Repeatability of body fat thickness measurement and body condition scoring in sheep

DIPLOMARBEIT

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List of abbreviations

BCSlu  body condition score lumbar
BCSst  body condition score sternal
cm  centimetre
κ  Cohen’ s Kappa coefficient
MHz  megahertz
mm  millimeter
p  p-value
RFTl  rump fat thickness left
RFTr  rump fat thickness right
SD  standard deviation
SFT  sternal fat thickness
1 Introduction

The assessment of the body fat thickness and body condition is important for a good flock management and prevention of diseases. The determination of back fat thickness in dairy cows is carried out by ultrasonography and is part of routine livestock surveillance (STAUFENBIEL, 1992; SCHRÖDER and STAUFENBIEL, 2003). A study by LEEB et al. (2007) reported the systematic validation of body condition score (BCS) and rump fat thickness (RFT) in dairy goats. A comparable study in sheep has not been realised until now. To evaluate the accuracy of the measuring system, it is important to compare the individual data from one investigator as well as to compare the measured data between different investigators. Several similar studies were carried out in cattle already. KLEIBÖHMER et al. (1998) reported the accuracy and repeatability of body condition scoring and found a high reproducibility after a one-day training course and several weeks of practise.

With continuous monitoring of the body condition of sheep, metabolic problems such as pregnancy toxaemia could be identified earlier or even prevented (ROOK, 2000). Nutrition can be optimized by adjusting the feeding to the BCS of the sheep, especially during early lactation and for late pregnant ewes (ROOK, 2000; BROZOS et al., 2011). CALDEIRA et al. (2007) showed that the BCS has a significant impact on blood metabolites and hormone levels in sheep. Ewes which are under or over conditioned are more susceptible for metabolic diseases than sheep with an optimal body condition. Furthermore, an optimal body condition contributes fundamentally to a higher ovulation rate and therefore to a higher number of lambs (RUSSEL, 1984). RAOOF (2011) showed that an optimal BCS has positive effects on milk production, birth weights and wool. In contrast to dairy cows, body condition scoring in sheep is performed not only by lumbar but also sternal palpation.

1.1 Aim of the study

The study was conducted to compare the results of the fat thickness measurements and BCS determination in sheep within an investigator (intra observer repeatability)
and between different investigators (inter observer repeatability). A further objective was to evaluate if there is a difference in determining the RFT and the BCS between unshorn and sheared sheep.
2 Literature

2.1 Rump fat thickness and sternal fat thickness measurement in sheep and goats

Different methods for determining the BCS in different livestock can be applied. In general, body condition scoring in sheep is realised by palpation of the lumbar region. Several other methods as measuring the RFT were implemented and discussed. SILVA et al. (2006) used the ultrasonographic measurement of RFT and sternal fat thickness (SFT) in sheep to estimate \textit{in vivo} the carcass composition by using real time ultrasound. The measuring points in this investigation were between the third and fourth \textit{lumbar vertebra} and over the third \textit{sternebra} of the \textit{sternum}. A similar study in goats was realised by TEIXERA et al. (2008). They estimated the carcass composition and body fat partition in goats by real-time ultrasonography. WOLF (2008) measured the RFT in dairy goats between \textit{tuberositas ischiadica} and \textit{trochanter major} according to the references from LEEB et al. (2007). This study compared the RFT with body condition scoring methods (visual, lumbar, sternal), weight, thoracic circumference and withers high. Furthermore, they compared the investigators with each other and the results of the single investigators. The inter observer repeatability was between 27 to 41% for visual BCS, 29 to 47% for lumbar BCS and 32 to 42% for sternal BCS. The intra observer repeatability was between 38 to 73% for visual BCS, 42 to 56% for lumbar BCS and 36 to 47% for sternal BCS. (WOLF, 2008)

2.2 Purpose and aim of body condition scoring

The objective of body condition scoring is an optimized health herd and consequently a more efficient production. During gestation, the body condition of the ewe influences the development of the offspring. It takes six up to eight weeks on good pasture for an ewe to gain one point on the condition score scale (STUBBINGS, 2007). In sheep herds, particularly pregnancy toxaemia can be prevented by optimizing feed ration adjusted to the BCS. The farmer or the veterinarian should perform body condition scoring regularly to detect variations as soon as possible.
Because it is very difficult for the farmers, who control their flock daily, to recognise minimal changes in their herds, the scoring should be performed by infrequent and impartial observer for example the local veterinarian (ROOK, 2000). Using the 5-point scale, very lean ewes (BCS < 2) or obese ewes (BCS ≥ 4) are at high risk to become affected by pregnancy toxaemia than ewes with an optimal BCS (BROZOS et al., 2011). The optimal BCS for ewes at the time of mating and parturition is 2.5 to 3 (RANKINS and PUGH, 2012). CALDEIRA et al. (2007) showed that the BCS has a significant impact on blood metabolites and hormone levels in sheep. Ewes that are under or over conditioned are more susceptible for metabolic diseases than sheep with an optimal body condition. Ewes with an optimal body condition have a higher ovulation rate resulting in a higher number of lambs (RUSSEL, 1984). Furthermore, BCS has an impact on the wool yield. Sheep with a BCS of 4 had the highest wool production compared to other groups with a lower BCS (SEJAN et al., 2009). A study from Iraq showed that the BCS has significant effects on milk production, birth weight of the lambs and wool quality. The ewes with a BCS from 3 to 4 are excellent in all traits (RAOOF et al., 2011).

2.3 Body condition scoring in sheep and goats

The implementation of body condition scoring in ewes is recommended in several books and studies. RUSSEL et al. (1984) suggested to assess the condition by palpation of the lumbar region, on and around the backbone in the loin area, just behind the last rib and above the kidney. Animals are scored on a score from 0 to 5. The scoring system by LEEB et al. (2007) is described in detail in table 1 and figure 1 and 2. STUBBINGS (2007) described the same classification from 0 to 5, and recommended to use half point scores in practise because the difference between full scores is relatively large. This method was implemented by ASCHENBACH and RAHMANN (2011) for evaluating the body condition scoring in goats. This study, however, concluded that BCS was not useful for measurement of the nutritional status of dairy goats.

CALAVAS et al. (1998) assessed the accuracy of a body condition scoring in ewes under field condition. The κ coefficient in this study was categorized into six classes
ranging from very poor to very good. They reported good intra observer repeatability ranging from 52.1 % to 100%, but a poor inter observer repeatability with significant differences between the observers.

Table 1. BCS-system lumbar and sternal by LEEB et al. (2007)

<table>
<thead>
<tr>
<th>Score</th>
<th>Result lumbar</th>
<th>Result sternal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/very thin</td>
<td>Muscles cover the transverse processes only two thirds, therefore the bone is distinct palpable.</td>
<td>Link between rib cartilage and sternum palpable, central recess of the sternum palpable due to missing fat.</td>
</tr>
<tr>
<td>2/thin</td>
<td>Transverse and spinous processes are distinct palpable, the skin between forms a concave line.</td>
<td>Link hardly palpable, as covered with some fat, central recess of sternum is filled with fat thus a straight line is palpable.</td>
</tr>
<tr>
<td>3/good</td>
<td>The space among transverse and spinous processes is filled up with muscles, the skin between forms a straight line.</td>
<td>Due to increased fat on the sternum are distinct recesses on both sides of the sternum palpable.</td>
</tr>
<tr>
<td>4/very good</td>
<td>The bones are hard to palpate, the skin forms a convex line.</td>
<td>Sternum and ribs are hard to palpate, recess on both sides of the sternum disappears.</td>
</tr>
<tr>
<td>5/obese</td>
<td>Along the dorsal line there is a distinct recess visible, due to convex line.</td>
<td>No recess palpable, the skin forms a protrusion of muscles and fat on both sides.</td>
</tr>
</tbody>
</table>
Figure 1. Body condition score lumbar, score 1 to 5 (LEEB et al., 2007)

Figure 2. Body condition score sternal, score 1 to 5 (LEEB et al., 2007)
2.4 Body condition scoring in cattle

The visual body condition scoring and determination of the RFT by ultrasonography is often used in dairy cows (STAUFENBIEL, 1992; SCHRÖDER and STAUFENBIEL, 2003).

The BCS adequately reflects the subcutaneous fat tissue of cows. EDMONSON et al. (1989) developed a scoring system for Holstein dairy cows to simplify different methods of body condition scoring. The system gives consistent results with small variability among assessors, no significant difference attributable to experience of assessors, and no significant cow assessor interaction. The correlation of BCS assessed by different investigators is a measure for reproducibility of BCS (EVANS, 1978). The advantage of visual body condition scoring is that it is easy to learn (KLEIBÖHMER et al., 1998) and does not need any technical equipment. KLEIBÖHMER et al. (1998) compared the measurements of 13 less experienced investigators with a gold standard, determined as the average of two experienced investigators. The investigators had a one-day introduction and training course and six weeks training using their own cattle. They reported 84% agreement, but quarter points on the BCS scale were not regarded. FERGUSON et al. (2006) assessed body condition using digital images and showed that assessment of BCS in dairy cattle is possible from digital pictures or a video. RASCHKE (2007) developed a pattern to evaluate BCS in German Simmentals and Holstein Friesian calves. In this study, 11 investigators evaluated 38 calves twice. The intra observer repeatability was considerable high. Compared to the first scoring, 84.2% of the second scorings differed less than a quarter point.

RFT measuring is easy to learn and a helpful tool to estimate the body fat. It can be implemented in the routine surveillance of body condition score. Furthermore, a repeated measurement can help to monitor postpartal lipolysis (STAUFENBIEL et al., 1992). Moreover, DOMECQ et al. (1995) showed in their study a significant relationship between BCS and RFT.
3 Materials and Methodes

3.1 Animals

The study was conducted at the Teaching and Research Farm Kremesberg (LFG), University of Veterinary Medicine Vienna (VUW), Austria. In total, 65 ewes from three different breeds were included in this trial (Tyrol mountain sheep, n = 20; Tyrol Steinschaf, n = 4; Merino, n = 51). All ewes were kept on deep litter and were fed ad libitum with hay and silage of lucerne. Additionally, squeezed oat was fed as concentrate. During summer, the sheep had access to pasture every day. Basic data of sheep, such as body weight, thoracic circumference and reproductive status (non pregnant, pregnant or lactating) were recorded at the first day of the study (table 2) and after shearing at the end of the study.

The study was discussed and approved by the institutional ethics committee according to §8ff of Law for Animal Experiments, and was not classified as an animal experiment.

3.2 Design of the study

The study started in April 2013 and lasted two weeks. The first examination included the determination of the basic data of the experimental animals, as well as the body condition score lumbar (BCSlu), body condition score sternal (BCSst), rump fat thickness left (RFTl), rump fat thickness right (RFTr) and sternal fat thickness (SFT) in sheep with wool. The second examination in the subsequent week included the evaluation of the parameters mentioned above but in sheared sheep. The body weight was estimated with a mechanical livestock scale (Florenz Josef Waagen-Gewichtefabrik AG, Simbach/Inn, Germany) and the thoracic circumference of all ewes was determined with a measuring tape (W. Prym GmbH & Co KG, Stolberg/Rhineland, Germany) one week before and one week after shearing. The body condition scoring was performed by palpation of the lumbar and sternal site of the sheep (LEEB et al., 2007; MATTHEWS, 2009) and was graded from 1 to 5 (Figure 1 and 2). Score 1 is the lowest assessment, which is indicative for under conditioned sheep; score 5 is the highest that represents obese or over conditioned
animals.

RFT and SFT were determined with an ultrasonic device (Easi Scan bovine scanner, Technology Ltd, Livingston, Scotland), with a 5MHz linear array and with ultrasonic gel as contact medium.

RFT was measured between *tuberositas ischiadica* and *trochanter major* (figure 3.)

![Figure 3. Measuring point of rump fat thickness in sheep (LEEB et al. 2007)](image)

![Figure 4. Ultrasonographic picture of a rump fat thickness measurement in sheep](image)
SFT was measured at the lowest point of the sternum, 3 cm caudal from the cranial point of the *manubrium sterni*. The ultrasonographic estimation was applied across the longitudinal axis of the *sternum* (figure 5).

![Sternal fat thickness](image)

**Figure 5. Ultrasonographic picture of a sternal fat thickness measurement in sheep**

Six investigators with different experiences in BCS, RFT and SFT were part of this study: one student of veterinarian medicine as investigator one (I1), one veterinarian with no experience in BCS in sheep (I2), one multi-media art student with no experience in sheep (I3), one employee from the LFG (I4), one farmer (I5) and one veterinarian with experience in BCS in sheep (I6). Prior to the start, an introduction and training of the techniques for evaluation of BCS, RFT and SFT was performed. All investigators had a guideline with images of the BCSlu and BCSst during the entire study period.

The study protocol showed in table 2 was conduced 4 times per localisation, twice in unshorn sheep and twice in sheared sheep. This results in 4 time points for each investigator. (time point 1: examination of all locations in unshorn sheep on the first
day in the first week per investigator; time point 2: examination of all locations in unshorn sheep on the second day in the first week per investigator; time point 3: examination of all locations in sheared sheep on the third day in the second week per investigator; time point 4: examination of all locations in sheared sheep on the fourth day in the second week per investigator) Two investigators performed the measurements at the same time. The results were recorded in a list by the investigator. The investigators had different sheep to determine at the same time.

Table 2. Study protocol for determining BCSlu, BCSst, SFT, RFTr and RFTl at one time point. This protocol was performed in unshorn and one week later in sheared sheep.

<table>
<thead>
<tr>
<th>Examination time</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>I4</th>
<th>I5</th>
<th>I6</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.m.²</td>
<td>BCSlu³</td>
<td>BCSst⁴</td>
<td>BCSlu</td>
<td>BCSst</td>
<td>BCSlu</td>
<td>BCSst</td>
</tr>
<tr>
<td></td>
<td>SFT⁵</td>
<td>SFT</td>
<td>SFT</td>
<td>SFT</td>
<td>SFT</td>
<td>SFT</td>
</tr>
<tr>
<td></td>
<td>RFTr⁶</td>
<td>RFTl⁷</td>
<td>RFTr</td>
<td>RFTl</td>
<td>RFTr</td>
<td>RFTl</td>
</tr>
<tr>
<td>p.m.²</td>
<td>BCSst</td>
<td>BCSlu</td>
<td>BCSst</td>
<td>BCSlu</td>
<td>BCSst</td>
<td>BCSlu</td>
</tr>
<tr>
<td></td>
<td>RFTr</td>
<td>RFTl</td>
<td>RFTr</td>
<td>RFTl</td>
<td>RFTr</td>
<td>RFTl</td>
</tr>
</tbody>
</table>

¹ I = Investigator  
² a.m. = morning, p.m. = afternoon  
³ BCSlu = Body condition score lumbar  
⁴ BCSst = Body condition score sternal  
⁵ SFT = Sternal fat thickness  
⁶ RFTr = Rump fat thickness right  
⁷ RFTl = Rump fat thickness left

3.3 Statistical analysis

Data were digitized using Open Office tables software (Version 3.4.1, Apache foundation, USA) and dissected using the PASW statistical software (PASW Statistic 18, IBM, 2010, Ehningen, Germany). The Pearson correlation coefficient was used to
analyse if there is a correlation between two time points in unshorn and in sheared ewes measuring the RFTI, RFTr and SFT for all and within each investigators. Cohen’s kappa coefficient (k) was calculated to illustrate the inter observer reliability between BCSIu and BCSst and whether the results of the different investigators at the same days were comparable. The level of significance for statistical tests was set at \( p < 0.05 \). Analysis of variance (ANOVA) was used to compare the averages, values for RFTI, RFTr and SFT for the investigators and at the different days. The Pearson correlation coefficient and Cohen’s kappa coefficient (k) were calculated of the mean measurements of all investigators and of the measurements of each single investigator.
4 Results

The study was conducted with 65 sheep from three different breeds. Table 3 shows the average thoracic circumference and body weight in unshorn sheep. Most of the ewes were between 40 and 150 days of pregnancy (n = 60). The average thoracic circumference and body weight were 112cm and 100 kg. In sheared sheep thoracic circumference was 111 cm and body weight was 98 kg.

Table 3. Descriptive data of sheep enrolled in the study, including reproductive status, breed, the average of thoracic circumference and body weight in unshorn sheep

<table>
<thead>
<tr>
<th>Reproductive status</th>
<th>N</th>
<th>Merino</th>
<th>Tyrol</th>
<th>Tyrol mountain sheep</th>
<th>Thoracic circumference Ø (cm)</th>
<th>Weight Ø (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-pregnant</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>110</td>
<td>94</td>
</tr>
<tr>
<td>Pregnant</td>
<td>50</td>
<td>34</td>
<td>3</td>
<td>13</td>
<td>114</td>
<td>109</td>
</tr>
<tr>
<td>Lactating</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>112</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>42</td>
<td>4</td>
<td>19</td>
<td>112</td>
<td>100</td>
</tr>
</tbody>
</table>
4.1 Fat thickness measurement

Figures 6 to 8 show the estimated marginal means measured on time point 1 to time point 4 by six different investigators. In figure 6, all investigators determined RFT between 10 and 12 mm in unshorn sheep (time point 1 and time point 2), except for I1. For investigator 1, a difference in the measurement of the left RFT between time point 1 and time point 2 of 1.4 mm was found. Measuring the sheared sheep the mean variations between the investigators were higher than in unshorn sheep.

![Figure 6. Estimated marginal means of the left rump fat thickness measured at four different time points by six investigators](image-url)
The most noticeable finding in figure 7 is the great difference within the investigator 5 between time point 1 and 3. In unshorn sheep, I1, I2, I3, I4 and I6 determined the right RFT constantly between 10 and 12 mm with ± 2 mm. The variation of the mean values of all measurements was higher in sheared sheep compared to unshorn sheep with 8 to 14 mm.

Figure 7. Estimated marginal means of the right rump fat thickness measured at four different time points by six investigators.
The highest difference in all means was estimated in the sternal fat thickness (figure 8) only I2 presented a reliable measurement (± 1 mm) at all time points.

Figure 8. Estimated marginal means of the sternal fat thickness measured at four different time points by six investigators
The box plot diagram (figure 9) shows the variation of all investigators determining the left RFT. Investigator 5 was found with the most homogeneous results measurement with variations between 6 and 15 mm.

![Figure 9. Box plots of the left rump fat thickness](image)

Measuring the right RFT showed slightly higher variations within all time points compared with the left RFT (figure 10).

![Figure 10. Box plots of the right rump fat thickness](image)
Figure 11 describes the variations of SFT determined by the six investigators.

Figure 11. Box plots of the sternal fat thickness
The results of all investigators were analysed and compared between unshorn and sheared ewes (table 4). The correlation coefficient of the RFTI between the first and second measurements in unshorn sheep was 0.83 (p < 0.05). A significant correlation of 0.84 (p < 0.05) for determining the RFTI was also found between measurements in sheared ewes. The correlation for all investigators estimating the SFT in unshorn sheep was 0.31 (p < 0.05), in sheared sheep it increased up to 0.80 (p < 0.05).

Table 4. Correlation between two measurements in unshorn and sheared sheep, respectively, for six investigators.

<table>
<thead>
<tr>
<th>Comparison of the time points&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Investigators</th>
<th>All</th>
<th>I&lt;sup&gt;a&lt;/sup&gt; 1</th>
<th>I 2</th>
<th>I 3</th>
<th>I 4</th>
<th>I 5</th>
<th>I 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RFTI</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unshorn 1:2</td>
<td>0.83**</td>
<td>0.34**</td>
<td>0.44**</td>
<td>0.55**</td>
<td>0.29*</td>
<td>0.39**</td>
<td>0.75**</td>
<td></td>
</tr>
<tr>
<td>sheared 3:4</td>
<td>0.84**</td>
<td>0.04</td>
<td>0.58**</td>
<td>0.47**</td>
<td>0.70**</td>
<td>0.26*</td>
<td>0.39**</td>
<td></td>
</tr>
<tr>
<td><strong>RFTr</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unshorn 1:2</td>
<td>0.64**</td>
<td>0.19</td>
<td>0.39**</td>
<td>0.08</td>
<td>-0.06</td>
<td>0.17</td>
<td>0.75**</td>
<td></td>
</tr>
<tr>
<td>sheared 3:4</td>
<td>0.77**</td>
<td>0.10</td>
<td>0.74**</td>
<td>0.45**</td>
<td>0.68**</td>
<td>0.38**</td>
<td>0.29*</td>
<td></td>
</tr>
<tr>
<td><strong>SFT</strong>&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unshorn 1:2</td>
<td>0.31*</td>
<td>0.24</td>
<td>0.18</td>
<td>0.13</td>
<td>-0.70</td>
<td>-0.07</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>sheared 3:4</td>
<td>0.80**</td>
<td>0.55**</td>
<td>0.64**</td>
<td>0.25*</td>
<td>0.68**</td>
<td>0.31*</td>
<td>0.48**</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> I = Investigator
<sup>b</sup> RFTI = Rump fat thickness left
<sup>c</sup> RFTr = Rump fat thickness right
<sup>d</sup> SFT = Sternal fat thickness
<sup>e</sup> 1 = time point 1, 2 = time point 2, 3 = time point 3, 4 = time point 4
* p < 0.01
**p < 0.05
The difference between the RFT measured at time point 1 and time point 2 determined by the six investigators is plotted against the RFT measured at the first time point in figure 12. Investigator 4 and 5 showed the greatest mean difference in measuring the RFT of -0.1 ± 2.5 mm (-7.5 to 6.5) and -1.5 ± 1.5 mm (-4.5 to 2.0).

Figure 12. Difference between the results of the six investigators (I1 – I6) in unshorn sheep determining the rump fat thickness (left + right)
The most noticeable result of the difference between time point 3 and time point 4 was found in I3 with a mean of -0.1 ± 1.9 mm (-6.0 to 8.5) (figure 13).

Figure 13. Difference between the results of the six investigators (I1 – I6) in sheared sheep determining the rump fat thickness (left + right)
In figure 14, the differences between the SFT on the time point 1 and 2 determined by the six investigators are plotted against the SFT measured on time point 1. Investigator 3 showed the greatest mean difference in measuring the SFT with \(-5.1 \pm 6.8 \text{ mm} \) (-25.0 to 16.0)

Figure 14. Difference between the results of the six investigators (I1 – I6) determining the sternal fat thickness in unshorn sheep
Figure 15 presents the result of the difference between time point 3 and time point 4, with the greatest mean of -1.65 ± 6.8 mm (-23.0 to 26.0) for I3.

![Figure 15. Difference between the results of the six investigators (I1 – I6) in sheared sheep determining the sternal fat thickness](image)

Figure 15. Difference between the results of the six investigators (I1 – I6) in sheared sheep determining the sternal fat thickness

The correlation between the three different sites for determining the fat thickness, summarized for all investigators are shown in table 5. A strong correlation (0.63 to 0.76) was found between the RFTl and RFTr at all four time points (p < 0.05). On time point 1, the correlation between SFT and RFTl was 0.37, but there was an increase in the correlation coefficient at time point 4 with up to 0.70 (p < 0.05). The strongest correlation was found between SFT and RFTr at time point 4 of 0.79 (p < 0.05). Investigator 2 had the strongest correlation on almost all days compared with the other investigators. Investigator 5 had the strongest correlation (0.85, p < 0.05) between SFT and RFTr.
<table>
<thead>
<tr>
<th>Investigator</th>
<th>Time point</th>
<th>RFT\textsuperscript{a}:RFT\textsuperscript{b}</th>
<th>SFT\textsuperscript{c}:RFT\textsuperscript{a}</th>
<th>SFT:RFT\textsuperscript{r}</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1</td>
<td>0.63**</td>
<td>0.37**</td>
<td>0.39**</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.76**</td>
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<td>0.22</td>
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<td>0.79**</td>
<td>0.62**</td>
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<td>4</td>
<td>0.69**</td>
<td>0.64**</td>
<td>0.57**</td>
</tr>
<tr>
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<td>0.04</td>
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<td>0.19</td>
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<td>0.46**</td>
<td>0.54*</td>
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<td>0.61**</td>
<td>0.59**</td>
<td>0.60*</td>
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<tr>
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<td>4</td>
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<td>0.55**</td>
<td>0.66*</td>
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<td>0.59**</td>
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<td>0.34*</td>
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<tr>
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<td>4</td>
<td>0.38**</td>
<td>0.46**</td>
<td>0.52*</td>
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</tbody>
</table>

\textsuperscript{a}Rump fat thickness left  
\textsuperscript{b}Rump fat thickness right  
\textsuperscript{c}Sternal fat thickness  
* \text{p} < 0.01  
** \text{p} < 0.05
4.2 Body condition scoring

The $\kappa$ coefficients for scoring the lumbar and sternal body condition are presented in table 6 for all investigators. The coefficient of all investigators increased from time point 1 (0.20; no significance) to time point 4 (0.71; $p < 0.05$). Whereas at time point 1 and 2 the $\kappa$ coefficient of I2 for the BCSlu and BCSst was not significant, a significant agreement of 0.51 and 0.55 ($p < 0.05$) was found at time point 3 and 4.

Table 6. Agreement (κ) of body condition score lumbar and sternal for investigator 1 to 6 and for all investigators

<table>
<thead>
<tr>
<th>Time point</th>
<th>All</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>I4</th>
<th>I5</th>
<th>I6</th>
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<tbody>
<tr>
<td>1</td>
<td>0.20</td>
<td>0.12</td>
<td>0.10</td>
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<td>-0.06</td>
<td>0.06</td>
<td>0.20</td>
</tr>
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<td>2</td>
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<td>0.19</td>
<td>-0.07</td>
<td>0.01</td>
<td>0.16</td>
<td>0.18</td>
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<tr>
<td>3</td>
<td>0.44**</td>
<td>0.07</td>
<td>0.51**</td>
<td>0.12</td>
<td>0.02</td>
<td>0.30*</td>
<td>0.17</td>
</tr>
<tr>
<td>4</td>
<td>0.71**</td>
<td>-0.07</td>
<td>0.55**</td>
<td>0.28</td>
<td>0.31*</td>
<td>0.05</td>
<td>0.25</td>
</tr>
</tbody>
</table>

* $I = $ Investigators  
* $p < 0.01$  
** $p < 0.05$
Furthermore, a difference between the correlations of the BCSlu and BCSst in unshorn and sheared sheep was found for the investigators. All investigators showed an agreement in unshorn sheep measuring the BCSlu of 0.54 to 0.80 (p < 0.05). In sheared sheep, the agreements for the investigators were 0.44 to 0.78 (p < 0.05). The coefficient κ of the sternal BCS was generally lower than the lumbar BCS (table 7).

Table 7. Agreement (κ) of the body condition score determined by different investigators for BCS lumbar and sternal in unshorn and sheared.

<table>
<thead>
<tr>
<th>Investigators</th>
<th>unshorn</th>
<th>sheared</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>BCSlu&lt;sup&gt;a&lt;/sup&gt;</td>
<td>BCSst&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1 2</td>
<td>0.63**</td>
<td>0.37**</td>
</tr>
<tr>
<td>1 3</td>
<td>0.73**</td>
<td>0.38**</td>
</tr>
<tr>
<td>1 4</td>
<td>0.80**</td>
<td>0.34**</td>
</tr>
<tr>
<td>1 5</td>
<td>0.69**</td>
<td>0.36**</td>
</tr>
<tr>
<td>1 6</td>
<td>0.61**</td>
<td>0.47**</td>
</tr>
<tr>
<td>2 3</td>
<td>0.66**</td>
<td>0.31*</td>
</tr>
<tr>
<td>2 4</td>
<td>0.68**</td>
<td>0.10</td>
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<tr>
<td>2 5</td>
<td>0.64**</td>
<td>0.31*</td>
</tr>
<tr>
<td>2 6</td>
<td>0.63**</td>
<td>0.52**</td>
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<tr>
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<td>4 5</td>
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<td>4 6</td>
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<td>0.11</td>
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<tr>
<td>5 6</td>
<td>0.54**</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<sup>a</sup> Body condition score lumbar  
<sup>b</sup> Body condition score sternal  
* p < 0.01  
** p < 0.05
5 Discussion

The assessment of the body fat thickness and body condition is important for a good flock management and the prevention of diseases.

In our study, we used three different breeds in different reproductive status. There was no difference in the descriptive statistics between unshorn and sheared ewes. To our knowledge, this is the first study determining the body fat thickness by different investigators on three different sites of the sheep. Measuring the RFT presented a higher variation of the mean values in sheared sheep than in unshorn sheep. The highest variation of the means was determined when measuring the SFT. These findings indicate that the results of determining the SFT should be interpreted with care. Each investigator had some variations in his results. Because we had no gold standard, it is not clear if somebody was better or worse.

Not only the lower variation within RFTl compared with RFTr is obvious, but also the higher correlation of RFTl for different time points compared with RFTr is obvious. By plotting the differences between the two time points in unshorn sheep and in sheared sheep, a systematically measurement error in all investigators could be illustrated. For example, the minimum and maximum difference for I3 in measuring the SFT in unshorn sheep were -2.5 to +7 mm and -23 to +26 mm for measuring the SFT in sheared sheep. The difference in sheared sheep was even higher than in unshorn sheep. Out of this notice it can be hypothesized that this investigator showed no learning effect. Further studies could investigate if a “learning effect” can be expected if the technic is applied on regular base and more frequently. To our knowledge, in sheep there is no standard curve for optimal fat thickness with regard to different reproductive status. Further research should focus on a defined optimal fat thickness with minimum and maximum along a reproductive cycle of the ewe.

It is obvious that for RFTl all investigators had a high correlation coefficient in the first week (0.83) and in the second week (0.84). This was similar for RFTr. Whereas the correlation coefficient of the SFT in unshorn sheep was 0.31, a better correlation with 0.80 was determined in sheared sheep. The correlations for the single investigators in unshorn sheep measuring the RFTr and SFT were poor, especially in I4 and I5.
For measuring the SFT in unshorn sheep, I4 had even a negative correlation of -0.70. For RFTl and RFTr there was a high correlation coefficient at time point 3 and 4 when the ewes were sheared. This could be explainable by the effect of training on the previous days or the fact that the sheep were sheared. Another impact could be the difficulty to find always the same point of measurement in unshorn or sheared sheep. Furthermore, it is necessary to put more pressure on the linear array in unshorn sheep than in sheared sheep to get a good contact with the skin. The increased pressure may have compressed the measured fat and it appeared thinner than it was.

Measuring the SFT it has to be noted that in some ewes a hyperkeratosis at the sternum and the point of measurement was found. This could have influenced the results. Small variations in the point of measurement as more towards cranial or caudal may have had an impact on the results. SILVA et al. (2006) applied the ultrasound probe on the longitudinal axis of the sternum. With this method they estimated the thickest point of the SFT and had always comparable results. SILVA et al. (2006) found the best correlation between carcass body fat quantity and subcutaneous fat depth over the 13th thoracic vertebra (r = 0.90). Also the study by TEIXEIRA et al. (2008) presented a high correlation between in vivo and carcass determination of fat thickness at the third and fourth sternebrae in goats (r = 0.94, p < 0.01). Furthermore, dairy goats have less subcutaneous fat and most of the body fat is intraperitoneal in the omentum and in perirenal tissues and hard to measure MATTHEWS (2009). Further research should be conducted to evaluate the repeatability of measuring the SFT on different sites.

There was a higher correlation coefficient for RFTl than RFTr determined by the individual investigators. This might have been influenced by the side for measuring. All investigators were right handed, hence it is easier to put the linear array on the correct place on the left side than on the right side.

A high correlation of 0.63 to 0.76 was found between the RFTl and RFTr at all four time points and all investigators. This is similar to DOMECQ et al. (1995) findings of a correlation between ultrasound measurement of right tailhead and left tailhead of 0.65 in dairy cows.
The agreement for BCSlu and BCSst was moderate. A distinct tendency was not recognizable. An influence by the visibility of the body condition in sheared sheep could be one reason for the higher correlation coefficients. Furthermore, I2 was a veterinarian with the most experience in body condition scoring in cattle compared with the other investigators. According to EDMONSON et al. (1989), body condition scoring in cattle is more a visual evaluation than palpating the lumbar region as it is in sheep.

In summary, it can be assumed that the investigator needs more experience and training than the investigators had in the present study to achieve a high repeatability result. The time of introduction was only approximately 15-20 minutes. The investigators were trained with pictures, graphics and with one sheep as an example.

In the study from KLEIBÖHMER et al. (1998) the investigators had a one-day training with repeated evaluations of cows. Prior to this one-day training they had an one-hour instruction about body condition scoring in dairy cows. After this training they had 6 weeks to apply what they had learned using their own cattle. The results of those trained investigators were compared with a gold standard, achieved from the results of two veterinarians that were experienced in body condition scoring in dairy cows. KLEIBÖHMER et al. (1998) reported a good accordance of 84%. With regard to these findings, in further studies training systems and introduction how to evaluate the body fat thickness and BCS in sheep should be improved.

The results could be also improved by splitting the scale of BCS in half or even quarter points. Variations between two BSC points could be assessed more exactly. Comparing all investigators, the correlation coefficients for BCSlu and BCSst in unshorn ewes were as high as in sheared sheep. BCSst had lower correlation coefficient in unshorn than in sheared sheep. Due to the good results of the investigators in measuring the BCSlu it can supposed that measuring BCSlu is more feasible than BCSst, independent if the sheep are unshorn or sheared. EDMONSON et al. (1989) investigated various body locations in dairy cows for potential measuring points of subcutaneous fat. These locations with a small assessor variance were interpreted as reliable areas to score cows.
The results from WOLF (2011) showed similar results, compared to our study, particularly a higher correlation in BCSlu (0.69 to 0.84) than in BCSst (0.62 to 0.75). In contrast to our good results in BCSlu, CALAVAS et al. (1998) reported a poor inter observer repeatability using lumbar palpation for BCS. However, they had very good results of the intra observer repeatability ranging from 52.1 % to 100%. The correlation for the intra observer repeatability in measuring the fat thickness in sheared ewes was high. In contrast, the agreement of body condition score lumbar and sternal was poor. The correlation between the fat thickness measurements was high, especially in sheared ewes. The agreement of the body condition score determined by different investigator for BCS was great for BCSlu in sheared ewes. Furthermore, the results for all measurement methods were better in sheared sheep than in unshorn sheep. The results were not satisfying, depending on the single investigators, but after evaluating the average of six measuring data the Spearman's Pearson correlation and kappa coefficients were very acceptable.
6 Summary

The assessment of the body fat thickness and body condition is important for a good flock management and prevention of diseases.

The study was conducted to evaluate the results of the fat thickness measurements and BCS determination in sheep within an investigator (intra observer repeatability) and between different investigators (inter observer repeatability). A further objective was to evaluate if there is a difference in determining the RFT and the BCS between unshorn and sheared sheep.

Six investigators with different experience in rump fat thickness measuring and body condition scoring were part of this study. The parameter rump fat thickness right, rump fat thickness left, sternal fat thickness, body condition score lumbar and body condition score sternal were obtained from 65 sheep. The parameter of the fat thickness was raised with a ultrasonic probe, body condition score was raised through palpation. The measurements were carried out in unshorn and sheared sheep.

The results showed that there is a higher correlation coefficient for rump fat thickness left than rump fat thickness right. A low correlation coefficient for measuring the sternal fat thickness points out that this measuring method is not feasible to score ewes.

The reproducibility for measuring BCS lumbal is greater than measuring BCS sternal. Consequently the measuring system for BCS sternal can not be recommended. Furthermore the results from the measurement methods listed above are better in sheared sheep than in unshorn sheep.

Based on the results the assessment of the body fat thickness and body condition should be performed lumbal.
7 Zusammenfassung

Die Rückenfettdicke sowie Körperkondition beim Schaf sind wichtige Parameter, um den Ernährungs- und Gesundheitszustand eines Schafs zu beurteilen.

Die Studie wurde durchgeführt, um die Wiederholbarkeit der Messungen von Fettdicke und Body Condition Scores (BCS) einzelner Beurteilern (inter observer repeatability) und innerhalb eines Untersuchers (intra observer repeatability) zu evaluieren. Zudem sollte gezeigt werden, ob sich das Vorhandensein des Wollkleides auf die Messergebnisse auswirkte.


Zusätzlich geht aus dieser Studie hervor dass alle Messarten bei geschorenen Schafen eine höhere Reproduzierbarkeit aufwiesen als bei Tieren mit einem Wollkleid.

Aufgrund der vorliegenden Ergebnisse sollte die Überprüfung der Körperkondition von Schafen, mittels Ultraschall oder palpatorisch lumbal durchgeführt werden.
8 References


RAOOF, S. (2011): The effect of breed and the body condition score in economic traits of sheep. Animal Recourse Department, Agriculture College, Salahaddin University - Erbil, 125-129.


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