Introduction
The bull riding industry is one of the fastest growing rodeo events and the major reason for its increased popularity is the bucking bulls [1]. Just like any professional athlete in a variety of musculoskeletal injuries, the majority of them being hoof and back injuries [3]. The size and temperament of bucking bulls makes them difficult to handle and restrain and limits the ability of veterinarians to diagnose injuries. Due to their volatile nature, evaluating spinal column injuries of bucking bulls is done using traditional imaging modalities such as radiography, ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI) is difficult. Infrared thermographic imaging provides a noninvasive and portable option to veterinarians that can be used chute-side in the evaluation of musculoskeletal injuries. Thermographic images provide information about skin surface temperature which reflects the underlying blood circulation [4]. Inflammation results in increased blood flow and increased tissue metabolism which can be observed as a focal elevation in temperature on a thermographic image [5]. If there is an acute injury resulting in inflammation, or a chronic injury resulting in fibrosis and a decrease in local tissue perfusion it can be visualized on a thermographic image. This change in the thermographic pattern will enable the veterinarian to focus on this location and recommend additional diagnostics and treatment.

Objectives
Objective 1: Determine the normal thermographic pattern and normal spinal contour of the topline of a bull.
Objective 2: Determine potential sites of the dorsum that have a change in thermographic pattern in bucking bulls.
Objective 3: Correlate changes in spinal contours with changes of the thermographic pattern.
Objective 4: Establish a novel, noninvasive thermographic imaging protocol to evaluate the back of a rodeo bucking bull.

Materials and Methods
• Non-bucking control group
  • 36 Hereford and Black Angus bulls.
  • Bucking group
  • 49 elite bucking bulls.
  • A thermographic camera (FLIR VET-T420) was used to obtain dorsoventral oblique images of the back.
  • The topline contour for each bull was inspected and any abnormalities were noted.
  • The thermographic images of the dorsum were divided into three regions of interest (ROI).
  • ROI-I was defined as the cranial thoracic region (T1-T8).
  • ROI-II was defined as the thoracolumbar region (T9-L2).
  • ROI-III was defined as the lumbosacral region (L3-sacrum).
  • Each ROI was evaluated using the FLIR box measurement tool and minimum, maximum and average temperatures were recorded.
  • Areas with a visibly increased or decreased temperature were deemed abnormal.
  • Results from analysis of the ROI were correlated with any abnormalities seen during visual inspection to determine their relationship.

Results
1. Technique
   • Artificial elevations in skin temperature from radiant solar heat were avoided by obtaining images before sunrise.
   • The images were collected while the bulls were eating from a feed bunk.
   • The camera was positioned approximately 2 feet in front of the bulls and at a height of approximately 8 feet.
   • 3 dorsoventral oblique images with an angle of 45° were taken from a distance of 5 feet from the bull’s withers.

2. Control group
   • Images were taken of 36 bulls with a mean age of 15 months (range = 7-40 months).
   • 11.1% of these bulls had visibly appreciable dorsum contour abnormalities of which 100% were detected thermographically as a hot spot (Table 1).
   • No focal cold spots were detected thermographically.
   • 50% of the contour abnormalities were located in ROI-I, 50% were located in ROI-II and 9% were located in ROI-III (Table 2).

3. Bucking group
   • Images were taken of 49 active bucking bulls with a mean age of 4 years old (range: 3-9 years) and 3 retired bucking bulls with a mean age of 11 years old (range: 8-13 years).
   • 33.7% of these bulls had visibly appreciable dorsum contour abnormalities of which 56.3% were detected thermographically as a hot spot (Table 1).
   • No focal cold spots were detected thermographically.
   • 33.3% of the thermographic abnormalities were located in ROI-I, 66.6% were located in ROI-II and 11.1% were located in ROI-III (Table 2).

Discussion
The images collected of the control group provided information that was used to establish the normal thermographic pattern of a bull’s topline. This consisted of a central streak of increased heat oriented over the dorsum midline (Fig. 1) and increased heat in the region of the whipers and scapula (Fig. 2-3).
• Due to thermal imaging’s high sensitivity (0.04°C), artifacts are common and therefore the animal must be acclimated to a cool environment and kept out of direct sunlight in order to obtain accurate images.
• The anterolateral region (T13) is a high motion area and experiences the most lateral bending and vertical flexion and extension [6].
• This could be an explanation for the increased prevalence of thermographic abnormalities in ROI-I which includes the anterolateral region.
• The visual inspection of the bull’s topline contour was less sensitive than the thermographic evaluation.
• This means that even though a bull may have a visible contour abnormality of its topline it may not be pathologic and should be confirmed thermographically.
• The increased sensitivity that thermographic imaging provides, could enable producers and veterinarians to screen bucking bulls for actively inflamed lesions prior to a rodeo.

Conclusion
• This study provides preliminary information regarding the distribution and prevalence of thermographic and contour abnormalities in rodeo bucking bulls.
• The overall goal of this study was to develop a standard infrared thermographic imaging protocol for veterinarians to use in their evaluation of the topline of bucking bulls.
• The novel imaging protocol could provide veterinarians throughout the country a safe and non-invasive technique to evaluate neuromusculoskeletal abnormalities of the back and limbs of bucking bulls.
• Additional research needs to be performed in order to correlate thermographic and contour abnormalities with performance limiting pathology in the back of rodeo bucking bulls.

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Table 1: Prevalence of visible and thermographic abnormalities in the control group and bucking group.

<table>
<thead>
<tr>
<th>Group ID</th>
<th>Control abnormalities</th>
<th>Thermographic abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group n=36</td>
<td>11.1%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Bucking Group n=49</td>
<td>32.7%</td>
<td>18.4%</td>
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</tbody>
</table>

Table 2: Distribution of thermographic abnormalities in the control group and bucking group.

<table>
<thead>
<tr>
<th>Group ID</th>
<th>ROI-I</th>
<th>ROI-II</th>
<th>ROI-III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group n=4</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Bucking Group n=9</td>
<td>33.3%</td>
<td>55.6%</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

Figure 1. An example of a normal thermographic pattern of a bull with ROIs shown.

Figure 2. A thermographic abnormality in ROI-I.

Figure 3. A thermographic abnormality in ROI-II.

Figure 4. A thermographic abnormality in ROI-III.

References

Evaluation of dorsal skin temperature of rodeo bucking bulls using infrared thermography.

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