Tuomas Häyrynen

SMART PHONE THERMAL CAMERA ACCESSORY DEVICE AS A MEAN TO ASSESS SADDLE FIT IN HORSES

SADULA HOBUSELE SOBIVUSE HINDAMINE KASUTADES NUTITELEFONI TERMOKAAMERA LISASEADET

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Thermal imaging has proven to be fast, cheap, non-invasive method of assessing different medical conditions of humans and animals. In recent years it has also been used in the quest to assess the fit of horse saddles in combination of more traditional methods. The results of present study show that thermal imaging can be a very useful and reliable method especially in finding ill-fitting saddles. It gives also the saddle fitter a unique opportunity to visually show the horse owner the fit of the saddle and to keep record of the changes in the fit of the saddle during longer periods of time in the form of digital pictures and videos. Recent developments in thermal imaging machinery is bringing this method of imaging financial more possible to all areas of medicine and to all practitioners as the price and size of diagnostically useful thermal imaging machines has gone drastically down.

Keywords: Thermal imaging, saddle, saddle fitting
Termopildistamine on osutunud kiireks, odavaks ning mitteinvasiivseks meetodiks inimeste ja loomade erinevate haigusseisundite hindamisel. Viimastel aastatel on seda kasutatud ka hobuste sadulate sobivuse hindamisel kombineerides seda traditsioonilite meetoditega. Uuringu tulemused näitavad, et termopildistamine võib olla väga kasulik ja usaldusväärne meetod, eriti ebasobivate sadulate avastamiseks. Samuti annab see sadulsepale ainulaadse võimaluse visuaalselt näidata hobuse omanikule sadula polsterduse sobivust ja pidada arvestust sadula sobivuse muutuste kohta pikema ajal digitaalsete piltide ja videote kujul. Hiljutised arengud termopildistamises teevad selle meetodi kätesaadavaks paljudele meditsiinivaldkonnas ja muuhulgas ka sadulseppadele kuna termokaamerate suurus ja hind on tunduvalt langenud.

Märksõnad: Termopildistamine, hobuse sadul, sadula sobitamine/polsterdamine
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<tr>
<td>App</td>
<td>Application</td>
</tr>
<tr>
<td>BCS</td>
<td>Body condition score</td>
</tr>
<tr>
<td>CT</td>
<td>Computed tomography</td>
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<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
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INTRODUCTION

Thermal imaging has been used in medicine for decades now as a mean to diagnose conditions involving increase or decrease in surface temperature of skin and underlying tissues (Ring and Ammer 2012). Thermal imaging can be used to detect changes in vascular circulation like emboli, inflammation, infection and other causes of increased or decreased vascular circulation (Turner 1991). In Human medicine thermal imaging is used for example to control patient vascular status in extremities and especially in hands (Chojnowski 2017).

In recent years Thermal imaging has made its foothold also in veterinary medicine in new previously unused ways. One of which is to aid in estimation of saddle fit in horses and specially to find ill-fitting saddles (Arruda et al. 2011). Only few studies have been made in this field of thermal imaging and more is needed.
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1. LITERATURE REVIEW

1.1. Principles of thermal imaging

The terms “thermal imaging”, “thermography” or “infrared thermographic imaging” refers to imaging method where infrared electromagnetic radiation emitted by studied surface is turned into a visible image (Chojnowski 2017; Redaelli et al. 2014). Infrared radiation is electromagnetic radiation whose wavelength is so long that it can't be detected by the human eye like normal light can (Redaelli et al. 2014). Infrared part of the electromagnetic spectrum is normally only sensed as heat if strong enough. The color of a surface in the thermal imaging picture and in some cases the shade of the color gives the viewer a representation the temperatures of the surfaces pictured (Chojnowski 2017). In modern thermal imaging devises two different possibilities can be chosen: multicolored or black and white picture. The color scale to indicate the differences in temperatures is made artificially by the cameras program and can be changed. If the picture is black and white it can also be white hot or black hot depending on the situation and which one is easier or to the liking of the viewer.

1.2. Thermal imaging devises

There are mainly two different types of thermal imaging devices: cooled and uncooled (Chojnowski 2017). The waste majority used today in medicine are with Mini-Bolometer type uncooled thermal sensor as they are cheaper and more easy to maintain and handle than the ones with cooled sensor and the technological advancements in recent years have reduced the price of good quality uncooled devises with large enough resolution to make diagnostic quality imaging (Vainionpää et al. 2012; Chojnowski 2017). When considering a thermal camera to be used in diagnostics some considerations must be made. One must take into account such things as resolution, type of the thermal sensor, sensitivity, spectral range, operation system /program, size and ease of use of the device (Vainionpää et al. 2012).
Resolution of the cameras used in medicine in recent years have been in the range of 160x120 to 640x480. Vainionpää et al. (2012) concluded in their study that 180x180 resolution (Flir b60) is enough to produce diagnostically valuable images but 160x120 has also been used successfully by Arruda et al. (2011). Thermal sensitivity is not usually an issue when selecting a thermal camera for medical use as majority of them have thermal sensitivity smaller than 0.3 degrees which is considered to be adequate (Turner 2001). Many different manufactures make suitable thermal cameras, to mention few Flir systems as by far the largest and most often used, but also smaller producers like Seek Thermal and Thermal expert. Many of the researchers and clinicians use cameras produced by Flir systems as they have many suitable models like E25 (160x120), b60 (180x180), T425 (320x240) and many more (Vainionpää et al. 2012; Arruda et al. 2011).

1.3. Advantages and limitations of thermal imaging

Thermal imaging is a noninvasive and nonharmful imaging method, because it does not require any surgical access to the body of the patient imaged and it will not cause any harm to either the patient or the person making the image (Chojnowski 2017; Redaelli et al. 2014). It does not use any penetrating radiation or radioactive substances, as is used in radiography and CT (computed tomography) or scintigraphy nor does the examined part receive ultrasound waves, like those in ultrasonography, and the examined part is not exposed to an electromagnetic field as in MRI (magnetic resonance imaging) (Chojnowski 2017). Thermal imaging is the least invasive for the patient and also for the operator from all the diagnostic imaging techniques used todays veterinary medicine (Redaelli et al. 2014). Thermal imaging camera can provide a real-time evaluation of changes in the surface temperature when used in video mode, creating a dynamic image of the object. This may be of considerable better in some case than other imaging techniques such as radiography that offer only still representations. Thermal imaging can produce much more information than a person detecting temperature differences by hand.

Another big advantage of thermal imaging is its ability to be used in injury prevention so that it can find distinct surface temperature variations that indicate minor tendon ligament injuries and other minor injuries that don't yet manifest as clinical signs but if training is
continued will worsen. Monitoring of treatment and healing processes is also possible without interference or invasive processes (Redaelli et al. 2014).

Thermal imaging has also some challenges as a diagnostic tool, but all of them are unique to thermal imaging: especially in previous years high quality thermal cameras have been very expensive to buy and maintain, thermal imaging gives very rarely more than area of further interest as it is not able to provide information on the origin and cause of the temperature difference it senses and final or additional imaging with other methods is usually most advised.

Thermal imaging has in some occasions a time limitation as it is sometimes important for the subject to acclimate 15-20 min to the environment's temperature when the image is taken from the body surface of the subject (Redaelli et al. 2014). The knowledge of the local skin temperature has low diagnostic value if it can't be compared with the opposite side of the body and surrounding tissues.

Thermal imaging is not immune to artifacts as no imaging modality. In thermal imaging artifacts are usually produced by unwanted material on the body surface, such as dirt, water, thick or short hair, scars, and sometimes by draught or sunlight or other source of heat or cold air. It is also very important to take more than one thermal image from different sides and different angles of the object or take video (Redaelli et al. 2014).

### 1.4. Thermal imaging in medicine

The future of thermal imaging in medicine and beyond is subject to the correct use of the technology and proper understanding of its limitations. Evolving medical applications for thermal imaging include inflammatory diseases, complex regional pain syndrome, Raynaud's phenomenon, fever screening in epidemic situations, juvenile idiopathic arthritis and autoimmune disease with arthritis such as systemic lupus erythematosus (Chojnowski 2017; Lasanen et al. 2015). Lasanen et al. (2015) studied 58 children with symptoms of joint inflammation and the temperatures were significantly higher in inflamed ankle joints than in the healthy joints. This indicates that thermal imaging may have potential for detecting joint inflammation in ankle joints of children. Screening type of imaging in finding areas of
interest seems to be the most used modality today (Lasanen et al. 2015).

1.5. Thermal imaging in Equine medicine

There are many ways in which thermal imaging can be useful in equine medicine. One way is to use of thermal imaging as a tool to assess the physiological properties and status of the horse. Thermal imaging can produce much more information than a person detecting temperature differences by hand and so it is useful for the early detection of laminitis, stress fractures, and tendinitis (Redaelli et al. 2014). By thermal imaging one can identify asymmetries and see changes in surface temperature and point out areas of special interest. Not to forget the value of recording findings in the form of picture or video.

Thermal imaging can also be used as a diagnostic tool. When thermal imaging is used as a diagnostic tool, both increases and decreases in temperature have an importance in making the diagnose. Thermal imaging is useful in scanning to identify which areas are of interest and should be further investigated with radiography or magnetic resonance imaging to make the final diagnose (Redaelli et al. 2014). Animal welfare issues can also be evaluated as suitable keeping temperature and emotional status may be evaluated in some cases (Redaelli et al. 2014; Rizzo et al. 2017). Thermal imaging can also be used to monitor the use of certain drugs e.g. local anesthetics, shock wave therapy, and to evaluate cast sores in fracture healing (Redaelli et al. 2014; Levet et al. 2009). Thermal imaging has been used in recent years also to evaluate the fit of saddles and other equipment (Arruda et al. 2011).

1.6. Saddle fitting

The assessment of saddle fit to a horse is a complex proses and requires high amount of knowledge and experience (Dyson et al. 2015). When assessing saddle fit one basically assesses the interface between the saddle and the horse. A correctly fitted saddle has soft flocking that is correctly distributed, the bearing surfaces are flat and even between the
panels (Dyson et al. 2015). The edges of the gullet around the vertebral column should be rounded and smooth. The gullet width must be uniform and wide enough to accommodate the spinous processes without touching them on the top or to the sides, this must be evaluated when rider is on the saddle (Dyson et al. 2015). It may not be possible to look all the way through the gullet, especially with dressage saddles. In these cases, other methods must be used, tradition is to test the clearance by inserting a dressage whip to the gullet and check that it moves freely all the way. The lowest part of the seat should be as horizontal as possible, and the saddle must not tip forward or backward (Dyson et al. 2015).

One of the most important factors is the uniform contact of the horizontal panels with the horse’s back, which is traditionally evaluated by feeling under the saddle by hand for any tight spots or gaps (Dyson et al. 2015). There must not be any areas of either reduced contact or no contact between the panels and the horse’s back. The most accurate traditional method has been applying of colored builder’s chalk powder into the horse’s coat over the saddle bearing area with a soft paintbrush and more recently the use of pressure mats (Dyson et al. 2015). Both of these methods require a ride of approximately 20 min using the usual program of exercises before assessing the results. Another traditional method is soaking the horse’s back with water and then assessing the distribution of water over the bottom of the saddle after ride (Dyson et al. 2015).

With conventionally flocked saddles it is advised to assess initially the fit of the panels without a rider on the saddle, but with an air-filled saddle girth tightened and a rider on the saddles better while air distributes evenly when under pressure. The saddle must also be checked with the saddle cloth intended for use, because of different thicknesses and materials of the saddle cloths and paddings. There is general rule of “two fingers”, they must fit under the pommel when the rider is standing in the stirrups, both before and after exercise. The width and length of the saddle must be matched for the shape of the horse’s back, there is no saddle that fits all horses no matter how good it is (Dyson et al. 2015). Forelimbs freedom of movement must be maintained, when the forelimb normally moves the scapulæ rotate backwards and with ill-fitting saddle hits the front part of the saddle flaps. This is assessed on a standing horse, by palpation while forelimbs are pulled forward one at a time. Front panels may overly the scapulæ provided, that there is room for the scapulæ to move freely. Check also that the saddle stays behind the scapulæ during and after exercise and the saddle does not drift forwards (Dyson et al. 2015).

The saddle tree or frame should never extend beyond the top of the last rib. Too long saddle
compromises the function of the middle gluteal and iliocostalis muscles and may impair lateral bending due to the increased pressure on the lumbar transverse processes while trying to bend (Clayton et al. 2014). When assessing the length of the saddle, keep in mind that the saddle has to be appropriate for both the horse and the rider. This can be a problem especially with larger riders, growing children and with horses and ponies that have shorter than normal backs. Some growing children may require a longer seat to accommodate their relatively “too long” thigh and gain better riding position. The front of the ventral panels should be parallel to the side of the shoulder (Dyson et al. 2015). The ventral panels should have uniform contact with the horse’s sides. Horses vary in the width and curvature of their back and the angle of their sides, so the width and curvature of the tree and the angle of the tree must be fitting to the individual horse the saddle is used on (Greve and Dyson 2013).

1.7. Ill-fitting saddle

Poorly fitting saddle will cause problems in short- and long-term for the horse and the rider. Greve and Dyson (2014) assessed 506 sports horses in regular work and from those 18.4% were found out to have been ridden in ill-fitting saddles with uneven contact along the length of the horse’s back, and in 32.8% of the cases the saddle was unbalanced, in 20.4% saddle was tipping backwards and in 12.5% saddle was tipping forwards.

The first signs are muscle soreness and focal patches of white hair under the saddle both of them are indicators of pressure points from ill-fitting saddle. The type of problem may be e.g. a twist on the tree of the saddle or too narrow gullet. An asymmetrical wear of the hair under the caudal parts of the saddle is associated normally with the saddle slipping to either side of the horse due rider imbalance or ill-fitting saddle. There is usually focal patch of hair wear closer to the midline on the opposite side, and a more diffuse area of less intense hair wear further away from the dorsal midline to the side of the slippage. If saddle is slipping all the time it may cause asymmetrical distribution of the saddle flocking, that is often mistaken to be the cause of the saddle slip and not the effect. If the horse flinches when groomed or behaves abnormally when being saddled or becomes hypersensitive to the touch in the withers and around the girth, it may be because a phenomenon named wind up. Swellings can occur under the saddle panels and/or behind the scapulae after exercise. These usually
appear only after ridden exercise, but it is difficult to prove an association with saddle fit. Dry patches under the front of the saddle surrounded by sweat after exercise reflect increased focal pressure (Dyson et al. 2015). Too many or too thick layers of padding beneath the saddle can cause dry patches on the dorsal midline surrounded by sweat after exercise by filling up the gullet and pressing on to the spinous processes. When saddle is moving too much the hairs under the saddle become ruffled especially under the front part of the saddle (Dyson et al. 2015). When the back of the saddle moves too much, it usually causes loss of hairs under the back parts of the saddle but if not addressed soon enough can abrade the skin and cause even scabby skin lesions that are very painful. The hair under the saddle may also become permanently curly (Dyson et al. 2015).

Long-term indicators of poor saddle fit are muscle atrophy, back stiffness and lack of proper function. In a younger horses ill-fitting saddle may compromise function of the back and cause epaxial muscles not to develop normally. Palpation is crucial when examining saddle fit as it may reveal sore spots and even adhesions between the skin and underlying fascia or deeper areas of fibrosis (Dyson et al. 2015). Excessive pressure and heat or friction causes injuries to the hair follicles and white hairs appear in the damaged area. There are also other causes of excess pressure to the midline caudal to the withers, like ill-fitting rugs that produce white hairs. Some mild symmetrical wear on the hairs can be normal, unlike asymmetrical that usually indicates some abnormal saddle movement of some sort. When the saddle constantly slips to one side, either because of asymmetry of the horse’s musculature, an ill-fitting saddle, rider imbalance or hindlimb lameness, the wear on the hair is asymmetrical (Dyson et al. 2015). The consequences of an ill-fitting saddle may also include restriction on forelimb step length, overall shortness of steps and unwillingness to bend to one or both sides (Greve and Dyson 2014).

Most signs related to ill-fitting saddles are nonspecific, but presence of one or more clearly indicates that saddle fit should be assessed as part of the diagnostic plan. If saddle constantly slips to one side, the most common cause is hindlimb lameness and the presence of saddle slip is not related to the severity of lameness, but the presence of saddle slip may actually be an indicator of subclinical lameness (Greve and Dyson 2014). It's more common for the saddle to slip to the side of the lame limb, but it should not be taken as a rule. Saddle slip may cause the rider to sit crookedly that may still increase the slipping if gone unnoticed (Greve and Dyson 2013b, 2014).
1.8. Factors in horse, saddle, rider interaction

All horses have some degree of left-right asymmetry (Dyson et al. 2015). Asymmetry in the shoulder area has a large influence on the position and movement of a saddle and the gullet plate and/or panel flocking of the saddle needs to be adjusted to accommodate the asymmetry at hand. Riders are somewhat asymmetrical neither inherently or by an acquired postural asymmetry. Rider should sit so that their shoulders and tuber coxae are level and maintain a stable position, with the shoulder, ‘hip’ and heel in alignment but this is not always the case (Greve and Dyson 2014). In a study of Greve and Dyson (2014) of 276 riders, 37% sat crookedly when viewed from behind. When rider is not sitting in balance the weight distribution is likely to somewhat compromise equine thoracolumbosacral function. Riders body size relative to the horse is a delicate but important and potential issue and its importance dependents on many factors like type, speed and duration of work and not least on rider skill and balance (Clayton et al. 2015).

General guide to the ratio between rider and horse could be that bodyweight of the rider should not greatly exceed 20% of the horse weight. Force applied on the horse by a heavy rider with an asymmetric position and repetitive condition is likely to place abnormally high stress on the horse’s back and increase the possibility of small muscular asymmetry to developments (Clayton et al. 2015).

1.9. Thermal imaging in saddle fitting

Only a few scientific studies have been made on thermal imaging as a part of saddle fitting or assessing the fit of saddles. But what little have been studied it looks promising and especially in finding the ill-fitting saddles thermal imaging is starting to prove its place as a diagnostic tool. Asymmetric contact between saddle panels and horses back observed in 62.8% of the saddles evaluated in the study of Arruda et al. (2011). This also implies that better education of riders, trainers and veterinarians for assessment of saddle-fit is required. There is no set way to use thermal imaging in saddle-fitting. The study made by Soroko et
al. (2018) used the following setup: Thermal imaging of the saddles was done on each horse/saddle two times with 2 weeks apart. On both days, horses were tacked up in the same way and training comprising of warm-up for 10 minutes and then canter at a distance of 2,200 m for 20 minutes was done the same way both days but by different rider with a different saddle. Thermal images of the saddle panels were taken and six regions of interest were marked, with mean temperature calculated with computer program within each region to indicate pressure distribution.

Arruda et al. (2011) used a bit different approach as they also took thermal image of the saddle panels. They evaluated the areas of contact for asymmetry, contact with the dorsal midline and they divide the images in four groups by contact areas (up to 25%, 50%, 75%, and 100% area of contact) Figure 1. Arruda et al. (2011) also took thermal images from the horses back to detect heat points after training and the images of the horses back was compared with the image of the saddle panels to find ill-fitting saddles and correlating hot points.
Figure 1. Contact area (%) between saddle panels and thoracolumbar region of horses identified by thermography. Contact until (A) 25%, (B) 50%, (C) 75%, and (D) 100% (Arruda et al. 2011).
2. AIM OF THE STUDY

Aim of this study was:

- To investigate if affordably priced smart phone accessory type thermal imaging cameras can successfully be used in aid of assessing saddle fit.

- To find some possible causes for artifacts and misinterpretations in using thermal imaging in aid of saddle fit assessment.
3. MATERIALS AND METHODS

3.1. Thermal camera

Thermal camera used in this study was Seek Thermal Compact series and android version to work with the smart phone in use. The Seek Thermal Compact was selected due to its reasonably high thermal sensor resolution (206 x 156), ease of use and image handling and the affordable price (~250 € at the time of study). It is proved to be also easily portable, light weight and very easy to use. More detail specifications of the thermal camera as follows:

- Sensor resolution 206 x 156
- 36° Field of View
- <9 Hz Frame Rate
- 1,000 ft. Detection Distance
- Focusable Lens (15cm to 300 meters) of chalcogenide glass
- Vanadium oxide microbolometer
- Pixel pitch 12 Microns
- Spectral range 7.5 – 14 Microns
- Weight 0,5 ounces
- -40°C to 330°C Detection
- Energy consumption ~280mW
- Waterproof Case Included
- Photos & Videos
- Free mobile app
- Spot Temperature
- High-Low Temperature
- Threshold Mode
- 9 Color Palettes
- Auto Mode Only
- Auto Emissivity
The Seek Thermal Compact camera was used in Motorola Moto G (g3) smart phone with Android version 6.0.1 interface. Final Image interpretation was made with normal computer using normal computer screen.

The Seek thermal camera was used supported by an aluminum tripod made by Slik Master with custom made holder for the camera and extension cord to attach the camera to the phone (Figure 2). Tripod and extension cord was used in order to eliminate any vibration from the operator taking the images. This out of normal set up was selected so that the image quality would be as good as the equipment can produce. The camera is normally attached straight to the smart phones body as in Figure 3.

Figure 2. Modified camera setup and saddle placement as used in study.

On the background while making the image a flat piece of plywood was used to obtain uniform back heat signal behind the saddle (Figure 2.). The plywood sheet was on slight angle and not touching the wall behind. This also aided in positioning the saddle when taking the image. Distance from the camera to the saddle while taking the image was set at 1.5 meters to gain full and sharp image. The 36° field of view in the thermal camera the limiting
factor when deciding the distance.

The Seek Thermal camera functions using the smart phones processor capacity and display by running a free App (application) by Seek Thermal. The App gives you the opportunity to select between 9 color palettes, modes and temperature scale of the image and store images in the phones memory or send the images. The app also has tutorials how to take images and use the device. The Seek Thermal also offers thermal cameras in iPhone compatible versions.

![Seek Thermal camera placement as intended by manufacturer.](image)

**Figure 3.** Seek thermal camera placement as intended by manufacturer.

### 3.2. Imaging setting and protocol

When taking images of the saddles for this study, the following protocol was used. A single thermal image from each saddle was taken with Seek Thermal Compact thermal camera attached to Motorola moto G (3g) smart phone and supported by Slik Master tripod. The image from the underside of the saddle was taken after the saddle had been on the horse that it is normally used. The time for each saddle on the back was 1 minute and the saddle
girth was tightened to its normal tightness as it is when normally ridden. No rider was put to sit in the saddle nor was the horse moved during the time the saddle was on the back. The duration of 1 minute was chosen in order to give enough time for heat to transfer from the horses back to the saddle, to give good repeatability and image quality. The image was then taken no more than 30 seconds after the saddle was removed from the horse so the heat distribution does not change before the image is taken. The saddles were monitored with the thermal camera before they were put on the horse in case of artificial heat signals, for example from being stored near heat source or from handling. All horses were at the stables in the morning of imaging and had been in the stable for the night to eliminate unequal heat distribution due to exercise.

No saddlecloth or any added material was used between the saddle and horse while study was performed. This is very important as saddle fit is traditionally assessed like this and the saddle should fit nicely to the back without any corrective materials added between the saddle and horse (Dyson et al. 2015).

The added materials can also affect the thermal image by changing the transfer or distribution of heat from the horse to the saddle as can be referred from previous studies. For example if there is thick fur padding between the saddle and horse just on the panels of the saddle the heat will not distribute evenly on the panels and misinterpretations can occur.

3.3. Animals and saddles used in the study

The sample material was collected from a riding school in Helsinki area. Most of the horses where owned by the riding school but two were privately owned, all lived at the stables they were studied. The riding school horses were all at full use in the school and none were known to be lame or otherwise sick. All the saddles used in the study were normally used at horse they were studied with. All horses were ridden by multiple riders and all saddles were used only on one horse. None of the horses had behavioral problems while saddling but some (41.7%) had known saddle fitting issues. All saddles had traditional tree structure and wool / synthetic fiber flocking.

Descriptive and all other data about the study subjects was collected and recorded by an
electronic questioning form after the imaging had taken place. And the data was electronically transferred to spreadsheet for data analyzing as presented in Tables 1. and 2.

Table 1. Descriptive data about the horses included to the study. (n=12)

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<th>Withers</th>
<th>Curvature of the back</th>
<th>Length of the back</th>
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<td>normal</td>
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<td>gelding</td>
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<td>normal</td>
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</tr>
<tr>
<td>gelding</td>
<td>horse</td>
<td>5</td>
<td>good</td>
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<td>4.5</td>
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<td>normal</td>
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<td>long</td>
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<td>horse</td>
<td>4</td>
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<td>4</td>
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<td>low</td>
<td>normal</td>
<td>long</td>
</tr>
<tr>
<td>gelding</td>
<td>horse</td>
<td>5.5</td>
<td>missing</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td>mare</td>
<td>horse</td>
<td>5</td>
<td>good</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td>gelding</td>
<td>horse</td>
<td>4.5</td>
<td>good</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td>gelding</td>
<td>pony</td>
<td>7</td>
<td>good</td>
<td>long</td>
<td>normal</td>
<td>short</td>
</tr>
<tr>
<td>gelding</td>
<td>pony</td>
<td>6</td>
<td>good</td>
<td>normal</td>
<td>straight</td>
<td>normal</td>
</tr>
<tr>
<td>9 gelding</td>
<td>10 horse</td>
<td>Average 4.8</td>
<td>7 good</td>
<td>9 normal</td>
<td>9 normal</td>
<td>5 normal</td>
</tr>
<tr>
<td>3 mare</td>
<td>2 pony</td>
<td>Min 4</td>
<td>5 missing</td>
<td>1 long</td>
<td>3 straight</td>
<td>3 short</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max 7</td>
<td>1 low</td>
<td></td>
<td></td>
<td>4 long</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mode 4</td>
<td>1 high</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4. Assessment

All interpretations of the thermal images and assessments of the animals were done by one person. Image interpretation was blinded, not knowing which of the thermal image was from which saddle / horse. The image quality obtained was found to be suitable to detect ill-fitting saddles and to detect problems in symmetry and area of contact as such problems were
observed with the saddles imaged in this study.

3.4.1. Saddle assessment

From the thermal images taken from the saddle the symmetry of the heat distribution in the saddle was assessed, representing the contact area with the horses back and the saddle. No visual asymmetry was found in the inspection of the saddles done by the author. The total contact area was estimated to determine if the saddle was having adequate contact area with the horse. A scale of 25%-50%-75%-100% was used to estimate the amount of contact area like in Arruda et al. (2011) which is illustrated in Figure 1. Points of unwanted contact areas in the middle tunnel for the spinal column were assessed to find ill-fitting saddles that can cause severe pain and behavioral problems while riding. In 41.7% of the imaged saddles an unwanted contact point was observed. Thermal image of an unwanted contact point shown in Figure 4. with red circle around the point of unwanted contact. In 66.6% of the imaged saddles some level of asymmetry was observed. Example image of asymmetric saddle shown in Figure 5.
From the saddles also following parameters were recorded for study purposes. Type of saddle, (dressage, show jumping or universal), type of girth (with or without stretches), type of flocking, known problems with saddle fit, length of the saddle to the length of the back, visual asymmetry of the saddle, is the saddle used on multiple horses, is the saddle normally used with additional padding.

As seen from the Table 2. 4 (33.3%) of the saddles were dressage models, 5 (41.7%) were show jumping models and 3 (25%) were universal models. From all the saddles in the study 7 (58.3%) were used with girth that had some sort of stretching material in its structure to ease the tightening of the saddle and 5 (41.7%) had no stretch. All saddles had traditional wool or fiber flocking and none were with air or latex type of flocking. The length of the saddle to the length of the back was found to be correct in all cases. No visual asymmetry was found in any of the saddles before imaging. All saddles were normally used only by the one horse that it was imaged with. From the saddles used in the study 5 (41.7%) were normally used with some additional materials between the saddle and the horse and 7
(58.3%) with only saddlecloth. Previously known problems with saddle fit was recorded on 5 (41.7%) of the cases in this study.

Figure 5. Thermal image illustrating asymmetry of contact area.
Table 2. Descriptive data about the saddles included to the study. (n = 12)

<table>
<thead>
<tr>
<th>Saddle type</th>
<th>Saddle used with additional material</th>
<th>Type of girth</th>
<th>Type of saddle flocking</th>
<th>Known problems with saddle fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>dressage</td>
<td>no</td>
<td>no stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>show jumping</td>
<td>yes</td>
<td>stretch</td>
<td>wool</td>
<td>yes</td>
</tr>
<tr>
<td>dressage</td>
<td>no</td>
<td>no stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>universal</td>
<td>no</td>
<td>stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>show jumping</td>
<td>yes</td>
<td>stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>universal</td>
<td>no</td>
<td>stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>show jumping</td>
<td>yes</td>
<td>stretch</td>
<td>wool</td>
<td>yes</td>
</tr>
<tr>
<td>dressage</td>
<td>no</td>
<td>no stretch</td>
<td>wool</td>
<td>yes</td>
</tr>
<tr>
<td>show jumping</td>
<td>no</td>
<td>stretch</td>
<td>wool</td>
<td>no</td>
</tr>
<tr>
<td>show jumping</td>
<td>yes</td>
<td>stretch</td>
<td>wool</td>
<td>yes</td>
</tr>
<tr>
<td>4 dressage</td>
<td>5 yes</td>
<td>7 stretch</td>
<td>12 wool</td>
<td>5 yes</td>
</tr>
<tr>
<td>5 show jumping</td>
<td>7 no</td>
<td>5 no stretch</td>
<td>0 air</td>
<td>7 no</td>
</tr>
<tr>
<td>3 universal</td>
<td></td>
<td></td>
<td>0 latex</td>
<td></td>
</tr>
</tbody>
</table>

3.4.2. Horse assessment

From the horses the following parameters were assessed and recorded after taking the thermal image and illustrated in Table 1: Gender, Height (< or > than 148 cm), BCS (Body condition score) 1-9 as in Henneke et al. (1983), musculature of the back, form of the withers, curvature of the back, length of the back, is the horse ridden by multiple riders. All horses had dry and similar length short summer hair at the site of saddle during the imaging. Only one horse had visible hair and skin defects at the site of saddle, it had few papules with loss of hair and thinning of skin. From the horses 9 (75%) were geldings and 3 (25%) were mares. The height of the horses was estimated and two (16.7%) of the subjects were under 148cm at the withers and so classified as pony other 10 (83.3%) were over 148
cm and classified as hoses. The average of BCSs of the subjects were 4.8 in the scale from 1 to 9. The lowest BCS was 4 and the highest was 7, mode of BCS was 4. When assessing the musculature of the back 7 (58.3%) of the horses had good musculature and 5 (41.7%) had some muscle mass missing from the back when compared with normal horses back. None of the horses had fatty back where the spinal collar is in a groove. From the horses 9 (75%) had withers classified as normal and 1 (8.3%) had long, 1 (8.3%) had low and 1 (8.3%) had high withers. When assessing the curvature of the horses back 9 (75%) were assessed as normal and 3 (25%) as straight. In the study group there were 5 (41.7%) horses that had normal length back, 3 (25%) horses that had short back and 4 (33.3%) that had long back.
4. RESULTS

The image quality obtained was found to be good enough to give aid in the detection of ill-fitting saddles and problems in contact area symmetry and areas of unwanted contact as such problems were observed with the saddles imaged in this study. Possible sources of artefacts and causes of misinterpretations were identified as wrong position of neck as seen in Figure 6. and uneven stand during the time when saddle is on the back of the horse before thermal image is taken from the saddle.

As seen from the Table 3. most of the saddles (58.3%) had 100% contact area between the horse and the saddle and only one saddle (8.3%) had 50% of contact area. Four saddles (33.3%) had 75% of contact area and none of the saddles had only 25% of contact area. Symmetry of the heat distribution between right and left side of the saddle was more widely distributed as the 3 category’s good, fair and bad all had 4 saddles (33.3%) in them. Heat signals of unwanted contact points were observed in 5 saddles (41.7%) and this might be the reason why so many of these saddles (41.7%) are normally used with additional materials between the saddle and the horse. But to mention not all saddles that had heat signal of unwanted contact point was normally used with additional material. No unwanted contact points were observed in 58.3% of saddles in this study.
**Table 3.** Analyzed data from the thermal images

<table>
<thead>
<tr>
<th>Saddle contact area</th>
<th>Symmetry of the saddle heat signal</th>
<th>Unwanted contact point</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>bad</td>
<td>no</td>
</tr>
<tr>
<td>75%</td>
<td>fair</td>
<td>yes</td>
</tr>
<tr>
<td>75%</td>
<td>fair</td>
<td>no</td>
</tr>
<tr>
<td>100%</td>
<td>bad</td>
<td>no</td>
</tr>
<tr>
<td>100%</td>
<td>good</td>
<td>no</td>
</tr>
<tr>
<td>75%</td>
<td>bad</td>
<td>no</td>
</tr>
<tr>
<td>100%</td>
<td>fair</td>
<td>yes</td>
</tr>
<tr>
<td>100%</td>
<td>good</td>
<td>no</td>
</tr>
<tr>
<td>100%</td>
<td>bad</td>
<td>yes</td>
</tr>
<tr>
<td>100%</td>
<td>good</td>
<td>yes</td>
</tr>
<tr>
<td>100%</td>
<td>fair</td>
<td>no</td>
</tr>
<tr>
<td>50%</td>
<td>good</td>
<td>yes</td>
</tr>
<tr>
<td>7 (100%)</td>
<td>4 good</td>
<td>5 yes</td>
</tr>
<tr>
<td>4 (75%)</td>
<td>4 fair</td>
<td>7 no</td>
</tr>
<tr>
<td>1 (50%)</td>
<td>4 bad</td>
<td></td>
</tr>
</tbody>
</table>
5. DISCUSSION

The use of proper support and stabilization of camera to eliminate movement while taking an image proved to be essential as one would assume. This becomes very relevant when using this kind of setup with high possibility of movement when used in hand. It is possible to obtain good quality images with this equipment also when the camera is held in hand. The possibility of movement is much higher in this case and should be avoided if possible.

During the imaging a few sources of previously unmentioned and crucial sources of artefacts and possibilities of misinterpretations were encountered. One being the absolute straightness of the stand of imaged horse. It was found that neck positioning is crucial when assessing for unwanted contact point in the space for the spinal column. When the horse was allowed to hold its head in lower position than normal, detection of unwanted contact point was found to be more uncertain. In these cases, the saddle may appear to be better fitting than it actually is. The influence of neck position in assessing unwanted contact points is illustrated in Figure 6. The position of the neck can have big difference in detecting problems and it can also create symmetry artefacts in image if bend to one side. Also, the straightness of the pose is important as it can cause incorrect imbalance in symmetry of the contact area. So horses legs should be next to each other and weight evenly distributed during the 1 minute of heat transfer from the horse to the saddle. The positioning of saddle to be in 90-degree angle towards the camera proved to be difficult and more thought should be but to getting this part easy and consistent to obtain good quality images in the future. Lens focus adjustment proved to be important and not be forgotten for good image quality, easy to do and but very important.
Figure 6. Effect of neck position in saddle images. In image (A) horses head lower than normal and in image (B) horses head in normal position

The use of additional materials between the horse and saddle changes the fit of the saddle and so decision was made to take all images without the use of any saddlecloths and additional paddings to gain the proper assessment of fit as it is done normally (Dyson et al.2015). Only in the case when temporary improvement in fit is needed the use of additional material should be approved.

Some of the horses in this study had very ill-fitting saddles but to the owners behalf I must say that all but one of those horses were using some additional material between the saddle and horse in normal day situation to correct the fit so the situation as whole is not as bad as the thermal image would suggest. It would be beneficial for these horses to get better fitting saddles in the future.

The Pro model of the Seek Thermal series is perhaps even more suitable then the Compact model for diagnostics as it has a better 320 x 240 thermal sensor and due to that sharper image quality. When compared to the traditional thermal imaging devices in market (FLIR K55) with similar 320x240 resolution the Pro model with its price of 450 € is still very affordable, as the traditional versions cost thousands of euros (4000+).
6. CONCLUSIONS

The image quality obtained was found to be somewhat suitable to detect ill-fitting saddles and to detect problems in symmetry and area of contact as such problems were observed with the saddles imaged in this study. Thus, the smart phone accessory type thermal imaging cameras may in some cases be successfully be used in aid when assessing saddle fit and screening for ill-fitting saddles.

Due to a small sample size of this study, further studies performed with bigger sample size would be recommended to determinate the true value of thermal imaging in saddle fitting and to estimate the prevalence of different types of problems observable by thermal imaging in saddle fitting.
SUMMARY

Thermal imaging is one of the imaging methods to be on the rise as the scientific research on it catches up with today’s demands. Along with recent technological advancements and due that the decrease in high quality thermal imaging cameras, the use of thermal cameras in the field of veterinary medicine looks to be good. Especially as it is as noninvasive as a imaging gets. New fields of use such as saddle fitting will arise as science and the imagination of practitioners create them. This is seen also by numerous professional saddle fitters that utilize thermal imaging in their work daily.

The image quality obtained was found to be suitable to detect ill-fitting saddles and to detect problems in symmetry and area of contact as such problems were observed with the saddles imaged in this study.

The findings of this study and studies of others implies that better education of riders, trainers and veterinarians for assessment of saddle-fit is required as the number of ill-fitting saddles is relatively high.
REFERENCES


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