FC (region 6, fore limb, caudal view).

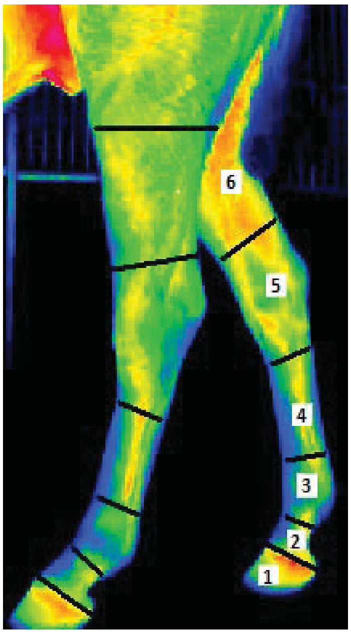


Fig 7

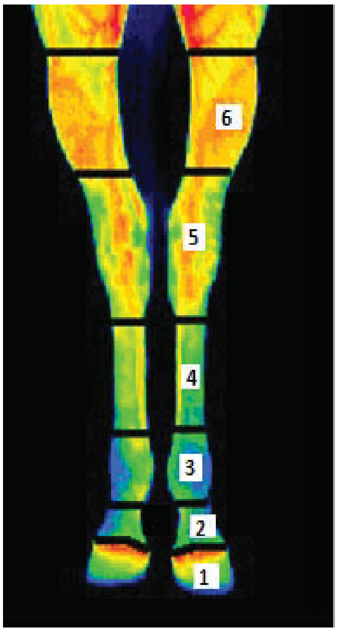


Fig 8

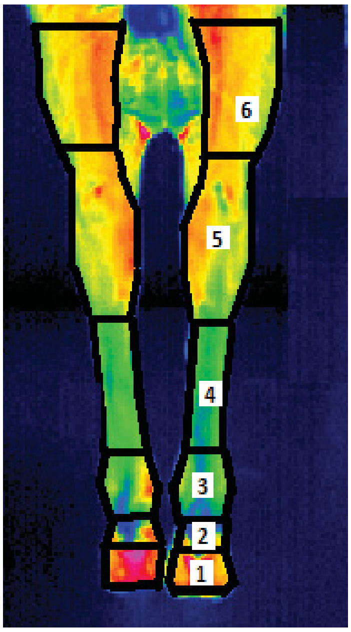


Fig 9

Fig 7: Illustration of the defined regions of a horse`s hind limb observed in mediolateral view. (*1*), 1HML (region 1, hind limb, mediolateral view). (*2*), 2HML (region 2, hind limb, mediolateral view). (*3*), 3HML (region 3, hind limb, mediolateral view). (*4*), 4HML (region 4, hind limb, mediolateral view). (*5*), 5HML (region 5, hind limb, mediolateral view). (*6*), 6HML (region 6, hind limb, mediolateralview). (*7*), 7HML (region 7, hind limb, mediolateral view).

Fig 8: Illustration of the defined regions of a horse`s hind limb observed in dorsal view. (*1*), 1HD (region 1, hind limb, dorsal view). (*2*), 2HD (region 2, hind limb, dorsal view). (*3*), 3HD (region 3, hind limb, dorsal view). (*4*), 4HD (region 4, hind limb, dorsal view). (*5*), 5HD (region 5, hind limb, dorsal view). (*6*), 6HC (region 6, hind limb, cranial view)

Fig 9: Illustration of the defined regions of a horse`s hind limb observed in plantar view. (*1*), 1HP (region 1, hind limb, plantar view). (*2*), 2HP (region 2, hind limb, plantar view). (*3*), 3HP (region 3, hind limb, plantar view). (*4*), 4HP (region 4, hind limb, plantar view). (*5*), 5HP (region 5, hind limb, plantar view). *(6*), 6HC (region 6, hind limb, caudal view).

Scans of the croup were made from caudal and lateral views for both sides. For the chest cranial views were performed. Regions that were defined from the croup were named as Croup1; sacroiliac region, Croup2; hip region, and the regions defined from the chest were named as C1; right shoulder region C2; left shoulder region. Figures 10, 11, 12 show the defined regions for croup and chest.

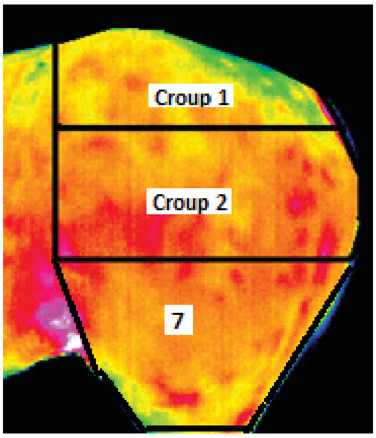


Fig 10

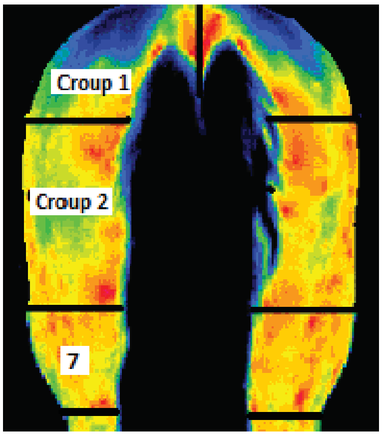


Fig 11

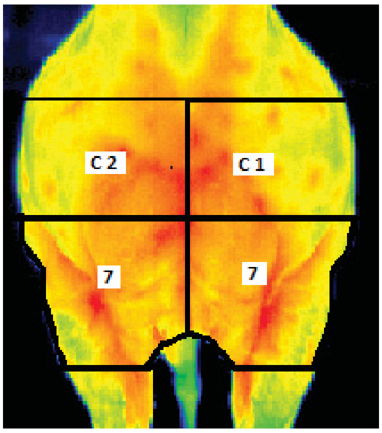


Fig 12

Fig 10: Illustration of the defined regions of a horse`s croup and R7 for hind limb from the lateral view. Croup 1L (sacroiliac region; lateral view). Croup 2L (hip region, lateral view). 7HC (region 7, hind limb, lateral view).

Fig 11: Illustration of the defined regions of a horse`s croup and R7 for hind limb from the caudal view. Croup 1C (sacroiliac region, caudal view), Croup 2C, (hip region, caudal view), 7HC (region 7, hind limb, caudal view)

Fig 12: Illustration of the defined regions of a horse`s chest and R7 for front limb from the cranial view. C1 (right shoulder region), C2 (left shoulder region), 7FC (region 7, front limb, cranial view).

For evaluation of the regional surface temperatures of the back, top line views were performed. Three regions were determined. First region for the back was symbolized as B1 and indicated the thoracic region, B2 and B3 indicated the lumbar region and sacral region respectively. Figure 13 illustrates the defined regions for the back.

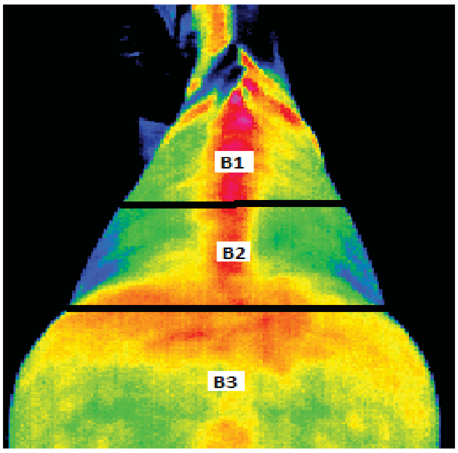


Fig 13: Illustration of the defined regions for back from the top line view. B1 (thoracic region), B2 (lumbar region), B3 (sacral region).

The thermograms which were used in evaluation of the neck were obtained from the lateral views from both sides. Regions that were defined from the neck were symbolized as N1, N2 and N3. The region from the atlas to the distal end of the axis was indicated by N1. N2 shows the region which is from the second to fifth cervical vertebrae. N3 symbolizes the last defined region of the neck and indicates the area between the fifth cervical vertebrae and the seventh cervical vertebrae as illustrated in figure 14.

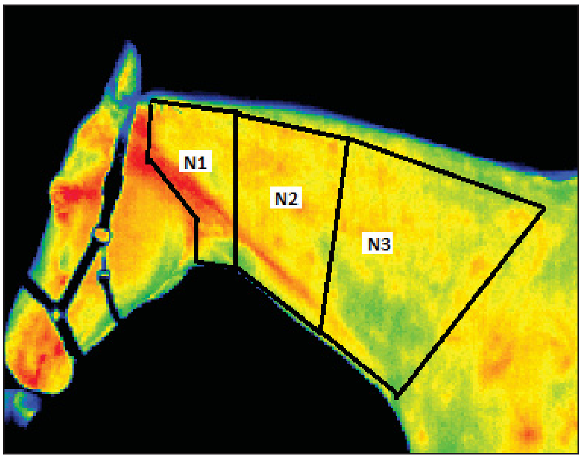


Fig 14: Illustration of the defined regions from the left side view of the neck. N1 (from the atlas to distal end of the axis), N2 (from the second to fifth cervical vertebrae), N3 (from the fifth cervical vertebrae to seventh cervical vertebrae).

With the aim of comparing clinical and thermographical findings, at the beginning of the evaluation, The hypotheses ‘the distribution of the temperature in the horse’s body is symmetric and compared to healthy tissue, injured or diseased tissue has an altered temperature’ were taken as basis. The regions which had different temperature than its symmetry were determined by thermography before clinic examination. The regions which have temperature differences than its respective symmetry due to presence of scar tissue, hairless skin, clipping, dirt and wetness were not evaluated.

The minimum temperature value that was recorded from suspected region and its symmetry, was named as RMin. Likewise the maximum temperature value within the suspected region and its symmetry were recorded and named as RMax. The mean temperature values of the symmetric regions were recorded and named as RMean. The differences of temperature values of symmetric regions were calculated and symbolized as ΔR. These values of ΔR were calculated for RMean, RMin and RMax values and symbolized as ΔRMean, ΔRMin and ΔRMax, respectively.

The regional surface temperature values (RST) (RMean, RMax and RMin, ΔRMean, ΔRMin, ΔRMax) for each region of interest and its symmetry were recorded.

For the second part of the evaluation, all regions were assigned into two groups. The first group included the regions which were defined as source of the inflammation by clinical examination of the horse. These regions were determined depending on clinic diagnosis and named as clinically diagnosed regions (CDR). CDR were divided in to 6 groups according to clinic diagnosis. Groups are ; 1- Injuries of the foot, 2- Joint injuries, 3-Tendon and ligament injuries, 4- Bone injuries, 5- Other disease, 6- the last group included the horses which had no tentative diagnosis.

The regions which were clinically normal but suspected as a source of the inflammation by thermography constituted the second group of the regions and named as thermographically suspected regions (TSR).

The statistical analyses were made by SPSS 15 for Windows. The significance of the mean temperature differences for each CDR group and TSR were analyzed by using Paired-samples t test and Student’s t test. Effects of two or more factors as obtaining the images from the dorsal, lateral, medial and palmar views and their interaction on the 3 response variables as RMean, RMin and RMax were studied using analysis of variance (ANOVA). Differences of the RST of the clinically diagnosed regions and thermographically suspected regions were analysed by using two ways ANOVA. The level of significance was established as $P<0.05$ in all statistical analyses.
The specificity of the thermography in the diagnosis was determined by Receiver Operating Characteristic curve (Roc Curve).

CHAPTER IV

RESULTS

IV.I. Surveys

In the present study 100 horses with 48 different diagnoses were evaluated using thermography during the period of one year. All these horses got a thorough clinical examination and a number of 87 horses were suffering from lameness. From all horses 24 cases had an acute and 63 cases had a chronic injury (Table 1).

Depending on clinic diagnosis horses were divided into 6 groups. Groups were: 1- Injuries of the hoof; 2- Joint injuries; 3-Tendon and ligament injuries; 4- Bone injuries; 5- Other disease; 6- Horses for which no diagnosis could be found. The numbers of the cases for groups were illustrated in table 1.

Table 1: Number and distribution of the examined horses according to groups of diseas

Group	N	Acute	Chronic
Injuries of the hoof	23	6	17
Joint disease	33	6	27
Tendon and ligament injuries	18	6	12
Bone injuries	6	1	5
Other disease	7	5	2
No diagnosis	13	-	-
Total	100	24	63

N: Number of the horses

From these 100 cases, 23 hoof injuries were diagnosed by clinical examination and summarized into one group. Different types of this hoof injuries were recorded and included laminitis (n= 3), pododermatitis purulenta (n= 4), podotrochlosis (n= 11), septic bursitis of the bursa podotrochlearis (n= 1), hollow wall of the hoof (n= 1), canker (n= 1), horn crack (n= 1), cyst of the coffin bone (n= 1). 33 horses suffering from joint injuries were recorded. This group included osteochondrosis dissecans (OCD, n= 18), arthritis (n= 8), arthrosis (n=6), hemarthrosis (n= 1). Bone injuries diagnosed in 6 horses. The types of those injuries were fracture of MC4 (n= 1), fracture of a carpal bone (n= 1), fracture of the distal phalanx (n= 1) fracture of the lateral sesamoid bone (n= 1) and radius fissure (n= 2). 18 horses were suffering from tendon and ligament injuries. Types of those injuries were tendonitis (n=7), desmitis (n=4), desmopathy (n=6), tendovaginitis (n= 1), anular ligament constriction syndrome (n=1). Seven horses with different diagnoses as bursitis of the calcaneal bursa (n= 1), spinal ataxia (n= 2), myalgia (n= 1), narrow spinous processes of the thoracic and lumbar vertebrae (n= 1), trauma (n= 2) could not be implicated in to previous groups. These cases were summarized into a group named as other disease. The last group consisted of non diagnosed cases (n=13).

IV.I.1 Age of the Horses

Horses aged from 1 to 24 years. In our study the horses between 5 to 10 years were mostly affected, followed by those older than10 years old. Young horses aged ‹5 years old had the lowest incidence as shown in table 2.

Table 2: Distribution in number and percent in the groups of disease according to age

Group (G)	‹ 5 years	5 to 10	› 10 years	N
Injuries of the foot (G1)	2	9	12	23
Joint injuries (G2)	10	13	10	33
Bone injuries (G3)	1	4	1	6
Tendon and ligament injuries (G4)	3	8	7	18
Other disease (G5)	1	4	2	7
Have no diagnosis (G6)	6	7	0	13
Percent %	23	45	32	100

N: Number of the horses

IV.I.2.Gender of the Horses

All sexes were represented within the number of 100 horses which were admitted to the Equine clinic. Among 100 horses there were 10 mares, 28 stallion and 62 geldings. The number and percentage of female, male and gelding were illustrated in table 3.

Table 3: Number of mares, stallions and geldings according to groups

Group	Mare	Stallion	Gelding	N
Injuries of the hoof	3	9	11	23
Joint disease	2	4	27	33
Bone injuries	1	3	2	6
Tendon and ligament injuries	1	6	11	18
Other disease	1	2	4	7
Have no diagnosis	2	4	7	13
Total	10	28	62	100

N: Number of the horses

IV.I.3. Affected Regions

The affected regions within horses studied in the survey were more common in the forelimb than in the hind limb. From all horses 54 were affected on the forelimbs while 28 were affected on the hind limbs. The forelimbs and hind limbs were affected either in the right or in the left sides and four cases were recorded with the affection in both forelimbs. The numbers of the bilateral affections in the hind limbs were seven as shown in the table 4. Five horses were recorded with other region injuries as back, neck and croup.

Table 4: Number and percentage of the affected limbs

Front Limb			**Hind Limb**			**Other regions**	**Total**
Right	**Left**	**Bilateral**	**Right**	**Left**	**Bilateral**		
22	28	4	8	13	7	5	82*

*: 5 horses were affected from the other regions (back = 2. neck = 2. croup = 1).

IV.II. Thermographical Evaluation

During the thermographical scanning from all thermographical images 604 symmetric regions were evaluated from the dorsal/cranial, the lateral, the medial and the palmar/plantar views. From this symmetric regions the regional mean (RMean), the regional minimum (RMin) and the regional maximum (RMax) temperature values were recorded. The ΔR values (absolute temperature differences from right and left symmetric regions) were calculated for each one. Finally 1392 regional surface temperature values (RST = ΔR.Mean, ΔR.Min, ΔR.Max, RMean, RMax and RMin) were recorded. 433 (31.1%) of the 1392 RST values were recorded from the regions which were defined as source of the inflammation by clinical examination of the horses.

IV.II.1. Distribution of the RST Values According to Age

A number of 265 values were recorded from horses which were between 0 to 5 years old. 73 of those values were from CDR and 192 were from TSR. From the horses between 5 to 10 years old 628 values were recorded and 499 values were determined from the horses older than 10 years old. In this study, the highest percent had been recorded from the horses aged 5 to 10 described as table 5.

Table 5: Distribution of the recorded RST values according to age

Age	N	Total	nCDR	nTSR
‹ 5 years	23	265 (19 %)	73	192
5 to 10 years	45	628 (45.1%)	190	438
› 10 years	32	499 (35.8%)	170	329
Total	100	1392 (100%)	433	959

N: number of the horses, nCDR: Number of the RST values recorded from the clinically diagnosed regions
nTRS : Number of the RST values recorded from the thermographically suspected regions

IV.II.2. Distribution of the RST Values According to Gender

Within the 1392 values (in total) 121, 471 and 800 values were recorded from mare, stallion and geldings, respectively. The gender of the horses and Distribution of the recorded values according to gender were summarized in table 6.

Table 6: Distribution of the RST values according to gender

Gender	N	Total	nCDR	nTSR
Mare	10	121 (8.7%)	38	83
Stallion	28	471 (33.8%)	119	352
Gelding	62	800 (57.5%)	276	524
Total	100	1392 (100.0%)	433	959

N= Number of the horses, nCDR: Number of the RST values recorded from the clinically diagnosed regions
nTRS : Number of the RST values recorded from the thermographically suspected regions

IV.II.3. Distribution of the RST Values According to Affected Region

In this study 433 values were recorded from the CDR. By these values 282 were recorded from the horses affected on the forelimbs, 114 on the hind limbs and 15 were recorded from the horses that were bilaterally affected. The values which were recorded from the TSR were 528, 561 and 159 from the forelimbs, hindlimbs and bilateral, respectively. Additionally, 25 and 15 values were recorded from the clinically diagnosed and thermographically suspected other regions (back, neck, croup, chest), respectively. Table 7a illustrates these distribution and table 7b shows the total number and distribution of the values according to the effected side of the body.

Table 7a: The total number and distribution of the RST values according to forelimbs and hind limbs

	CDR		TSR	
	Frequency	**Percent**	**Frequency**	**Percent**
Forelimbs	282	65.1	528	55.1
Hindlimbs	114	26.3	204	21.3
Both (hind and front)	12	2.8	16	1.7
Other region*	25	5.8	15	1.6
No diagnosis	-	-	196	20.4
Total	433	100.0	959	100.0

Other region: Back, neck, croup, chest, CDR: Clinically diagnosed regions, TSR: Thermographically suspected regions

Table 7b: The total number and distribution of the RST values according to the affected side of the body

	CDR		TSR	
	Frequency	**Percent %**	**Frequency**	**Percent %**
Right	126	29.1	285	29.7
Left	217	50.1	378	39.4
Both (left and right)	65	15.0	85	8.9
Other region	25	5.8	15	1.6
No diagnosis	-	-	196	20.4
Total	433	100.0	959	100.0

CDR: Clinically diagnosed regions, TSR: Thermographically suspected regions

IV.II.4. Evaluation of the RST Values Recorded from Clinically Diagnosed Regions

IV.II.4.1. Distribution of the RST Values According to the Description of Disease' Condition

By the values recorded from CDR 125 were from acute cases and 308 were from chronic cases. 196 values were recorded from the horses which had no diagnosis and 959 values were recorded from the thermographically suspected regions (Table 8). The total number and distribution of the values according to clinical diagnosis were illustrated in table 9.

Table 8: Total number and distribution of the RST values (RMean, RMax, RMin, ΔRMean, ΔRMin, ΔRMax) according to clinical and thermographical examination.

	Acute	Chronic	No diagnosis	Total
CDR	125 (%28.9)	308 (%70.7)	-	433 (%31.1)
TSR	169 (%17.6)	594 (%61.9)	196 (%20.4)	959 (%68.9)
Total	294	902	196	1392

CDR: Clinically diagnosed regions, TSR: Thermographically suspected regions

Table 9: Total number and distribution of the RST values according to clinical diagnosis

	n	%
Hoof injuries	155	35.7
Joint injuries	143	33.2
Tendon and ligament injuries	76	17.5
Bone Injuries	21	4.8
Other disease	38	8.8
Total	433	100

n: Number of the recorded values

IV.II.4.2. Injuries of the Hoof

Depending on clinical examination, among 100 horses 23 horses (N) were suffering from hoof injuries. 155 thermal measurements (n) were recorded from dorsal, lateral, medial and palmar views. 40 of the 155 values were recorded from the horses with acute injuries and 115 were recorded from the horses with chronic hoof injuries. Numbers and percentage of the horses and the recorded values according to acute and chronic cases were illustrated in table 10.

Table 10: Numbers and percentage of the horses with hoof injuries and recorded RST values according to acute and chronic cases

	N	n	%
Acute	6	40	25.8
Chronic	17	115	74.2
Total	23	155	100.0

N: Number of the horses with hoof injuries, n: Number of the recorded RST values

IV.II.4.2.1. Distribution of the RST Values According to Age

Within all horses with hoof injuries, evaluated values were mostly found in the group of horses older than 10 years followed by the group 5 to 10 years old. The lowest number of RTV were from young horses aged ‹ 5 years old as shown in table 11.

Table 11: Distribution of the RST values according to age

Age	‹ 5 years	5 to 10 years	› 10 years	Total
n	11 (7.1%)	67 (43.2 %)	77(49.7%)	155(100.0%)

n: Number of the recorded values

IV.II.4.2.2. Distribution of the RST Values According to Gender

Within all horses with hoof injuries, 19 evaluated values were found in the group of mare, 59 in the group of stallion and 77 in the group of geldings. The numbers of values were tabled according to gender in table 12.

Table 12: Distribution of the RST values according to gender

Gender	Mare	Stallion	Gelding	Total
n	19 (12.3%)	59 (38.1%)	77 (49.7%)	155 (100.0%)

n: Number of the recorded values

IV.II.4.2.3. Distribution of the RST Values According to Affected Region

In the group of horses with hoof injuries the forelimbs were affected in a higher percentage than the hind limbs. The left forelimb occupied the highest percentage of affections in forelimbs. Just 4 values from one horse were recorded with hind limb injuries as seen in table 13.

Table 13: Distribution of the RST values according to affected region

Front Limb			Hind Limb			
Right	**Left**	**Bilateral**	**Right**	**Left**	**Bilateral**	**Total**
43	79	29	4	-	-	155

IV.II.4.2.4. Significance of Temperature Differences on Hoof Injuries

The analyses of the mean of the RMean, RMin, and RMax values for symmetric regions from chronic and acute cases for the left or right side and their evaluation of significance are illustrated in table 14.

Table 14: General evaluation of the temperature differences between right and left side of the symmetric regions affected by hoof injuries

		Temperature of symmetric regions (°C)	
		Right	**Left**
RST	**n**	**Mean ± SX**	**Mean ± SX**
RMean	155	26.98±0.20^{a}	26.90±0.20^{a}
RMin	155	23.37±0.23^{a}	23.22±0.24^{a}
RMax	155	29.70±0.16^{a}	29.64±0.18^{a}

SX: Standard error, $^{a.}$: Values with same indices within one row are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As shown in table 14, for all regional surface temperatures no, significant differences could be found between symmetric regions of the horses with hoof injuries.

Nevertheless no significant differences were recorded between symmetric regions in general evaluation, after splitting the injuries in to right side, left side and bilateral injuries significant differences were recorded on left and right side injuries (Table 15).

For the horses with right side hoof injuries the differences of the mean temperature of the RMean, RMin, and RMax values between left and right hoof were significant. And for horses with left side injuries, differences of mean of the RMean and RMax values were significant while there were no significant differences on bilaterally affected horses as described in table 15.

Table 15: Significance of the temperature differences between right and left side of the symmetric regions according to affected side

			Temperature of symmetric regions (°C)	
			Right	**Left**
Affected Region	**RTV**	**n**	**Mean ± SX**	**Mean ± SX**
Right Limb	**RMean**	47	27.06±0.24[a]	26.34±0.28[b]
	R.Min	47	23.79±0.32 [a]	23.28±0.33 [b]
	RMax	47	29.51±0.24 [a]	28.75±0.24 [b]
Left Limb	**RMean**	79	26.39±0.31 [a]	26.73±0.31 [b]
	R.Min	79	22.87±0.35	22.94±0.36
	RMax	79	29.36±0.24 [a]	29.69±0.26 [b]
Bilateral	**RMean**	29	28.46±0.43	28.28±0.45
	R.Min	29	24.06±0.56	23.92±0.61
	RMax	29	30.96±0.37	30.96±0.38

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As expected, the right side temperature values, in the horses with right side injuries, were higher than the left side values for all RTV. Horses with left side injuries, injured sides (left) were warmer than the sound side. In the bilateral cases right and left side temperature values were closer to each other.

The significance of temperature values in the acute and chronic hoof injuries were summarized in table 16a and 16b. Those analyses were made without splitting the injuries in to right or left side injuries.

Table 16a: Significance of temperature differences between right and left side of the symmetric regions affected by acute hoof injuries

			Temperature of symmetric regions (°C)	
			Right	**Left**
	RST	**n**	**Mean ± SX**	**Mean ± SX**
Acute	**RMean**	40	28.84±0.33[a]	28.70±0.36[a]
	RMin	40	25.48±0.35[a]	25.42±0.36[a]
	RMax	40	31.04±0.31[a]	30.92±0.36[a]

SX: Standard error, [a.]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As indicated in the table 16a, no significant differences could be found between left and right side of the symmetric regions which were affected by acute hoof injuries.

The same results were recorded for the symmetric regions which were affected by chronic hoof injuries as illustrated in table 16b.

Table 16b: Significance of temperature differences between right and left side of the symmetric regions affected by chronic hoof injuries

			Temperature of symmetric regions (°C)	
			Right	**Left**
	RST	**n**	**Mean ± SX**	**Mean ± SX**
Chronic	**RMean**	115	26.34±0.22[a]	26.27±0.22[a]
	RMin	115	22.63±0.25[a]	22.47±0.26[a]
	RMax	115	29.24±0.17[a]	29.19±0.19[a]

SX: Standard error, [a.]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

Although in general evaluation, no significant differences between symmetric regions were recorded either in the acute or in the chronic cases, as seen in table 16a and 16b, after splitting the injuries into right side, left side and bilateral injuries, some significant differences were recorded. Significance of temperature differences in the acute hoof injuries according to affected region were summarized in table 17a.

Table 17a: Significance of temperature differences between right and left side of the symmetric regions according to affected region in acute hoof injuries

				Temperature of symmetric regions (°C)	
				Right	**Left**
	Affected Region	**RST**	**n**	**Mean ± SX**	**Mean ± SX**
Acute	**Right Limb**	**RMean**	18	28.04±0.33^{a}	26.94±0.38^{b}
		R.Min	18	24.89±0.37^{a}	24.13±0.3^{b}
		RMax	18	30.37±0.38^{a}	29.06±0.39^{b}
	Left Limb	**RMean**	15	28.44±0.55^{a}	29.47±0.35^{b}
		R.Min	15	25.09±0.63	25.47±0.53
		RMax	15	30.75±0.51^{a}	32.10±0.36^{b}
	Bilateral	**RMean**	7	31.78±0.23	31.62±0.28
		RMin	7	27.85±0.69	28.60±0.54
		RMax	7	33.41±0.26	33.17±0.38

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 17a, in horses with acute right side injuries the temperature differences between symmetric regions were significant for all RST values. The temperature values of the right sides were higher than on left sides.

In the horses which were affected from the left sides, although the differences of the RMean and RMax values between symmetric regions were significant, the differences of the RMin were not significant. The temperature values of the left sides were higher than the values recorded from right sides. And for bilateral cases no significant temperature differences could be found between right and left.

The significance of temperature differences between right and left side of the symmetric regions in the chronic hoof injuries according to affected region were illustrated in table 17b.

Table 17b: Significance of temperature differences between right and left side of the symmetric regions according to affected region in chronic hoof injuries

				Temperature of symmetric regions (°C)	
				Right	**Left**
	Affected Region	**RST**	**n**	**Mean ± SX**	**Mean ± SX**
Chronic	**Right Limb**	**RMean**	29	26.45±0.28[a]	25.97±0.37[b]
		RMin	29	23.10±0.43	22.75±0.48
		RMax	29	28.98±0.29[a]	28.55±0.31[b]
	Left Limb	**RMean**	64	25.91±0.34	26.08±0.33
		RMin	64	22.35±0.37	22.35±0.39
		RMax	64	29.03±0.25	29.12±0.27
	Bilateral	**RMean**	22	27.40±0.33	27.22±0.36
		RMin	22	22.86±0.47	22.43±0.45
		RMax	22	30.19±0.33	30.26±0.38

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As summarized in table 17b, in the horses with chronic right side injuries the temperatures of the right side were higher than left side. While the differences of RMean and RMax values between symmetric regions were significant, no significant differences could be found in RMin values.

In the horses which had left side injuries, although the RMean and RMax values of the affected sides were warmer than on sound sides, the differences were not statistically significant. And for the horses which were bilaterally affected, no significant differences could be recorded.

The comparison of the acute and chronic cases at the point of the regional temperature differences between symmetric regions is illustrated in table 18.

Table 18: Significance of temperature differences between acute and chronic hoof injuries

	Temperature (°C)	
	Acute (n=40)	Chronic (n=115)
RST	Mean ± SX	Mean ± SX
ΔRMean	1.09±0.15^{a}	0.70±0.06^{b}
ΔRMin	1.08±0.15	1.13±0.09
ΔRMax	1.34±0.19^{a}	0.79±0.08^{b}

SX: Standard error, ^{a,} ^{b}: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

The ΔRMean and ΔRmax temperature values which were recorded from the acute cases were higher than the ΔRMean and ΔRmax values which were recorded from the chronic cases. While the differences of those values were significant, differences of the ΔRMin values between acute and chronic cases were not significant.

IV.II.4.2.5. Significance of Views on Temperature Differences in Hoof Injuries

The effects of the views that obtained from dorsal, lateral, medial and palmar/plantar aspects on temperature differences were summarized in table 19.

Table 19: Significance of views on temperature differences

	Dorsal (n=40)	Lateral (n=42)	Medial (n=42)	Palmar/plantar (n=25)
RST	Mean ± SX	Mean ± SX	Mean ± SX	Mean ± SX
ΔRMean	0.80±0.15^{a}	0.85±0.13^{a}	0.74±0.1^{a}	0.94±0.18^{a}
ΔRMin	1.11±0.14^{a}	0.99±0.14^{a}	1.08±0.14^{a}	1.43±0.24^{a}
ΔRMax	0.99±0.18^{a}	1.04±0.19^{a}	0.80±0.13^{a}	0.90±0.18^{a}

SX: Standard error, $^{a.}$: Values with same indices within one line are not significant ($p> 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As summarized in table 19 there were no significant differences between the regional surface temperature values that recorded from the pictures obtained from dorsal/cranial, lateral, medial and palmar/plantar views. The view on the limb was without an influence on the differences of skin temperature in hoof injuries.

IV.II.4.2.6. Significance of Temperature Differences between Front and Hind Hooves

The general analyses of the temperature differences between front and hind hooves indicate that there were significant differences on all RTV between front and hind limbs for horses with right side injuries, while there were no significant differences for horses with left side injuries. Table 20 illustrates the significance of temperature differences between the values that were recorded from the horses with right and left side hoof injuries.

Table 20: Significance of temperature differences between front and hind hooves according to affected side of the body

			Temperature of symmetric regions (°C)	
			Front Limb	**Hind Limb**
	RST	**n**	**Mean ± SX**	**Mean ± SX**
Right Side	**RMean**	78	27.42±0.3^{a}	26.90±0.36^{b}
	RMin	78	23.53±0.35^{a}	23.06±0.39^{b}
	RMax	78	30.09±0.24^{a}	29.37±0.32^{b}
Left Side	**RMean**	78	27.37±0.32	27.29±0.31
	RMin	78	23.14±0.39	23.21±0.34
	RMax	78	30.00±0.25	29.85±0.24

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As summarized in table 20, the horses with right side injuries had higher temperature on front hooves and differences were significant. In the horses with left side hoof injuries, while RMean and RMax values of the front hooves were also higher than the hind hooves, differences were not statistically significant for all regional surface temperature values.

The comparison of the surface temperatures between front and hind hooves in horses with acute right and left side injuries were summarized in table 21a.

Table 21a: Significance of temperature differences between front and hind hooves according to affected side of the body in the horses with acute hoof injuries

				Temperature of symmetric regions (°C)	
				Front Limb	**Hind Limb**
	Affected Region	**RST**	**n**	**Mean ± SX**	**Mean ± SX**
Acute	**Right Side**	**RMean**	19	28.90±0.34[a]	28.16±0.40[b]
		R.Min	19	25.41±0.4	24.88±0.47
		RMax	19	31.28±0.35 [a]	30.51±0.4 [b]
	Left Side	**RMean**	19	28.75±0.37 [a]	28.17±0.44 [b]
		R.Min	19	25.40±0.40	24.95±0.46
		RMax	19	31.02±0.41 [a]	30.53±0.41 [b]

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in the table 21a, in the horses with acute right side injuries, regional surface temperature values of the front limbs were higher than the values that recorded from the hind limbs. The differences of the RMean and RMax values between front and hind hooves were significant.

Table 21b: Significance of temperature differences between front and hind hooves according to affected side of the body in the horses with chronic hoof injuries

				Temperature of symmetric regions (°C)	
				Front Limb	**Hind Limb**
	Affected Region	**RST**	**n**	**Mean ± SX**	**Mean ± SX**
Chronic	**Right Side**	**RMean**	59	26.94±0.35	26.5±0.45
		R.Min	59	22.92±0.42	22.47±0.47
		RMax	59	29.70±0.28 [a]	29.00±0.40 [b]
	Left Side	**RMean**	59	26.93±0.39	27.00±0.38
		R.Min	59	22.41±0.46	22.64±0.40
		RMax	59	29.68±0.29	29.63±0.28

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

Table 21b summarizes the significance of temperature differences between front and hind hooves in the horses with chronic left and right side hoof injuries. In the horses with chronic left side injuries, regional surface temperature values of the front limbs were higher than the values that recorded from the hind limbs. Same as the acute right side injuries, significant differences on the RMean and RMax values between front and hind hooves were recorded.

IV.II.4.3. Joint Injuries

Depending on clinical examination, among 100 horses 33 horses were suffering from joint injuries. 143 thermal measurements were recorded from dorsal, lateral, medial and palmar views. 28 of the 143 values were from 6 horses with acute injuries and 115 were from 27 horses with chronic injuries. Distribution of the regional temperature values according to acute and chronic cases were illustrated in table 22.

Table 22: Distribution of the RST values according to acute and chronic cases of joint injury

	N	n	%
Acute	6	28	19.6
Chronic	27	115	80.4
Total	33	143	100.0

N: Number of the horses with tendon/ ligament injuries, n: Number of the recorded regional surface temperature values

IV.II.4.3.1. Distribution of the RST Values According to Age

Within all horses with joint injuries, evaluated values were mostly from horses between 5 to 10 years old followed by horses older than 10 years. The lowest incidences of values were recorded from young horses aged ‹ 5 years old as shown in table 23.

Table 23: Distribution of the RST values according to age

Age	‹ 5 years	5 to 10 years	› 10 years	Total
n	38 (26.6%)	61 (42.7%)	44 (30.8%)	143(100.0%)

n: Number of the recorded regional surface temperature values

IV. II.4.3.2. Distribution of the RST Values According to Gender

Within horses with joint injuries, seven thermographical temperature values from mare were determined, 15 from stallion and 121 values from geldings. The occurrences of values according to gender are shown in table 24.

Table 24: Distribution of the RST values according to gender

Gender	Mare	Stallion	Gelding	Total
n	7 (4.9%)	15 (10.5%)	121 (84.6%)	143 (100.0%)

n: Number of the recorded values

IV.II.4.3.3. Distribution of the RST Values According to Affected Region

In this study within 33 horses with joint injuries, the forelimbs were affected either in the right or left side without any cases recorded with affection in both forelimbs. The hind limbs were affected in right, left and both sides. From the forelimb injuries 61 values were recorded, 79 values were recorded from the hind limb and three values were recorded from one horse with joint injuries on the neck (Table 25).

Table 25: Distribution of the RST values according to affected limb

Front Limb			Hind Limb			
Right	**Left**	**Bilateral**	**Right**	**Left**	**Bilateral**	**Total**
13	48	-	17	36	26	140*

*: 3 values were recorded from a horse that was affected by a neck problem

IV.II.4.3.4. Significance of Temperature Differences on Joint Injuries

The general analyses (analyzing the values without splitting the injuries into groups as right and left side injuries according to the affected region) of the mean of the RMean, RMin, and RMax values for symmetric regions were outlined in table 26.

Table 26: General evaluation of the temperature differences between right and left side of the symmetric regions in joint injuries

RST	n	Temperature of symmetric regions (°C) Right Mean ± SX	 Left Mean ± SX
RMean	143	27.67±0.24[a]	27.57±0.24[a]
RMin	143	23.97±0.23[a]	23.86±0.24[a]
RMax	143	29.60±0.38[a]	29.54±0.38[a]

SX: Standard error, [a.]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

In the horses with joint injuries no significant differences could be recorded between symmetric regions. The right sides of the symmetric regions were slightly warmer than the left sides.Table 27 illustrates the significance of temperature differences in the horses which were affected from the right side, left side and bilateral.

Table 27: Significance of temperature differences between right and left side of the symmetric regions in the joint injuries according to affected region

Affected Limb	RST	n	Temperature of symmetric regions (°C) Right Mean ± SX	 Left Mean ± SX
Right Limb	**RMean**	30	25.56±0.50	25.56±0.48
	RMin	30	21.88±0.56	21.63±0.50
	RMax	30	26.25±1.40	26.16±1.40
Left Limb	**RMean**	84	28.11±0.31	28.14±0.32
	RMin	84	24.37±0.28	24.51±0.32
	RMax	84	30.40±0.30	30.47±0.3
Bilateral	**RMean**	26	28.43±0.28[a]	27.81±0.34[b]
	RMin	26	24.69±0.32[a]	23.91±0.39[b]
	RMax	26	30.68±0.37	30.23±0.4

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

Like in the general evaluation, no significant differences were recorded on left and right sides injuries. In the horses which were bilaterally affected, the values recorded from the right sides were warmer than the values recorded from the left sides. The differences of mean of the RMean and RMin values between right and left side of the body were significant in bilaterally affected horses.

Significance of the temperature differences in acute and chronic joint injuries were illustrated in table 28a and 28b.

Table 28a: Significance of the temperature differences between right and left side of the symmetric regions in acute joint injuries

			Temperature of symmetric regions (°C)	
			Right	**Left**
	RST	n	**Mean ± SX**	**Mean ± SX**
Acute				
	RMean	28	28.62±0.43[a]	28.82±0.44[a]
	RMin	28	23.88±0.55[a]	24.26±0.60[a]
	RMax	28	31.13±0.37[a]	30.94±0.53[a]

SX: Standard error, [a]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 28a, no significant differences could be found between symmetric regions with acute joint injuries.

Table 28b illustrates the temperature values and significance of the differences between symmetric regions that recorded from the horses with chronic joint injuries.

Table 28b: Significance of temperature differences between right and left side of the symmetric regions in chronic joint injuries

			Temperature of symmetric regions (°C)	
			Right	Left
	RST	n	Mean ± SX	Mean ± SX
Chronic				
	RMean	115	27.38±0.27 [a]	27.19±0.27 [a]
	RMin	115	23.94±0.26 [a]	23.74±0.27 [a]
	RMax	115	29.18±0.46 [a]	29.14±0.45 [a]

SX: Standard error, [a.]: Values with same indices within one line are not significant (p> 0.05), n: Number of the recorded values, RST: Regional surface temperature values

As shown in the table 28b, there were no significant differences on the regional surface temperature values between symmetric regions recorded from the horses with chronic joint injuries. The temperature values of the contralateral regions were consistent.

The comparison of the acute and chronic cases at the point of the regional temperature differences between symmetric regions showed that there were no significant differences on mean of ΔRMean, ΔRMin, and ΔRMax values between acute and chronic cases (Table 29).

Table 29: Significance of the temperature differences between acute and chronic joint injuries

	Temperature (°C)	
	Acute (n=28)	Chronic (n=115)
RST	Mean ± SX	Mean ± SX
ΔRMean	0.59±0.14 [a]	0.67±0.06 [a]
ΔRMin	1.30±0.18 [a]	1.08±0.09 [a]
ΔRMax	0.97±0.32 [a]	0.75±0.07 [a]

SX: Standard error, [a.]: Values with same indices within one line are not significant (p> 0.05), n: Number of the recorded values, RST: Regional surface temperature values

Although the difference of the RMin and RMax values recorded from the acute cases were higher than the values recorded from the chronic cases, the difference of RMean values were higher in chronic cases. None of those differences were statistically significant.

IV.II.4.3.5. Significance of Views on Temperature Differences

In joint injuries, there were no significant differences between the regional surface temperature values that obtained from dorsal, lateral, medial and palmar/plantar views in ΔRMean and ΔRMax, while a significant difference was recorded for ΔRMin as demonstrated in table 30.

Table 30: Significance of views on temperature differences

	Temperature (°C)			
	Dorsal/Cranial	**Lateral**	**Medial**	**Palmar/plantar**
RST	**Mean ± SX**	**Mean ± SX**	**Mean ± SX**	**Mean ± SX**
ΔRMean	0.61±0.13 [a]	0.72±0.10 [a]	0.73±0.09 [a]	0.55±0.11 [a]
ΔRMin	0.72±0.09[a]	1.29±0.16[b]	1.32±0.18 [b]	1.28±0.25 [b]
ΔRMax	0.54±0.1 [a]	0.79±0.09 [a]	0.77±0.10 [a]	1.23±0.39 [a]

SX: Standard error, [a, b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

In the horses with joint injuries, RMin values that recorded from the dorsal views were cooler and significantly different from the other orientations.

IV.II.4.4. Tendon and Ligament Injuries

From 18 horses with tendon/ ligament injuries 76 thermographical RST values were evaluated. Within 18 horses, 6 were suffering from acute injuries and 12 from chronic injuries. From acute injuries 32 values were recorded and 44 from the chronic injuries. Table 31 shows the distribution of the number and percentage of values.

Table 31: Distribution of the RST values from horses with tendon/ligament injuries according to acute and chronic cases

	N	n	%
Acute	6	32	42.1
Chronic	12	44	57.9
Total	18	76	100.0

N: Number of the horses, n: Number of the recorded regional surface temperature values

IV.II.4.4.1. Distribution of the RST Values According to Age

From the horses with tendon/ligament injuries, evaluated temperature values were mostly from the horses older than 10 years old followed by horses 5 to10 years old. The lowest value number was from young horses aged ‹ 5 years old as shown in table 32.

Table 32: Distribution of the RST values according to age

Age	‹ 5 years	5 to 10 years	› 10 years	Total
n RST	10(13.2%)	31 (40.8%)	35 (46.1%)	76 (100.0%)

n: Number of the recorded RST values, RST: Regional surface temperature values

IV.II.4.4.2. Distribution of the RST Values According to Gender

In the group of tendon/ligament injuries 4 temperature values were determined from mares, 25 values from stallions and 49 from geldings. The thermographical RST values were tabled according to gender in table 33.

Table 33: Distribution of the RST values according to gender

Gender	Mare	Stallion	Gelding	Total
n	4 (5.3%)	23 (30.3%)	49 (64.5%)	76 (100.0%)

n: Number of the recorded RST values, RST: Regional surface temperature values

IV.II.4.4.3. Distribution of the RST Values According to Affected Region

In this study within 18 horses with tendon/ligament injuries, forelimbs were affected either in the right or left sides without any cases recorded with affection in both forelimbs. The hind limbs were also affected in right and left sides without any affection in both hind limbs. The values recorded from the forelimb injuries were 57 in number and 19 from the hind limbs as outlined in table 34.

Table 34: Distribution of the RST values according to affected region

Front Limb			Hind Limb			
Right	**Left**	**Bilateral**	**Right**	**Left**	**Bilateral**	**Total**
35	22	-	12	7	-	76

IV.II.4.4.4. Significance of the Temperature Differences on Tendon and Ligament Injuries

General analyses of the symmetric regions with tendon/ligament injuries showed that there were no significant differences in regional temperature values as shown in table 35. As mentioned before the general analyses were made without splitting the injuries into groups according to affected side.

Table 35: General evaluation of significance of the temperature differences between right and left side of the symmetric regions affected by tendon/ligament injuries

		Temperature of symmetric regions (°C)	
		Right	**Left**
RST	**n**	**Mean ± SX**	**Mean ± SX**
RMean	76	27.48±0.25 [a]	27.41±0.26 [a]
RMin	76	23.88±0.25 [a]	23.98±0.28 [a]
RMax	76	29.67±0.23 [a]	29.68±0.25 [a]

SX: Standard error, [a.]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

The statistical analyses of the RST values from the symmetric regions which were affected by tendon injuries showed that the regions temperatures were consistent. No significant differences could be found.

Significance of the temperature differences between right and left side of the symmetric regions in tendon/ligament injuries according to effected side of the body were summarized in table 36.

Table 36: Significance of the temperature differences between right and left side of the symmetric regions in tendon/ligament injuries according to effected side of the body

			Temperature of symmetric regions (°C)	
			Right	Left
Affected Limb	RST	n	Mean ± SX	Mean ± SX
Right Limb	RMean		27.8±0.42 [a]	26.95±0.46 [a]
	RMin		23.7±0.42	23.58±0.42
	RMax		29.99±0.39 [a]	29.33±0.44 [a]
Left Limb	RMean		27.22±0.29 [a]	27.81±0.27 [a]
	RMin		24.04±0.29	24.33±0.37
	RMax		29.40±0.28 [a]	29.98±0.26 [a]

SX: Standard error, a. b: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

In the horses affected by tendon/ligament injuries, affected sides were warmer than the contralateral symmetric side. The regional temperature differences were recorded as 0.84±0.21, 0.11±0.27 and 0.66±0.15 for RMean, RMax and RMin values, respectively, in the horses with right side injuries. While the differences were significant in RMean, RMax values, no significant differences could be recorded in RMin values.

Table 37a and 37b illustrates the significance of the temperature differences in acute and chronic tendon/ligament injuries, respectively. The temperature values recorded from chronic cases were unexpectedly higher than the values recorded from acute cases.

Table 37a: Significance of the temperature differences between right and left side of the symmetric regions in acute tendon/ligament injuries

			Temperature of symmetric regions (°C)	
			Right	Left
	RST	n	Mean ± SX	Mean ± SX
Acute	**RMean**	32	25.88±0.29^{a}	26.46±0.35^{b}
	RMin	32	22.93±0.33	23.09±0.44
	RMax	32	28.25±0.29^{a}	28.78±0.39^{b}

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

Although significant temperature differences were recorded between right and left symmetric regions in RMean and RMax, there was no significant temperature difference in RMin for horses with acute tendon / ligament injuries. Right sides of the symmetric regions were warmer than the left sides for all RST values.

Table 37b: Significance of the temperature differences between right and left side of the symmetric regions in chronic tendon/ligament injuries

			Temperature of symmetric regions (°C)	
			Right	Left
	RST	n	Mean ± SX	Mean ± SX
Chronic	**RMean**	44	28.65±0.27^{a}	28.11±0.34^{b}
	RMin	44	24.58±0.31	24.63±0.33
	RMax	44	30.70±0.25^{a}	30.33±0.28^{b}

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As recorded for the acute cases, the right sides of the symmetric regions were also warmer than the left sides for all RST values in chronic tendon/ligament injuries. The mean of the regional temperature differences (ΔR) of the RMean and RMax values between right and left side of the symmetric regions were recorded as 0.58±0.20 and 0.53±0.27, respectively. Those ΔR values were significant. For RMin values the ΔR value was 0.16±0.30 and did not cause a significant difference.

While the difference of RMean and RMax values was significant in both acute and chronic cases, higher temperature values were recorded from the horses with chronic tendon/ligament injuries. It is also recorded that the temperatures were higher in chronic cases while the temperature differences between symmetric regions were lower in chronic cases than the acute cases.

Table 38 shows the significance of the temperature differences between the RTS values that recorded from acute and chronic cases. While there was a significant difference in ΔRMax values, the differences in ΔRMean and ΔRMin values were not significant.

Table 38: The significance of the temperature differences between acute and chronic tendon/ligament injuries

	Temperature (°C)	
	Acute (n=32)	**Chronic (n=44)**
RST	**Mean ± SX**	**Mean ± SX**
ΔRMean	0.92±0.16 [a]	0.88±0.16 [a]
ΔRMin	1.23±0.21 [a]	1.15±0.14 [a]
ΔRMax	1.21±0.19 [a]	0.74±0.10 [b]

SX: Standard error, [a, b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As summarized in table 38, while the RST values recorded from the acute cases were higher than the values recorded from chronic cases, the significant differences were recorded for RMax values.

IV.II.4.4.5. Significance of Views on Temperature Differences in Tendon/ligament injuries

Table 39 illustrates the effects of the different views on temperature differences of the symmetric regions in the group of tendon/ligament injuries,

Table 39: Significance of views on temperature differences in tendon/ligament injuries

	Temperature (°C)			
	Dorsal/Cranial (n=20)	**Lateral (n=20)**	**Medial (n=19)**	**Palmar/plantar (n=15)**
RST	**Mean ± SX**	**Mean ± SX**	**Mean ± SX**	**Mean ± SX**
ΔRMean	1.07±0.27 ^{a}	0.82±0.24 ^{a}	0.91±0.22 ^{a}	0.81±0.16 ^{a}
ΔRMin	1.19±0.21 ^{a}	1.19±0.20 ^{a}	1.34±0.33 ^{a}	1.02±0.25 ^{a}
ΔRMax	1.06±0.23 ^{a}	0.8±0.16 ^{a}	1.07±0.22 ^{a}	0.90±0.22 ^{a}

SX: Standard error, ^{a,}: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As can be seen in table 39, there were no significant differences between the regional temperature values that were obtained from the dorsal, lateral, medial and palmar/plantar views.

IV.II.4.5. Bone Injuries

In the group of bone injuries 21 thermographical determined temperature values were recorded from 6 horses. Only one case was acute and 5 cases were chronic. The number and distribution of the values illustrated in table 40.

Table 40: Distribution of the temperature values of acute and chronic cases of bone injuries

	N	n	%
Acute	1	4	19.0
Chronic	6	17	81.0
Total	7	21	100.0

N: Number of the horses, n: number of the recorded values

IV.II.4.5.1. Distribution of the RST Values According to Age

Most evaluated temperature values were found in horses with bone injuries, the group of 5 to 10 years old horses followed by horses ‹ 5 years old. The lowest occurrence of temperature values were from horses older than 10 years old as shown in table 41.

Table 41: Distribution of the RST values according to age

Age	‹ 5 years	5 to 10 years	› 10 years	Total
n	4 (19.0%)	14 (66.7%)	3 (14.3%)	21 (100.0%)

n: number of the recorded values

IV.II.4.5.2. Distribution of the RST Values According to Gender

In the group of bone injuries 4 temperature values were determined from mares, 11 values from stallions and 6 from geldings. The thermographical determined values were shown according to gender in table 42.

Table 42: Distribution of the RST values according to gender

Gender	Mare	Stallion	Gelding	Total
n	4 (19.0%)	11 (52.4%)	6 (28.6%)	21 (100.0%)

n: number of the recorded values

IV.II.4.5.3. Distribution of the RST Values according to affected region

Within 21 values recorded from the group of bone injuries, 14 values were from the right forelimb and 7 values were from left forelimb. No temperature values were recorded from horses with bone injuries on both fore limb or hind limbs.

IV.II.4.5.4. Significance of Temperature Differences on Bone Injuries

The general analyses (analyzing the RST values without splinting in to groups according to the affected side) of the temperature differences between symmetric regions with bone injuries were summarized in table 43.

Table 43: General analyses of significance of the temperature differences between right and left side of the symmetric regions affected by bone injuries

		Temperature of symmetric regions (°C)	
		Right	Left
RST	n	Mean ± SX	Mean ± SX
RMean	21	29.06±0.71^{a}	28.52±0.58^{b}
RMin	21	25.07±0.57	24.91±0.46
RMax	21	30.84±0.65^{a}	30.43±0.54^{b}

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As pointed out in table 43, in the horses with bone injuries, right sides of the affected symmetric regions were warmer than left sides of the affected regions. The differences in RMean and RMax values between right and left symmetric regions were significant while the differences in RMin values were not significant.

Table 44: Significance of temperature differences between right and left side of the symmetric regions according to affected limb in bone injuries

			Temperature of symmetric regions (°C)	
			Right	Left
Affected Limb	RST	n	Mean ± SX	Mean ± SX
Right Limb	**RMean**	14	28.60±1.00^{a}	27.95±0.81^{a}
	RMin	14	25.13±0.83^{a}	24.75±0.66^{a}
	RMax	14	30.43±0.93^{a}	29.87±0.77^{a}
Left Limb	**RMean**	7	29.97±0.65^{a}	29.67±0.39^{a}
	RMin	7	24.95±0.52^{a}	25.21±0.47^{a}
	RMax	7	31.67±0.56^{a}	31.55±0.38^{a}

SX: Standard error, ^{a}: Values with same indices within one line are not significant ($p> 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 44, no significant differences between right and left side of the symmetric regions according to affected side of the body were recorded in bone injuries. This result could be ascribed to the analyzing the acute and chronic cases together. We had just one acute case with right side injuries. Among the horses with chronic bone injuries two horses were affected from left, three horses were affected from right side.

Table 45 shows the significance of the temperature differences between the RTS values that recorded from the horses with acute bone injuries and the RTS values that recorded from the chronic cases.

Table 45: Temperature differences between acute and chronic bone injuries

RST	**Temperature (°C)**	
	Acute (n=4)	**Chronic (n=17)**
	Mean ± SX	**Mean ± SX**
ΔRMean	2.41±0.12[a]	0.47±0.09[b]
ΔRMin	3.10±0.38[a]	1.05±0.19[b]
ΔRMax	1.90±0.29[a]	0.47±0.11[b]

SX: Standard error, [a, b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 45 significant differences of all regional surface temperatures between acute and chronic cases were recorded in the horses affected by bone injuries. Mean of the temperature differences of the symmetric regions in acute cases were warmer than the values that recorded from chronic cases. About 1 to 2 °C differences were recorded between the regions affected by acute and chronic injuries.

IV.II.4.5.5. Significance of Views on Temperature Differences in Bone Injuries

Significance of temperature differences between the regional temperature values obtained from dorsal, lateral, medial and palmar/plantar views is summarized in table 46.

Table 46: Significance of views on temperature differences in bone injuries

	Temperature (°C)			
	Dorsal/Cranial (n=8)	Lateral (n=7)	Medial (n=4)	Palmar/plantar (n=2)
RST	Mean ± SX	Mean ± SX	Mean ± SX	Mean ± SX
∆RMean	0.60±0.32[a]	0.73±0.32[a]	1.21±0.41[a]	1.45±0.64[a]
∆RMin	1.21±0.26[a]	1.41±0.53[a]	1.34±0.60[a]	2.64±0.59[a]
∆RMax	0.68±0.31[a]	0.63±0.3[a]	1.01±0.34[a]	0.87±0.38[a]

SX: Standard error, [a.]: Values with same indices within one line are not significant ($p > 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

It was observed that there were no statistically significant differences in all TSR values those were recorded from different orientations of views.

IV.II.4.6. Other Diseases

In this group 38 values were evaluated from 7 horses. 21 of the values were recorded from acute cases and 17 values were from chronic cases. The number and distribution of the values according to acute and chronic cases is illustrated in table 47.

Table 47: Distribution of the RST values according to acute and chronic cases

	N	n	%
Acute	5	21	55.3
Chronic	2	17	44.7
Total	7	38	100.0

N: Number of the horses with other disease, n: Number of the recorded RST values

IV.II.4.6.1. Distribution of the RST Values According to Age

In this group the evaluated values were mostly from horses which were between 5 to10 years old followed by horses older than 10 years old. The lowest occurrences of values were from horses aged younger than 5 years old as shown in table 48.

Table 48: Distribution of the RST values according to age

Age	‹ 5 years	5 to 10 years	› 10 years	Total
n	10 (26.3%)	17 (44.7%)	11 (28.9%)	38 (100.0%)

n: Number of the recorded values

IV.II.4.6.2. Distribution of the RST Values According to Gender

In the group of other diseases 4 temperature values were determined from mares, 11 values from stallions and 23 from geldings. The thermographical determined values were shown according to gender in table 49.

Table 49: Distribution of the RST values according to gender

Gender	Female	Male	Gelding	Total
n	4 (10.5%)	11 (28.9%)	23 (60.5%)	38 (100.0%)

n: Number of the recorded values

IV.II.4.6.3. Distribution of the RST Values According to Affected Region

Within 38 RST values recorded from the group of other diseases, 16 values were from hind limbs, 22 were from other regions (chest = 4, back = 14, neck = 4).

IV.II.4.6.4. Significance of Temperature Differences on Other Disease

The temperature differences between affected and the symmetric normal contralateral regions are summarized in table 50.

Table 50: General analyses of significance of the temperature differences between right and left side of the symmetric regions affected by other diseases

		Temperature of symmetric regions (°C)	
		Right side	**Left Side**
RST	**n**	**Mean ± SX**	**Mean ± SX**
RMean	38	26.91±0.39[a]	27.41±0.36[b]
RMin	38	24.22±0.53 [a]	24.53±0.42 [a]
RMax	38	29.14±0.4 [a]	29.87±0.33 [b]

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 50, significant differences were recorded for RMean and RMax values while RMin differences were not significant in the group of other diseases. The left sides of the symmetric regions were warmer than the right sides.

In the horses with other diseases, temperature differences between right and left side of the symmetric regions according to affected side of the body were illustrated in table 51.

Table 51: Significance of the temperature differences between right and left side of the symmetric regions according to affected side of the body in the horses with other diseases

			Temperature of symmetric regions (°C)	
			Right	**Left**
Affected Region	**RST**	**n**	**Mean ± SX**	**Mean ± SX**
Left Limb	**RMean**	6	28.47±0.72 [a]	30.19±0.66 [b]
	R.Min	6	23.55±0.84	23.75±0.59
	RMax	6	30.69±0.55 [a]	32.77±0.58 [b]
Bilateral	**RMean**	10	27.76±1.13	28.57±0.58
	R.Min	10	26.09±1.37	26.52±1.00
	RMax	10	29.82±0.92	30.62±0.32
Other Region	**RMean**	22	26.11±0.31	26.13±0.29
	R.Min	22	23.56±057	23.83±0.44
	RMax	22	28.41±0.24	28.73±0.34

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values, Other region: Chest = 4, back = 14, neck = 4

As summarized in table 51, significant differences were recorded for RMean and RMax values from the horses with left side injuries. Affected regions were warmer than the unaffected regions. In the horses affected from chest, neck, back and in the horses affected bilaterally no significant differences could be recorded.

Table 52a and table 52b summarize the significance of temperature differences in acute and chronic cases.

Table 52a: Significance of temperature differences between right and left side of the symmetric regions in acute cases

			Temperature of symmetric regions(°C)	
			Right	Left
	RST	n	Mean ± SX	Mean ± SX
Acute	**RMean**	21	26.85±0.42^{a}	27.48±0.50^{b}
	RMin	21	23.32±0.61^{a}	23.79±0.48^{a}
	RMax	21	29.22±0.34^{a}	30.33±0.46^{b}

SX: Standard error, $^{a.\ b}$: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As illustrated in table 52a, significant differences were recorded for RMean and RMax values while there were no significant differences in RMin values in acute cases. Right sides of the symmetric regions were warmer than the left sides.

In the chronic cases the significance table was totally different from the acute cases. No significant differences were recorded for RMean, RMin and RMax values as shown in table 52b.

Table 52b: Significance of temperature differences between right and left side of the symmetric regions in chronic cases

			Temperature of symmetric regions(°C)	
			Right	Left
	RST	n	Mean ± SX	Mean ± SX
Chronic	**RMean**	17	27±0.71^{a}	27.32±0.51^{a}
	RMin	17	25.34±0.84^{a}	25.44±0.67^{a}
	RMax	17	29.05±0.59^{a}	29.30±0.46^{a}

SX: Standard error, $^{a.}$: Values with same indices within one line are not significant ($p> 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

Table 53 pointes out the regional temperature differences (ΔR) for RMean, RMin and RMax temperatures between acute and chronic cases.

Table 53: Temperature differences between acute and chronic cases

RST	Temperature (°C)	
	Acute (n=21)	Chronic(n=17)
	Mean ± SX	Mean ± SX
ΔRMean	0,73±0,17 [a]	1,02±0,31 [a]
ΔRMin	1,41±0,27 [a]	0,85±0,21 [a]
ΔRMax	1,23±0,24 [a]	1,01±0,36 [a]

SX: Standard error, [a]: Values with same indices within one line are not significant (p> 0.05), n: Number of the recorded values, RST: regional surface temperature values

As tabled, there were no significant differences between acute and chronic cases. Whereas the ΔRMin and ΔRMax values recorded from acute cases were higher than chronic cases, ΔRMean values recorded from chronic cases were higher than acute cases.

IV.II.5. Evaluation of the Thermogaphically Suspected Regions

Among 1392 regional surface temperature values, 959 were recorded from the thermographiccally suspected regions. These regions were suspected as a source of inflammation by thermogaphy and determined due to the presence of temperature asymmetry between contralateral limbs.

In table 54 the significance of the temperature differences between symmetric regions that were suspected as a source of inflammation by thermogaphy were summarized.

Table 54: Significance of temperature differences between right and left side of the symmetric regions in thermographically suspected regions

		Temperature of symmetric regions (°C)	
		Right	Left
RST	**n**	**Mean ± SX**	**Mean ± SX**
RMean	959	26.78±0.1 ^{a}	27.03±0.09 ^{b}
RMin	959	23.31±0.1 ^{a}	23.56±0.09 ^{b}
RMax	959	29.18±0.09 ^{a}	29.45±0.08 ^{b}

SX: Standard error, $^{a,\ b}$: Values with different indices within one line are significant ($p< 0.05$), n: Number of the recorded values, RST: Regional surface temperature values

As summarized in table 54, there were significant differences between the regional surface temperatures that recorded from the TSR and their contralateral symmetry. The temperature values recorded from the left side of the body were higher than the values recorded from the right side of the body.

IV.II.6. Significance of the Temperature Differences between the Thermogaphically Suspected Regions and Clinically Diagnosed Regions

The significance of temperature differences between the symmetric regions that defined by clinic diagnosis and the symmetric regions that recorded from the thermogaphically suspected regions were illustrated in table 55.

Table 55: Significance of the regional temperature differences between CDR and TSR

	Temperature Differences (°C)	
	CDR(n=433)	TSR(n=959)
RST	**Mean ± SX**	**Mean ± SX**
∆RMean	1.05±0.04[a]	0.78±0.04[b]
∆RMin	1.37±0.04 [a]	1.15±0.05 [b]
∆RMax	1.18±0.08 [a]	0.89±0.05 [b]

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: regional surface temperature values, CDR: Clinically diagnosed region, TSR: Thermographically suspected region

As summarized in table 55, the temperature differences of the CDR were higher than the temperature differences of the TSR. The differences between two groups were significant for all RST values.

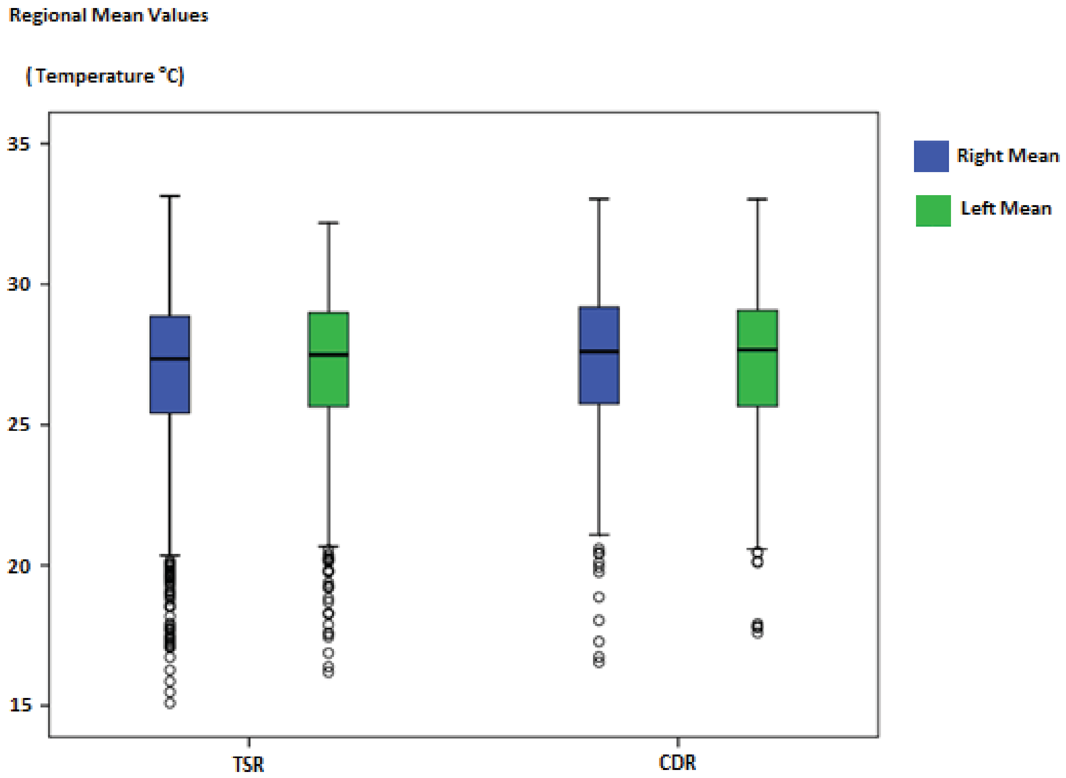
Table 56: Significance of temperature difference between CDR and TSR according to affected side of the body

		Temperature of symmetric regions (°C)	
		CDR (n=433)	TSR(n=959)
Symmetric Region	**RST**	**Mean ± SX**	**Mean ± SX**
Right Side	**RMean**	27.39±0.14[a]	26.78±0.09 [b]
	RMin	23.81±0.14 [a]	23.31±0.09 [b]
	RMax	29.67±0.14 [a]	29.18±0.09 [b]
Left Side	**RMean**	27.34±0.13 [a]	27.03±0.09 [b]
	RMin	23.77±0.13 [a]	23.56±0.09 [b]
	RMax	29.67±0.13 [a]	29.45±0.09 [b]

SX: Standard error, [a. b]: Values with different indices within one line are significant ($p < 0.05$), n: Number of the recorded values, RST: Regional surface temperature values, CDR: Clinically diagnosed region, TSR: Thermographically suspected region

The temperature differences between CDR and TSR according to affected side of the body were summarized in table 56. Significant differences were recorded between CDR and TSR for all regional surface temperature values. The regions that suspected as a source of inflammation by thermography but accepted as normal by clinic examination had significant lower temperature than the CDR, in right and left side of the body.

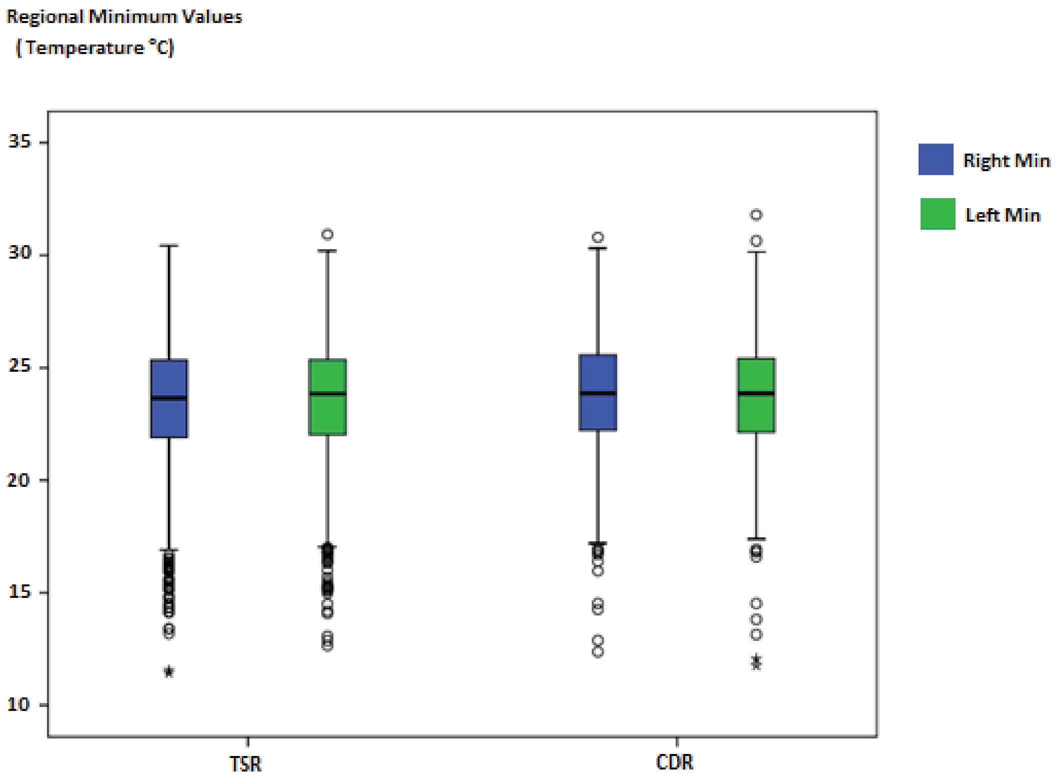
Addition to those findings Figure 1, Figure 2, Figure 3 illustrate the mean of RMean, RMin and RMax temperature of the symmetric regions according to CDR and TSR, respectively.



TSR: Thermographically suspected region, CDR: Clinically diagnosed region

Fig 15: The mean of the RMean temperature values according to TSR and CDR

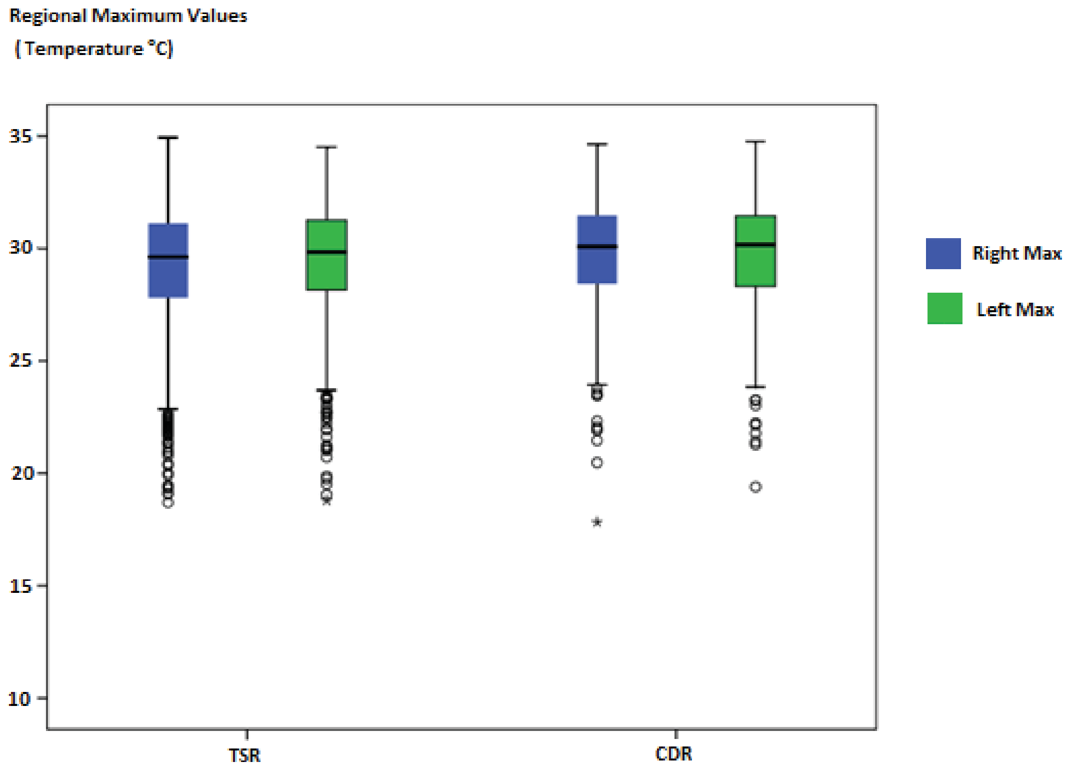
As described in figure 15, the mean of the regional mean values recorded from the clinically diagnosed regions were warmer than the mean of the regional mean values that recorded from the thermographically suspected regions for right and left sides of the body.



TSR: Thermographically suspected region, CDR: Clinically diagnosed region

Fig 16: The mean of the RMin temperature values according to TSR and CDR

As described in figure 16, the mean of the regional minimum values that recorded from the clinically diagnosed regions were warmer than the mean of the regional minimum values that recorded from the thermographically suspected regions for right and left sides of the body.

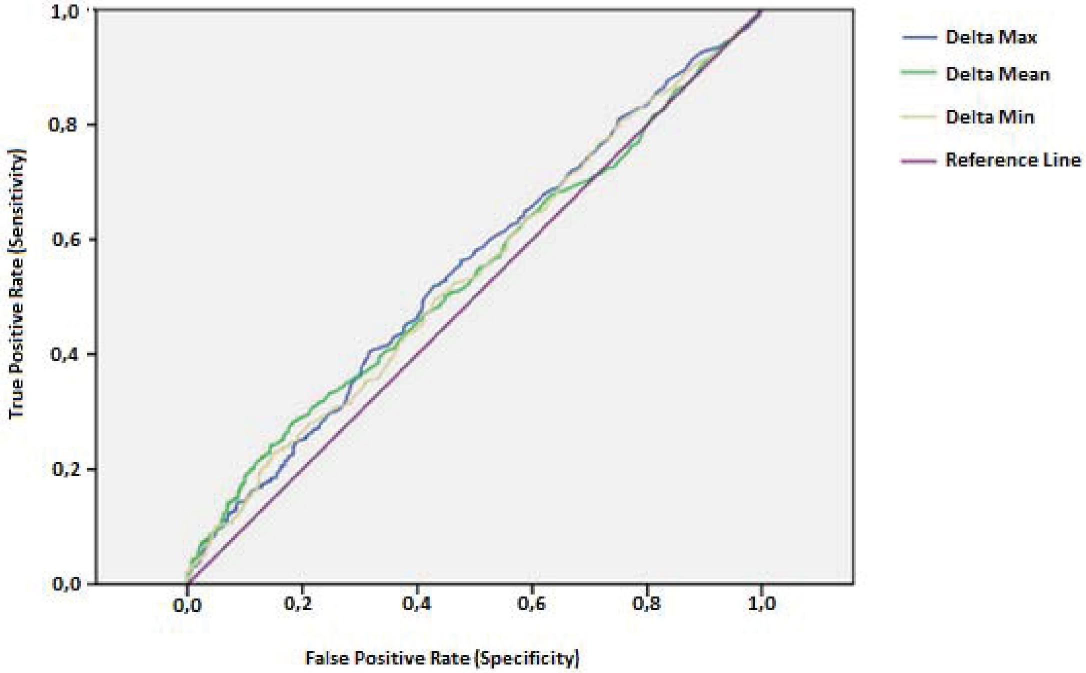


TSR: Thermographically suspected region, CDR: Clinically diagnosed region

Fig 17: The mean of the RMax temperature values according to TSR and CDR

As described in figure 17, the mean of the regional maximum values that recorded from the clinically diagnosed regions were warmer than the mean of the regional maximum values that recorded from the thermographically suspected regions for right and left sides of the body.

Depending on thermographic findings from CDR and TSR, the sensitivity and specificity of the thermography about allowing an accurate localization of inflammatoric and degenerative condition were determinated by Receiver Operating Characteristic curve (Roc Curve). The areas under the curves were 0.54, 0.54 and 0.55 for ΔRMean, ΔRMin and ΔRMax values, respectively, as shown in figure 4.



Delta Max: Absolute difference of regional maximum temperatures of respectively symmetric regions, Delta Mean: Absolute difference of regional mean temperatures of respectively symmetric regions, Delta Min: Absolute difference of regional minimum temperatures of respectively symmetric regions.

Fig 18: Roc Curves for ΔRMean, ΔRMin and ΔRMax values

As described in figure 18, depending on the ΔRMean, ΔRMin and ΔRMax values the specificity rates of the thermography were not so different. The highest specificity rate was recorded as %55 for ΔRMax values.

In this study 100 horses got a through clinical and thermographic examination. Among all horses, 87 horses had a clinical diagnosis. In 13 horses, although thermal pattern changes were present, no pathologic lesion could be recorded by clinic examination. By these 87 horses, in 66 horses addition to thermal pattern changes in injured region (TF), thermal pattern changes in the areas that were not related with the injured region (ATF: additional thermographic findings) were also recorded. In 21 horses no thermal pattern changes in the areas that were not related with the injured region were recorded. Table 57 shows the distribution of the cases according to the clinic diagnosis and thermographic findings.

Table 57: Distribution of the cases according to the clinic diagnosis and thermographic findings

N	CD	TF	ATF
13	-	-	+
11	+	+	-
17	+	-	+
59	+	+	+

N: Number of the horses: CD; Clinic diagnosis, TF: Thermographic findings, thermal pattern changes in injured region, ATF: Additional thermographic findings, thermal pattern changes in the areas that were not related with the injured region

As illustrated in Table 57 among 100 horses 13 had no clinic diagnosis but had additional thermographic changes, all 87 horses, which had a clinic diagnosis (CD), 70 horses showed thermal pattern changes in the areas that were related with the injured region (TF). Although 13% of these horses had no additional thermographic finding, 87% of the horses had thermal pattern changes which were not related with the clinic diagnosis.

CHAPTER V:

DISCUSSION

The clinical basis of thermographic interpretation is correlating the temperature recordings with inflammatoric and degenerative conditions (LOUGHIN et al., 2007). This technique measures the emitted heat from the skin and can demonstrate the loss of the normal symmetric distribution of the surface temperature within an image (PUROHIT, 1980; TURNER et al., 1986; HOLMES et al., 2003; BOWERS et al., 2009).

Thermography makes use of the fact that heat is one of the most effective factor in evaluation of the inflammation PUROHIT et al. (1980 a), TURNER (1996 c). With developing technology of thermography, device becomes easier to handle as well as more accurate with various advantages. It does not expose the patient and investigator to harmful radiation, can be performed without anesthesia or sedation, safety for the veterinarian and provides objective, repeatable graphical and numerical data. In the basis of a high degree of right-to left symmetry in the body, changes in normal pattern would indicate the possible inflammation (PUROHIT, 2004). Thermography makes use of the fact that heat is one of the most effective factor in evaluation of the inflammation PUROHIT et al. (1980 a), TURNER (1996 c).

Thermography have been used in examinations of equine orthopedic diseases like laminitis, arthritis, tendon and ligament injuries, muscle injuries, navicular disease, fractures, nerve injuries, back pain and hind limb lameness.

The goal of the present study was to determine if infrared thermography would be a benefit in the diagnosis of equine lameness at the beginning of the orthopedic examination of horses. Horses which were referred to the equine clinic with the complains of lameness had been examined with thermography before clinic examination. During the case selection surface contour and previous treatments were took into the consideration. Horses which were dirty, wet, clipped from one side and the horses which were sedated and treated with topical agents were excluded.

A series of thermograms were obtained from each horse. The regions that suspected as source of the inflammation due to presence of the thermal asymmetry were determined. The regional mean, regional minimum and regional maximum values were evaluated for each region. After performing the all examinations (thermographic and clinic), it has been discovered that not all suspected regions were diagnosed by clinic examination. Because of this finding, regions were classified as thermographically suspicious and clinically diagnosed regions. The temperature differences between clinically abnormal and normal symmetric regions that were diagnosed by clinic examination were determined. The regions were analyzed by dividing into 6 groups according to clinic diagnosis. As mentioned before, regional surface temperature values were evaluated for each lameness groups.

The reason for dividing the regions that were diagnosed by clinic examination into groups was the various locations on the same limb have different temperatures, as mentioned by VERSCHOOTEN et al. (1997) the regions of the horse`s body have different normal patterns. For instance, TURNER (1986), STROMBERG (1973), KOLD et al. (1998) reported that normal joints are cooler compared to the other structures around them and the coronary band, due to its rich blood supply, is the warmest area on the limb. To analyze these regions together would give false positive and negative results.

In this study we discovered that when evaluating the injuries it was necessary to split injured regions into right and left side of the body. Otherwise, the heat changes on right and left sides were neutralizing by each other. During the evaluation of the acute and chronic cases statistically, splitting the injuries in to right and left side groups according to affected side of the body was also preferred. This was not possible for some groups as other disease, due to the small case number.

The evaluation of the mean temperature values that were obtained from the horses with foot injuries was made between all four hooves, front to front and front to rear, as proposed by TURNER (1991 a), TURNER (1996 b) and EDDY et al. (2001).

The results for injuries of the foot indicated that the differences between effected region and the normal contralateral region were significant for all RST values in horses with acute right side foot injuries. It is also important to say that in the acute left and right side hoof injuries, significant temperature differences were recorded between front and rear feet on RMean and RMax values, while there was no significant difference on RMin values. The temperature values of the front hooves were higher than the hind hooves. Depending on the study results we discovered elevated heat in abnormal regions.

At the point of acute hoof injuries those results are in concurrence with the opinion of PUROHIT (1980), WALDSMITH (1992), TURNER (2001), EDDY et al. (2001), who mentioned in their reports that thermography was useful for diagnosis and evaluation of the foot injuries. They also emphasized that there were noticeable heat increases in abnormal regions. The significance of the RMean, RMin and RMax values was not separately evaluated by them. Evaluating the regional surface temperature values separately proved that the differences of RMin values were only significant in acute right side hoof injuries.

Those insignificant indications for RMin values may be attributed to the use of manually drawn regions for determining the regions in the question. While drawing the regions, even one pixel taken in from out of the border of the region, could change the real minimum temperature value. The temperature outside of the detected region of the body is lower. Therefor only regional minimum values are influenced by recording a pixel outside of the body contour. Thus the failure rate could increase and cause false positive and negative results. Accuracy of the regional minimum values is especially important in the diagnosis of the diseases that characterized with reduced heat as sacroiliac subluxation (TURNER, 2001) and dorsal intervertebral osteoarthritis (FONSECA et al., 2006). Additionally the false calculation of the regional minimum values could also affect the regional mean values and cause the variations in the regional temperatures. These false positive and negative effects of extra pixels that were taken in from out of the border of the interested regions on RMean values would not be as strong as the effects on RMin values.

In this study, when evaluating the images with taking one of the RST as criteria no significant differences could be recorded between RMean, RMax and RMin values. Our personal choice was to evaluate the thermograms by using RMean and RMax values. The possibility of the false positive or negative results due to RMin values must not be neglected.

For the horses with chronic hoof injuries, although significant differences were recorded from the horses with right side injuries, no significant differences were recorded from the horses with left side injuries. These findings may be attributed to the presence of heat increases because of the weight bearing on opposite leg for compensating the primary injury as mentioned by WALDSMITH (1992). In horses with bilateral chronic and acute hoof injuries temperature values of the symmetric regions were consistent and showed no significant temperature differences. The amount of heat generated from chronic and bilateral injuries was not sufficient to compose a detectable temperature difference. This is in agreement with reports of GREEN (1999), SIMON et al., (2006) who attributed that the surface temperatures become normal in chronic injuries and that bilateral inflammation causes similar changes on both sides on thermal pattern. This is in concurrence with the opinions mentioned by CETINKAYA et al. (2011) who reported in their studies that thermal imaging#was useful in diagnosis of all acute cases but no local temperature increases were recorded in chronic cases via infrared camera.

The comparison of the acute and chronic hoof injuries at the point of regional temperature differences indicated that differences in the acute hoof injuries were significantly higher than in chronic hoof injuries. This expected result may be referred to the amount of the generated heat which is higher in acute inflammation than in chronic.

PUROHIT, (1980); VADEN et al. (1980), TURNER et al., (1986), VADEN et al. (1980) STROMBERG (1973), TURNER (1998); KOLD et al., (1998), TURNER et al. (2001), TURNER (2001) and EDDY et al. (2001) indicated that thermographic changes could be detected in the joint injuries. Despite of these results horses with acute or chronic joint injuries, showed no significant temperature differences between symmetric regions. In the group of joint injuries among 33 horses 27 were chronic cases and 9 horses were suffering from osteochondrosis. This consequence is in close consensus to the interpretation of VERSCHOOTEN et al. (1997), who mentioned that no temperature changes were observed in the horses suffering from osteochondrosis of the hock or stifle.

Our results for joint injuries are also in concurrence with the opinion mentioned by EDDY et al. (2001), who attributed this to the reduced ability of infrared thermography in chronic and subclinical injuries, because of the deficient heat generation. He also indicated that in the horses with degenerative joint disease of the hock (bone spavin), pastern and coffin joints (ringbone) while lameness was present, thermal pattern of the corresponding affected region did not indicate an increased thermal difference comparison to the symmetric non affected region.

Excellent findings in our study were the significant differences on the RMean and RMax values recorded from the bilaterally affected horses. These findings may be correlated to the factors that influence the joints thermal pattern. The thermal pattern of the joints are depending on the chronicity of the problem, the degree of synovial involvement, the actual amount of cartilage damage, and the presence or absence of osteochondral fragments. Due to interactions of these factors and their effects on the inflammatory response, as mentioned by GREEN (1999) and TURNER et al. (2001), no specific correlation can be made between heat and joint inflammation.

In the present study significant temperature differences were obtained in RMean and RMax values for acute and chronic tendon injuries. This is in concurrence with results recorded by WEIL et al. (1998), TURNER (1998); TURNER (2001), who indicated that thermography predicted the location of the tendon injuries with high percentage.

The same statutes which were observed in tendon injuries were also observed in bone injuries. Thermography gave positive results. Temperature differences between symmetric regions, affected by bone injuries, were significant for RMean and RMax values in acute and chronic injuries, while the differences in RMin values were not significant. Although the temperature differences were also significant in chronic cases, heat increases were less than in acute cases. The results of bone injuries are in concurrence with the reports recorded by PUROHIT (1980), WEIL et al. (1998), GREEN (1999) and TURNER (2001) who mentioned that thermography was useful in diagnosis of the bone injuries.

The group of other diseases included seven horses with different diagnosis as bursitis of the calcaneal bursa (n= 1), spinal ataxia (n= 2), myalgia (n= 1), narrow spinous processes of the thoracic and lumbar vertebrae (n= 1), trauma (n= 2). In general evaluation (without splitting the injuries in to groups according to affected side of the body) significant differences were recorded in RMean and RMax values between symmetric regions. In this regard, our results were in concurrence with following studies. TURNER (2001) indicated in his report that bursitis was a reason for local temperature differences between symmetric regions. STROMBERG (1971), TURNER (1991) and TURNER (1996 c) reported that muscle injuries were the best application of the thermography. FONSECA et al. 2006 said injuries of the vertebral spine can be diagnosed by thermography. Although differences were significant in general evaluation, no significant differences could be recorded in horses affected from chest, neck and back. In our study these results can be attributed to the small case number and inhomogene groups. As mentioned before the regions on the same side of the horse`s body have different temperatures from one area to the next. Due to low case number, the horses affected from different regions of the body like chest, neck and back were evaluated together.

Previous reports on the use of thermography by TURNER (1986) and GREEN (1999) suggested that circumferential scans, at least in two directions, should be performed during the thermographic examination of extremities. One question that arises: Is there a significant difference between the regional temperature values that obtained from different directions of views (dorsal, lateral, medial and palmar)? It is recorded in this study that different orientations of views had no significant effect on evaluation of the regional temperature differences except the RMin values that obtained from the dorsal views in joint injuries. The reason of the significant differences on RMin values could be explained by the high possibility of false positive and negative results during the calculating of the RMin values as described before.

For foot injuries this findings may be ascribed to the presence of coronary band from the dorsal, lateral and medial views and the area between bulbs of the heel from the palmar/plantar views. PUROHIT et al. (1980 a) and TURNER (2001) found that coronary band and the area between bulbs of the heel are 1 to 2 °C warmer then the rest of the hoof. They also said that the highest temperature value of the sound leg had been recorded from in this area. Presence of these structures may cause similar changes on regional surface temperature values in each orientation of the views. Especially when evaluating the thermographic image on the basis of the regional maximum values. Because during the calculation of the regional maximum temperatures, the program calculates the maximum values from the region. Coronary band and bulbs of the heel have a higher temperature than the rest of the region.

For joint injuries, as described before, any significant temperature differences weren't recorded between affected region and its symmetric counterpart. Due to interactions of effective factors as maintained before, true positive or false positive results and inefficiency of the different directions of views should be acceptable for joint injuries.

In the tendon and ligament injuries the reason for missing differences between different aspects may be attributed to the possibility of obtaining the views directly from the injured tendon from lateral, medial and palmar aspects because in many injuries no anatomical structure is underlying between skin and tendon. Whole leg inflammation due to tendon injuries could be a reason for increased heat on dorsal views.

This investigations showed that 71% of the regional temperature differences between symmetric affected and non-effected regions were higher than 1 ºC in acute cases and 33% of the values were higher than 1 ºC in chronic cases. Our results did not agree with those mentioned by STROMBERG, (1971); WEBBON (1978); PALMER (1983); WALDSMITH (1992); MARR (1992) TURNER (1996 a), TURNER et al. (1998), HOOSHMAND,(1998)CETINKAYA et al. (2011). They demonstrated that an asymmetry of 1 ºC or more temperature differences should be present for possible pathology.

Additionally also WEBBON (1978) and ALMERS et al. (2005) found that the regional surface temperatures of the limbs were usually symmetric in lameness free horses. The temperature differences between contralateral limbs were less than 1 ºC in over 90% percent of healthy horses WEBBON (1978). PALMER (1983) supported those findings and found a rate around 88%. In short, previous studies took the 1 ºC as a cut-of value and accepted the temperature differences less then 1 ºC as a normal variation of the thermal pattern of the horse. In our opinion cut-of value for thermographic evaluation should be around 0.7 ºC.

Our data were recorded from the regions that determined as a source of the inflammation by clinic diagnosis, but just 40% of our values would indicate the present inflammation depending on those criteria. These results of the present study may be explainable for chronic cases because of the effect of chronicity on the thermal pattern. This is in concurrence with the opinion that mentioned by TURNER et al. (2001) who reported in their research that the more chronic injury, the less changes in the thermal pattern are caused. Among the all horses examined by thermography in this research, in 45 horses lameness duration was ranging from two weeks to two years.

In the present investigation, among 1392 regional surface temperature values, 433 were recorded from the clinically diagnosed regions and 959 values were recorded from thermographically suspected regions. In all regions which were defined as a source of inflammation by clinical examination, except regions from the horses with joint injuries, corresponding local temperature increases were observed by thermography. Although the temperature differences between the thermographically suspected region and its symmetry were statistically significant, not all regions that suspected as a source of inflammation due to temperature changes were diagnosed by clinic examination. Briefly, every lesion, except joint injuries, caused a detectable heat increase but not every detectable heat increase indicated a lesion.

These additional thermographic findings from clinically normal regions may be ascribed to the presence of subclinical inflammation where abnormal heat increases can be detected as mentioned by VADEN et al. (1980). This speculation had been supported by the studies of GREEN (1999), TURNER et al. (2001), OTILIA et al. (2006), TURNER et al. (1983), and HOLMES et al. (2003) found that the changes on thermal patterns of the injured regions had been recorded 2 weeks before the clinical lameness were occurred. STROMBERG (1971) suggested that a local temperature increase of 1 to 2 ºC is a sufficient sign of an early or sub-clinical tendon lesion. In this regard FONSECA et al., (2006) and PUROHIT, (1980 b) recorded abnormal thermal changes in some horses with no ultrasonographical evidence of inflammation in the corresponding region.

Additional thermographic findings may also be attributed to the presence of the secondary inflammatoric areas that develop as a result of compensating the primer injury as mentioned by WALDSIMITH et al. (1994). Variously MARR (1992) reported in her study that in 16 horses which were examined weekly during the training period abnormal thermal profiles had been recorded and did not develop flexor tendon injury. In this respect PUROHIT (1980) and

PUROHIT et al. (1980 a) added that thermographic pattern changes in clinically sound regions could be partly explained by in terms of normal biologic variation.

Furthermore, in our study, additional findings can be ascribed to transportation of the horses. Most of the horses which were used in the study were brought to our clinic via transporters. Owing to the fact that infrared thermography is a very sensible tool for temperature changes, the traumas that occurred during the transportation or contact of the horses skin to the part of the vehicle could be a reason for thermal pattern changes that is unrelated with the main injury.

Other important points are the applied bandages or transport boots on horse legs. TURNER (1986) suggested that bandages should not be kept on the horses' leg within two hours before the scan. In another study, it is indicated by TURNER et al. (2001) that thermography can also be performed despite the use of bandages if the symmetry is conserved. RINGER et al. (2005) indicated that they observed local heat increases after removing the bandages. In the present study, horses which had bandages were also allowed 10 to 20 minutes to acclimate to the examination room. Excessive compression of the bandages in one leg could cause the thermal pattern changes between contralateral legs due to superficial slight inflammation. This slight inflammation may not be seen by naked eyes but could be determined by infrared thermography. This time that is given to horses for acclimatization may not be enough for horses with bandages. This also could be a reason for additional abnormal thermal pattern findings.

Previous reports on the use of thermography in the diagnosis of equine orthopedic disease were performed basically in three circumstances. PUROHIT et al. (1980 b), VADEN et al. (1980), TURNER et al. (1983), TURNER et al. (1986) have evaluated the thermographic findings in individuals with a specific disease or injury. PUROHIT et al. (1980 a), COLLES et al. (1997), TURNER (1996 c), WALDSMITH (1992), KOLD et al. (1998) have evaluated the thermographic findings together with the other imaging modalities like X-ray and ultrasonography. WEIL et al. (1998), FONSECA et al. (2006) had evaluated the findings that recorded from the specified regions as forelimbs and hind limbs. Thus, the sensitivity and specificity of the Infrared Thermography in diagnosis of equine orthopedic diseases have not been described.

In the current study a thermographic scanning, which includes all parts of the horse`s body, performed independently and immediately before clinic examination. The examiner was not informed about thermographic findings, likewise the investigator of thermography was also not informed about clinic diagnosis. The investigator of thermography defined the suspected regions independently from the clinic diagnosis. This protocol of the study allowed us to evaluate the specificity of the infrared thermography in diagnosis of the equine orthopedic diseases.

The results of current study showed that, if the differences between regional mean values of evaluated thermograms were used as an indicator of the inflammation, the specificity of the thermography was recorded as 54%. If regional minimum values were used, the specificity of the thermography was

54% and the specificity of the thermography was recorded as 55% when regional maximum values were used as an indicator of the inflammation.

In this study thermography was only particularly helpful in determining the localization of the lesion and diagnosis independent to the orthopedic examination. As mentioned before, except regions with joint injuries, corresponding significant temperature changes were recorded in all regions where the reason for lameness was diagnosed by clinical examination. All local temperature changes did not indicate a corresponding clinical abnormality. Among 100 horses, 87 had a clinic diagnosis. From these horses, 76 had additional thermographic findings which were not related with the injured region, 11 had no additional thermographic findings. 17 horses had no thermographical findings but had additional thermographic findings.

Our study showed the importance of identifying the reasons for the normal thermal pattern changes in the suspected regions. Infrared thermography`s ability to demonstrate the localization of the inflammatory region is questionless. In the current study it was observed that, although, thermography was able to attest the changes in skin temperature graphically and numerically, every detectable heat alteration did not indicate a corresponding lesion. 87% of the cases had temperature alterations in the areas which were not related with the injury. Additional criteria were required to enhance the diagnostic impact of the infrared thermography. It must also be emphasized that the surface contour, effects of bandages and transport should also be taken in to consideration during the thermographic examination. Result of the thermography are not convincing until now. The presence of nice, colorful pictures must not be overestimated.

CHAPTER VI:

CONCLUSION

Although evidence of its diagnostic value is certain, thermography has not been used in routine clinic examination as other imaging technologies (radiography, ultrasonography). In the present study routine clinical investigations were performed with thermography. Thermographical findings at the beginning of the clinic examination of orthopedic diseases in the horses were recorded. The surgeon was not informed about the thermographical findings. Following the clinic examination of the patients, thermographic results were compared with the actual clinical diagnoses. In our experience we discovered that in all regions which were defined as a source of inflammation by clinical examination, except regions from the horses with joint injuries, corresponding local temperature increases were observed by thermography. However, not all regions that were suspected as a source of inflammation due to local temperature increases were diagnosed by clinic examination. The specificity rates of the thermography were recorded as %54, %54, and % 55 for ΔRMean, ΔRMin and ΔRMax values, respectively. The results of this study suggest that at the beginning of the orthopedic examination, thermography was not able to allow an accurate localization of inflammatory and degenerative conditions of the equine locomotion system.

CHAPTER VII

SUMMARY

The purpose of this study was to evaluate the thermographical status at the beginning of the orthopedic examination allowing an accurate localization of inflammatoric and degenerative condition on equine locomotor system. The study was carried out in 100 equine patients out of the routine patients material. Before clinical examination standardized thermographic examination was performed for each horse. Multiple thermographical images were obtained. Images included right and left side view of the whole body, croup, chest, neck from both sides and the back in top line view. For evaluating the RST (regional surface temperatures) manually defined regions were determined. The hypotheses 'the distribution of the temperature in the horse's body is symmetric and compared to healthy tissue, injured or diseased tissue has an altered temperature' were taken as basis. The regions which had different temperature than its symmetry were determined by thermography independently and immediately before clinic examination. The surgeon was not informed about thermographic findings, likewise the investigator of thermography was also not informed about clinic diagnosis. The regional surface temperature values (RTV) (RMean, RMax and RMin, ΔRMean, ΔRMin, ΔRMax) for each region of interest and its symmetry were recorded. Following the clinic examination all regions were assigned into two groups. The first group included the regions which were defined as source of the inflammation and pain by clinical examination of the horse. These regions were determined depending on clinic diagnosis and named as clinically diagnosed regions (CDR). The regions which were clinically normal but suspected as a source of the inflammation by thermography constituted the second group of the regions and named as thermographically suspected regions (TSR). CDR were divided in to 6 groups according to clinic diagnosis. The significance of the mean temperature differences for each CDR group and TSR were analyzed by using Paired-samples t test and Student's t test. Effects of two or more factors as obtaining the images from the dorsal, lateral, medial and palmar views and their interaction on the 3 response variables as regional mean, regional minimum and regional maximum were studied using analysis of variance (ANOVA). Differences of the RST of the CDR and TSR were analyzed by using two ways ANOVA. The level of significance was established as $P<0.05$ in all statistical analyses. The specificity of the thermography in the diagnosis was determined by Roc Curve. The regional mean (RMean), regional minimum (RMin) and regional maximum (RMax) values were evaluated for each region. In this study, when evaluating the images with taking one of the RST as criteria, no significant differences could be recorded between RMean, RMax and RMin values. It is also recorded that different orientations of views had no significant effect on evaluation of the regional temperature differences except the RMin values that obtained from the dorsal views in joint injuries. Our personal choice was to evaluate the thermograms by using RMean and RMax values. While defining the regions, even one pixel taken in from out of the border of the region, could change the real minimum temperature value. The possibility of the false positive or

negative results due to RMin values must not be neglected. Among all horses, 87 horses had a clinic diagnosis. In 13 horses, although thermal pattern changes were present, no pathologic lesion could be recorded by clinic examination. By these 87 horses, in 11 horses thermal pattern changes were recorded just from the areas that were related with the injured region, in 76 horses thermal pattern changes were also recorded from the areas that were not related with the injured region (ATF). In this study, it is observed that every lesion, except joint injuries, caused a detectable heat increase but not every detectable heat increase indicated a lesion. The specificity rates of the thermography were recorded as %54, %54, and % 55 for ΔRMean, ΔRMin and ΔRMax values, respectively. The importance of identifying the reasons for the thermal pattern changes in the suspected regions was emphasized. The results showed that at the beginning of the orthopedic examination, thermography was not able to allow an accurate localization of inflammatory and degenerative conditions of the equine locomotion system.

CHAPTER VII

ZUSAMMENFASSUNG

Inhalt der Studie war es, den thermographischen Status zu Beginn einer orthopädischen Untersuchung zu evaluieren, um entzündliche und degenerative Prozesse des Bewegungsapparates beim Pferd genau zu lokalisieren. 100 Pferdepatienten aus dem Routinepatientengut wurden zu dieser Untersuchung herangezogen. Vor der klinisch-orthopädischen Untersuchung jedes dieser Pferde wurde die thermographische Untersuchung vorgenommen. Zahlreiche thermographische Bilder wurden unter standardisierten Bedingungen aufgenommen. Die Abbildungen beinhalteten rechte und linke Seitenansichten des Gesamtkörpers, der Kruppe, der Brust, des Halses von beiden Seiten und des von oben her aufgenommenen Rückens. Zur Bestimmung der RST (regional surface temperature = regionale Oberflächentemperatur) wurden manuell bestimmte Körperregionen in ihren Konturen definiert. Die Hypothesen, Die Verteilung der Oberflächentemperatur ist symmetrisch“ und „Im Vergleich zu gesundem Gewebe hat Gewebe nach einer Traumatisierung oder einer anderen Erkrankung veränderte Temperatur“ wurden geprüft. Regionen mit unterschiedlicher Temperatur zwischen der mutmaßlich betroffenen und der kontralateralen Seite wurden detailliert weiter aufgenommen, alles vor Beginn der klinischen Untersuchung. Der untersuchende Tierarzt war über die Befunde der thermographischen Untersuchung nicht informiert, die die Thermographie durchführende Autorin war zu diesem Zeitpunkt ebenfalls nicht über die klinische Diagnose informiert. Die regionalen Temperaturwerte (RTV regional temperature values in Form von RMean, RMax, RMin) wurden für jede region of interest und die andere Seite errechnet sowie dann im Seitenvergleich die Temperaturdifferenzen ΔRMean, ΔRMax und ΔRMin ermittelt. Nach der klinischen Untersuchung wurden alle Regionen zwei Gruppen zugeordnet. Die erste Gruppe beinhaltete alle jene Regionen, die durch die klinische Untersuchung als der Sitz von Entzündung und Schmerz lokalisiert wurden. Diese klinisch festgestellten Regionen wurden als CDR (Clinically diagnosed regions) zusammengefasst. Regionen hingegen, welche klinisch unauffällig waren, aber thermographisch als Sitz einer Entzündung verdächtig waren, wurden als TSR (Thermographically suspected regions) bezeichnet. CDR wurden nach Ihrer klinischen Diagnose sechs Untergruppen, wie Huferkrankungen, Gelenkerkrankungen, Sehnen etc., zugeteilt.

Eine eventuelle Signifikanz (Signifikanzgrenze jeweils $p<0.05$) der mittleren Temperaturunterschiede (ΔRMean) wurden für jede der CDR-Gruppen und die TSR Gruppe mittels paired sample t-Test und Student`s t-Test geprüft. Mittels ANOVA (Varianzanalyse) wurde der Einfluss anderer Faktoren, wie der Abbildung einer Region von doral, lateral, medial oder palmar und der Einfluss der Aufnahmerichtung auf RMean, RMax, RMin geprüft. Unterschiede der RST-Parameter bei CDR und TSR wurden mit Zweiweg-ANOVA analysiert. Die Spezifität der Thermogaphie in der Diagnostik wurde mit der Roc-Analyse beurteilt.

Es bestand kein Unterschied, ob RMean, RMax, RMin zur Beurteilung einer lokalen Temperaturveränderung herangezogen wurde. Unterschiedliche Aufnahmerichtungen hatten ebenfalls keinen Einfluss auf die ermittelten Werte von ΔRMean, ΔRMax und ΔRMin, mit Ausnahme der dorsalen Aufnahmerichtung bei Gelenksproblemen. Die Autorin spricht sich für die Auswertung der Thermogramme unter Verwendung der Parameter von ΔRMean, ΔRMax aus. Wird ΔRMin ausgewertet, kann schon die Beurteilung eines einzigen Pixel außerhalb der Kontur der Region zu einem falsch positiven oder falsch negativen Ergebnis führen.

Von allen 100 untersuchten Pferden hatten 87 eine gesicherte klinische Diagnose. Bei 13 Pferden waren thermographische Befunde zu erheben, jedoch konnte keine pathologische Läsion im Rahmen der klinischen Untersuchung festgestellt werden. Bei den 87 Pferden mit gesicherter Diagnose konnten in 11 Fällen thermographische Befunde ausschließlich am Ort der klinischen Diagnose erhoben werden. Bei 76 Pferden hingegen wurden neben den thermographischen Befunden am Ort der klinischen Diagnose zusätzliche thermographischen Befunde (ATF = additional thermographic findings) in einer Region ohne klinischen Befund erhoben werden.

Nach der Studie brachte jede Läsion, mit Ausnahme der großen Gruppe von Gelenkläsionen, einen messbaren Anstieg der lokalen Temperatur mit sich, aber nicht jeder messbare Anstieg der lokalen Temperatur ging auch mit einer lokalen Läsion einher. Für ΔRMean, ΔRMax und ΔRMin wurde die Spezifität mit 54%, 54% und 55% festgestellt. Die Bedeutung, Ursachen für die Temperaturerhöhung klinisch festzustellen, muss betont werden. Die Resultate ergaben, dass die zu Beginn einer orthopädischen Untersuchung durchgeführte thermographische Untersuchung in vielen Fällen nicht imstande ist, entzündliche und degenerative Veränderungen am Bewegungsapparat des Pferdes genau zu lokalisieren.

CHAPTER VIII

REFERENCES

ALLMERS, E.; HOLLENBERG, C., HELDT, S.; MEYER, W. (2005): Routine use of an infrared thermomether in measuring the body surface temperature pattern of horse.
Tierarztl. Prax. Ausg. G Grosstiere Nutztiere. 33(3): 181-187.

AUTIO, E.; NESTE, R.; AIRAKSINEN, S.; HEISKANEN, M.L. (2006): Measuring the heat loss in horses in different seasons by infrared thermography.
J. Appl. Anim. Welf. Sci. 9(3): 211-21.

AUTIO, E.; HEISKANEN, M.L.; MONONEN, J. (2007): Thermographic evaluation of the lower critical temperature weanling horse.
J. Appl. Anim. Welf. Sci. 10 (3): 207-216.

AWERBUCH, M.S. (1991 a): Thermography- wither the niche
Med. J. Aust. 154: 444-447.

AWERBUCH, M.S. (1991 b): Thermography- its current diagnostic status in musculoskeletal medicine.
*Med. J. Aust.*154: 441- 443.

BATHE, A. P. (2007): Thermography. In: FLOYD, A.E.; MANSMA, R. A.: *Equine Podiatry*
Sounders, Virginia, pp. 167-203.

BORNKLAV, N. (2004); Infrared thermography of composites. In; KESSLER, M.R.: *Advanced Topics in Characterization of Composites*. Trafford, Canada, pp. 113-131.

BOUE, C.; CASSAGNE, F.; MASSOUD, C.; FOURNIER, D. (2007): Thermal Imaging of a vein of the fore arm: Analysis and thermal modelling.
Infrared Physics & Technology 51: 13-20.

BOWERS, S.; GANDY, M.; ANDERSON, B.; RYAN, P.; WILLARD, S. (2009): Assessment of pregnancy in the late-gestation mare using digital infrared thermography.
Theriogenology 72; 372-377.

BOWMAN, K.F.; PUROHIT, R.C.; GANJAM, V.K.; PECHMAN, R.D.; VAUGHAN J.T. (1983): Thermographic evaluation of corticosteroid efficacy in amphotericin B induced arthritis in ponies.
Am. J. Vet. Res. 44: 51-56.

BROOKS, P. M. (1991): Thermography- turning up the heat.
Med. J. Aust. 154: 436-437.

BRAVERMAN, Y. (1989): Potential of infra-red thermography for the detection of summer seasonal recurrent dermatitis (sweet itch) in horses.
Veterinary Record 125: 372-374.

CARLOMAGNO, G. M.; CARDONE, G. (2010): Infrared thermography for convective heat transfer measurements.
Exp. Fluids 49: 1187-1218.

CETINKAYA, M. A.; DEMİRUTKU, A. (2012): Thermography in the assessment of equine lameness.
Turk J. Vet. Anim.Sci. 36(1): 43-48.

CLARK, J.A.; CENA, K. (1977): The potential of infrared thermography in veterinary diagnosis.
Veterinary Record 100: 402-404.

COLLES, C.M.; PUSEY, A.G.; BROOKS, J. (1997): Thermography is a sensitive adjunct to diagnosis.
BMJ 314: 1041-1042.

DELAHANTY, D.D.; GEORGI, J.R. (1965): Thermography in Equine Medicine.
JAVMA 147(3): 235-238.

DELCHAR, T.A. (1997): Infrared thermography with an optical scanning system, In; *Physics in Medical Diagnosis.*
Chapman & Hall, London, pp. 22.

DYSON, K.; LAKHANI, K.; WOOD, J. (2001): Factors influencing blood flow in the equine digits and their effect on uptake of 99m technetium methylene diphosphonate in to bone.
Equine Vet. J. 33(6): 591-598.

DYSON, S.; MARKS, D. (2003): Foot pain and elusive diagnosis.
Vet. Clin. Equine 19: 531-565.

EDDY, A.L.; VAN HOOGMOED, L.M.; SNYDER, J.R. (2001): The role of thermography in the management of equine lameness.
Vet. J. 162: 172-181.

FONSECA, B.P.A.; ALVES, A.L.G.; NICOLETTI, J.L.M.; THOMASSIAN, A.; HUSSNI, C.A.; MIKAIL, S. (2006): Thermography and ultrasonography in back pain diagnosis of equine athletes.
J. Equine Vet. Sci. 26 (11): 507-516.

GAUSSORGUES, G. (1994): *Infrared thermography*, Chapman & Hall, London, pp. 5-15

GHAFIR, Y.; ART, T.; LEKEUX, P. (1996): Thermographic facial pattern flowing an &/2 adrenergic agonist injection in two horses suffering from Horner`s syndrome.
Equine Vet. Educ. 8 (4) 192-195.

GRAF von SCHWEINITZ , D.G. (1999): Thermographic diagnostics in equine back pain.
Vet. Clin. North Am. Equine Pract. 15; (1):161-177.

GRAF von SCHWEINITZ, D. G. (1998): Thermographic evidence for the effectiveness of acupuncture in equine neuromuscular disease.
Acupuncture in Medicine 16(1): 14-17.

GREEN, E.M. (1999); Thermography. In; *Equine Medicine and Surgery*, 5th Ed, Mostby, pp. 1333-1340.

GUTHRIE, A.J.; LUND, R.J. (1998): Thermoregulation, base mechanism and hyperthermia.
Vet. Clin. North Am. Equine Pract. 14(1):45-59.

HEAD, M.J.; DYSON, S. (2001): Talking the temperature of equine thermography.
Vet. J. 162: 166-167.

HILDEBRANDT, C.; RASCHNER, C.; AMMER, K. (2010): An overview of recent application of medical infrared thermography in sports medicine in Austria.
Sensors 10: 4700-4715

HODGSON, D.R.; DAVIS, R.E.; MCCONAGHY, F.F. (1994): Thermoregulation in the horse in response to exercise.
Br. Vet. J. 150(3): 219-234.

HOLMES, L.C.; GAUGHAN, E.M.; GORONDY, D.A.; HOGGE, S.; SPIRE, M.F.(2003): The effect of perineural anesthesia on an infrared thermographic images of the forelimb digits of normal horses.
Can. Vet. J. 44: 392-396.

HOOSHMAND, H. (1998): Is thermal imaging of use in pain management?
Pain Digest 8: 166-170.

JHONSON, S.R.; HUSSEY, S.B.; MORLEY, P.S. (2011): Thermographic eye temperature as an index to body temperature.
J. Equine Vet. Sci. 31: 63-66.

KASTBERGER, G.; STACHL, R. (2003): Infrared imaging technology and biological applications.
Behavior Research Methods, Instruments & Computers 35(3): 429-439.

KOLD, S.E.; CHAPPELL, K.A. (1998): Use of computerized thermographic image analysis (CTIA) in equine orthopedics: review and presentation of clinical cases.
Equine Vet. Educ. 10(4): 198-204.

KOUPELIS, T. (2011): The electromagnetic spectrum. In: *In quest of the universe*.
6th Ed, Jones and Bartlett publishers, Canada, pp. 101.

LEVET, T.; MARTENTS, A.; DEVISSCHER, L.; DUCHATEAU, L.; BOGAERT, L.; VLAMINCK, L. (2009); Distal limb cast sores in horses: Risk factors and early detection using thermography.
Equine Vet. J. 41(1):18-23.

LAI, H.S.; DUH, Y.C.; TSAI, W.S.; SUN, W. Z. (1998): Role of thermography in the diagnosis of undescended testes.
European Urology 33: 209-213.

LINDA, M.; VAN HOOGMOED, V.; SNDER, J.R. (2002): Use of infrared thermography to detect injections and palmar digital neurectomy in horses.
Vet. J. 164: 129-141.

LOUGHIN, C.A.; MARINO, D.J. (2007): Evaluation of thermographic imaging of the limbs of healthy dogs.
Am. J. Vet. Res. 68(11): 1064-1069.

LOVE, T.J. (1980): Thermography as an indicator of blood perfusion.
Ann. NY Acad. Sci. 335: 429–437.

MACDONALD, A.G.; LAND, D.V.; STURROK, R.D. (1994): Microwave thermography as a non-invasive assessment of disease activity in inflammatory arthritis.
Clinical Rheumatology 13(4):589-592.

MARR, M.C. (1992): Microwave thermography: a non-invasive technique for investigation of injury of the superficial digital flexor tendon in the horse.
Equine Vet. J. 24(4): 269-273.

MCCAFFERTY, D.J. (2007): The value of infrared thermography for research on mammals: Previous applications and future directions.
Mammal Review 37(3): 207-223.

MORGAN, K. (1998): Thermoneutral zone and critical temperatures of horses**.**
J. Therm. Biol. 23(1): 59-61.

MORGAN, K.; EHRLEMARK, A.; SALLVIK, K. (1997): Dissipation of heat from standing horses exposed to ambient temperatures between -3 and 37 °C.
J. Therm. Biol. 22(3): 177-186.

OTILIA, C.; TANASE, A.; MICLAUS, I. (2006): Digital Infrared thermography in assessing soft tissues injuries on sport equines.
Buletin USAMV-CN 63: 228-233.

PALMER, S.E. (1983): Effect of ambient temperature upon the surface temperature of the limb.
Am. J. Vet. Res. 4(6): 1098-1101.

PROUDFOOT, J. (2009): Uses of Infrared Thermography in Zoo Animal Medicine.
81st *Western Veterinary Conference*

PUROHIT, R.C.; MCCOY, M.D. (1980 a): Thermography in the diagnosis of inflammatory processes in the horse.
*Am. J. Vet. Res.*41 (8): 1167-1174.

PUROHIT, C.R.; MCCOY, M.D.; BERGFELD, W.A. (1980 b): Thermographic diagnosis of Horner`s syndrome in horses.
Am. J. Vet. Res. 41 (8): 1180-1182.

PUROHIT, C.R. (1980): The diagnostic value of thermography in equine medicine.
Proc. 26th Am. Assoc. Equine Pract. 26: 317-326.

PUROHIT, C.R.; HUDSON, R.S.; RIDDELL, M.G.; CARSON, R.L.; WOLFE, D.F.; WALKER, D.F. (1985): Thermography of the bovine scrotum.
Am. J. Vet. Res. 46 (11): 2388-2392.

PUROHIT, C.R. (2004): Thermographic evaluation of the neurovascular system in the equine.
Thermology International 3: 89-92.

PUROHIT, C.R. (2007): History and research review of thermography in veterinary medicine at Auburn Universty.
Thermology International 17(4): 127-132.

PURVES, K.V.; ORIANS, G.H.; HELLER, C.H.; SADAVA, D. (1997): Electromagnetic spectrum In: *Life: The Science of Biology*, 5th Edition, Sinauer associates Inc, New York, pp. 169

RING, E.F.J.; AMMER, K. (2000): The technique of infra red imaging in medicine.
Thermology International 10(1): 7-14.

RING, E.F.J. (2007): The historical development of temperature measurement in medicine
Infrared Physics & Technology 49: 297-301.

RINGER, S. K.; LISCHER, C.J.; UELTSCHI, G. (2005): Assessment of scintigraphic and thermographic changes after focused extracorporeal shock wave therapy on the origin of the suspensory ligament and the fourth metatarsal bone in horses without lameness.
Am. J. Vet. Res. 66(10): 1836-1841.

SCHAEFER, A.L.; JONES, S.D.M. (2004): Early detection and prediction of infection using infrared thermography.
Can. J. Anim. Sci. 84: 73-80.

SIMON, E.L.; GAUGHAN, E.M.; EPP, T.; SPIRE, M. (2006): Influence of exercise on thermographically determined surface temperatures of thoracic and pelvic limbs in horses.
J. Am. Vet. Med. Assoc. 229(12): 1940-1044.

STASHAK, T.S. (2002): Thermography In: *Adams` lameness in horses*.
5th Ed, Lippincott Wiliams & Wilkings, Philadelphia, pp. 310-312.

STEWART, M.; WEBSTER, J.R.; AL SCHAEFER, A.L.; COOK, N.J.; SCOTT, S.L. (2005): Infrared thermography as a non-invasive tool to study animal welfare.
Animal Welfare 14: 319-325.

STRODEL, R.C. (2001): Special Procedures and Testing: Thermography. In: *Medical evidence: acquisition and use.*
Lawyers & Judges, United States, pp. 96-98.

STROMBERG, B. (1971): The normal and diseased flexor tendon in race horse
Acta Radiol (supply) 305: 1-94.

STROMBERG, B. (1974): The Use of Thermography in Equine Orthopedics
Veterinary Radiology 15(1): 94-87.

STROMBERG, B. (1973): Morphologic, thermographic and ^{133}Xe clearance studies on normal and diseased superficial digital flexor tendons in race horses.
Equine Vet. J. 5(4): 156-161.

TUNLEY, B.V.; HENSON, F.M. (2004): Reliability and repeatability of thermographic examination and the normal thermographic image of the thoracolumbar region in the horse.
Equine Vet. J. 36(4): 306-12.

TURNER, T.A.; FESSLER, J.F.; LAMP, M.; PEARCE, J.A.; GEDDES, L.A. (1983): Thermographic evaluation of horses with podotrochlosis.
Am. J. Vet. Res. 44(4): 535-539.

TURNER, T.A. (1986): Hind limb muscle strain as a cause of lameness in horses.
Proc Am. Assoc. Equine Pract. 34: 281.

TURNER, T.A.; PUROHIT, C.R.; FESSLER, J.F. (1986): Thermography: A review in equine medicine.
Comp. Cont. Educ. Pract. Vet 8: 855-861.

TURNER, T.A. (1996 a): Uses and limitations of thermography
Pferdeheilkunde 12(4): 684-685.

TURNER, T.A. (1996 b): Alternative methods of soft tissue imaging.
Proc. Dubai International Equine Symposium 1: 165-176.

TURNER, T.A. (1998): Use of thermography in lameness evaluation.
AAEP Proceedings. 44: 224-226.

TURNER, T.A. (1991): Thermography as an aid of to the clinical lameness evaluation.
Vet. Clin. North Am. Equine Pract. 7(2): 311-338.

TURNER, T.A. (1996 c): Thermography as an aid in the localization of upper hind limb lameness.
Pferdeheilkunde 12 (4): 632-634.

TURNER, T.A. (2001): Diagnostic thermography.
Vet. Clin. North Am. Equine Pract. 17(1): 95-113.

TURNER, T.A.; PANSCH.; WILSON, J.H. (2001): Thermographic assessment of Ricing Thoroughbreds.
Am. Assoc. Equine Pract. 47: 344-346.

TURNER, T.A. (2003): Examination of the equine foot.
Vet. Clin. North Am. Equine Pract. 19: 309-332.

VADEN, M.F.; PUROHIT, R.C.; MCCOY, M.D.; VAUGHAN, J.T. (1980): Thermography: a technique for subclinical diagnosis of osteoarthritis.
Am. J. Vet. Res. 41(8): 1175-1179.

VALBERG, S.J. (2006): Diagnostic approach to muscle disorders.
Am. Assoc. Equine Pract. 52: 340-346.

VAN HOOGMOED, V.L.; SYNDER, J.R.; ALLEN, A.K.; WALDSMITH, J.D. (2000): Use of infrared thermography to detect performance enhancing techniques in horses.
Equine Vet. Educ. 12(2): 102-107.

VERSCHOOTEN, F.; DESMET, P.; VERBEECK, C. (1997): Skin surface temperature measurements in horses by electronic thermometry.
Equine Practice 19(4): 16-23.

VOLLMER, M.; MÖLLMAN, K.P. (2010): *Infrared Thermal Imaging*, WILEY – VHC Verlag GmbH & Co, Weinheim, pp. 9-27.

VON SCHULTHESS, G. K.; SMITH, H.J. (1998): Physics, techniques and procedures In: HOLGER, P.; ALLISON, D.: *The Encyclopedia of Medical Mmaging*, Volume 1, Medical Media, London, pp. 254.

VON SCHWEINITZ, D.G. (1998): Thermographic evidence for the effectiveness of acupuncture in equine neuromuscular disease.
Acupuncture in Medicine 16 (1): 14-17.

WALDSMITH, J.K. (1992): Real time thermography: A diagnostic tool for the equine practioner.
AAEP Proceedings. 38 455-466.

WALDSMITH, J.K.; OLTMANN, J.I. (1994): Thermography: subclinical inflammation, diagnosis, rehabilitation, and athletic evaluation.
J. Equine Vet. Sci. 14: 8-10.

WEBBON, P.M. (1978): Limb skin thermometry in racehorses.
Equine Vet. J. 10 (3): 180-184.

WEIL, M.; LITZKE, L.F.; FRITSCHR, R. (1998): Diagnostic validity of thermography in equine lameness.
Tierarztl. Prax. Ausg. G Grosstiere Nutztiere. 26 (6): 346-354.

YANMAZ, L.E.; OKUMUS, Z.; DOGAN, E. (2007): Instrumentation of thermography and its applications in horses.
J. Anim.Vet. Adv. 6(7): 858-862.

ZETTERMAN, E.; SALMI, A.; SUOMINEN, S.; KARONEN, A.; ASKO_SELJAVAARA, S. (1999): Effect of cooling and warming on thermographic imaging of the perforating vessels of the abdomen.
Eur. J. Plast. Surg. 22: 58-62.