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The merit of condition score and fat score as alternatives to liveweight for managing the nutrition of ewes

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Abstract. The liveweight profile of Merino ewes is related to the production and profitability of the sheep enterprise, but few producers measure liveweight to manage the nutrition of Merino ewes. In this paper we examine the relationship between changes in liveweight and condition score using data from the Lifetimewool project and compare condition score and fat score as alternative monitoring tools. Analyses of liveweight and condition score data from 15 flocks of Merino ewes representing a range of different genotypes and environments showed that the relationship between change in liveweight and condition score was on average 9.2 kg per unit change in condition score or 0.19 times the standard reference weight of the flock. In two experiments experienced operators were used to estimate the condition score and fat score in over 200 ewes and accredited ultrasound scanners measured the eye muscle and fat depth at the C site in the same ewes. All assessments were repeated several times in random order. Within 24 h of the assessments the sheep were slaughtered at local abattoirs where the tissue depth at the GR site was measured on the hot carcasses. Both condition score and fat score were highly repeatable though subject to operator bias. They were related to each other and to the objective measures of fat and eye muscle depth at the C site. However, 95% of sheep below condition score 2.5 had a tissue depth (muscle and fat) at the GR site $\leq$3 mm, by definition equal to fat score 1. As the condition score of ewes on commercial properties often fluctuates between scores 2 and 3, and small changes in condition score within this range can have large effects on welfare and profit, we conclude that condition score is the most appropriate alternative to liveweight for managing the nutritional profile of ewes.

Introduction

Liveweight profile of Merino ewes is related to production of the ewe (Ferguson *et al*. 2011) and her progeny (Oldham *et al*. 2011; Thompson *et al*. 2011*a*, 2011*b*) and the profitability of the sheep enterprise (Young *et al*. 2011). Surveys show that few farmers routinely weigh ewes to manage their nutrition as they believe this practice has little value, is time consuming and/or expensive (Jones *et al*. 2011). In addition, measurement of maternal liveweight must be corrected for gut fill, wool growth, conceptus and moisture (CSIRO 2007). Hence, in framing nutritional guidelines, it is essential to have a simple, quick and cheap alternative method to liveweight that is precise (repeatable) and accurate (minimal bias) and can be readily adopted for managing the nutrition of ewes (Curnow *et al*. 2011).

Condition score was developed in Australia (Jefferies 1961) and has since been accepted and used internationally to estimate the 'energy status' or 'nutritional wellbeing' of adult ewes (Russel *et al*. 1969; Delfa *et al*. 1989; Teixeira *et al*. 1989; Caldeira and Vaz Portugal 1991; Oregui *et al*. 1991; Sanson *et al*. 1993; Frutos *et al*. 1997; Caldeira *et al*. 2007; CSIRO 2007). These studies almost uniformly conclude that condition score is preferred over liveweight for this purpose. The Nutrient Requirements of Domesticated Ruminants (CSIRO 2007) suggest 0.15 times standard reference weight as a prediction of the change in liveweight per unit change in condition score, but this relationship is based on few animals. Condition score uses manual palpation of tissue cover (muscle and fat) over the backbone and the short ribs (loin) immediately behind the last long ribs. Importantly, assessors also integrate the shape/fullness of the eye muscle between the backbone and ends of the short ribs with their assessment of tissue cover to allocate a score between 1 (very thin) and 5 (very fat) (Jefferies 1961; Russel *et al*. 1969). Delfa *et al*. (1989) dissected the lumbar joint from ewes in condition scores between 1.5 and 4.5 into muscle, bone, subcutaneous and intramuscular fat. They concluded that eye muscle depth and fat thickness over the eye muscle were both highly correlated with body condition score further confirming the assertion of Jefferies (1961) and Russel *et al*. (1969) that both were equally important in establishing condition score. The condition score in flocks of commercial ewes tends to be normally

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distributed with a mean between 2 and 3 and a range of 1.5–4.5 (Latxa ewes, Oregui *et al*. 1991; Merino ewes, Kelly 1992).

The depth of tissue (fat and muscle) 110 mm from the backbone over the last long rib (GR site and GR tissue depth) has been used to help estimate the lean meat yield of prime lamb carcasses in New Zealand since the early 1970s (Kirton and Johnson 1977; Kirton *et al*. 1978). Subsequently, the concept of fat scoring live lambs to predict GR tissue depth was developed and used with liveweight to market young sheep for meat (Kirton *et al*. 1991; Hegarty *et al*. 2006). Initially, fat score assessors 'felt lambs by hand mainly over the backbone and tail stump' (Kirton *et al*. 1991) and were as accurate as ultrasonic machines, which measure fat over the eye muscle (Bass *et al*. 1982; as cited in Kirton *et al*. 1991). However, Kirton *et al*. (1991) reported that while the 'best drafters were able to rank lambs moderately well', 'all drafters underestimated GR values' but more importantly consistently 'overestimated lean carcasses and underestimated fatter carcasses'. In Australia a subjective fat scoring system, using a 1–5 scale was first proposed by Moxham and Brownlie (1976) and has evolved into a system where the fingers of the assessor are specifically run over the skin of the sheep at the GR site and the feel of the ribs is used to estimated GR tissue depth (O'Halloran *et al*. 1986; White and Holst 2006). Importantly, the accuracy of fat score can be verified by comparing estimated values to measured tissue depth at the GR site on carcasses, with each whole unit (1–5) relating to 5-mm ranges in tissue depth at the GR site (O'Halloran *et al*. 1986).

More recently fat scoring has also been used to manage the 'nutritional wellbeing' or 'reproductive fitness' of adult ewes (Shands *et al*. 2009) and these workers suggested that fat score is more discriminating than condition score among leaner animals.

In this paper we tested the hypothesis that the relationship between liveweight and condition score used in the Nutrient Requirements of Domesticated Ruminants (CSIRO 2007) is valid using large numbers of ewes of differing Merino genotypes. In addition we compared condition score and fat score as alternatives to liveweight for managing the nutrition of ewes.

Materials and methods

All procedures reported in this paper were conducted according to the guidelines of the Australian Code of Practice for the Use of Animals for Scientific Purposes and received approval from the various State Department Animal Ethics Committees.

Relationship between change in liveweight and change in condition score

The relationship between change in liveweight and change in condition score was explored using data from Lifetimewool experiments at multiple sites across Australia. Ferguson *et al*. (2011) and Behrendt *et al*. (2011) describe the design of the plot- (2 sites × 3 years) and paddock-scale (15 sites) experiments, respectively. In brief, the plot-scale experiments involved up to 1500 Merino ewes at two sites in each of 3 years. The ewes were managed to achieve condition score 2 or 3 at Day ~100 of pregnancy and then grazed on pastures managed to target feed on offer between 800 and 3000 kg DM/ha during late pregnancy and lactation. The paddock-scale experiments involved randomly splitting a flock of up to 1000 Merino ewes at about Day 50 of pregnancy into flocks of high and low nutrition. The two flocks of ewes were then differentially managed with the aim of achieving a difference between the flocks of 1 condition score at about Day 140 of pregnancy. The liveweight and condition score of the different flocks was monitored approximately fortnightly based on a new random selection of 100 ewes from each flock.

The change in liveweight and change in condition score of ewes resulting from the different nutritional treatments were recorded for each experiment at each measurement point between Day 100 and Day 140 (typically three measurement points and 600 ewes in each plot- or paddock-scale experiment). The ratio of the average change in liveweight to average change in condition score over all these measurement points was calculated, provided a sufficient change was achieved to estimate the ratio with adequate precision. Only data from 10 paddock-scale experiments which achieved a minimum condition score difference of 0.5 and liveweight difference of 5 kg between high and low nutrition groups met this criterion. Similarly, only data from all ewes in the highest and lowest nutritional treatments from the plot-scale experiments in all years at Hamilton (Vic.) and 2 years at Kendenup (WA) met this criterion.

Experiment 1: alternative methods for estimating nutritional wellbeing

A mix of mature-aged and young (~12 months old) medium-wool Merino ewes from the south-west of Western Australia were selected to represent a range of condition scores. With the aim of generating an even wider range of body condition, half of the flock with a condition score less than or equal to the flock average (condition score 2.5) were grazed on green pasture (~700 kg DM/ha) for 3 weeks, while those with a condition score greater than the flock average grazed 1000 kg DM/ha and were provided *ad libitum* access to finisher pellets (metabolisable energy 11.5 MJ/kg DM, 16.5% crude protein) over the same period. The condition score (Jefferies 1961; Russel *et al*. 1969) and fat score (Shands *et al*. 2009) were then recorded for 93 sheep and real-time ultrasound was used to measure the fat depth at the C site and eye muscle depth at the C site (Luff 2005). Both condition score and fat score were assessed by four experienced operators and the fat and eye muscle depth at the C site was measured by two accredited ultrasound scanners and each measure was repeated three times in a random order. The condition score operators assessed in either half or quarter scores. Commercially, fat score is normally measured in scores that relate linearly to 5-mm increments of estimated tissue depth at the GR site; however, in this experiment the fat score operators assessed in mm of estimated tissue depth at the GR site. Approximately 24 h after the above measurements, the sheep were slaughtered at an abattoir where the tissue depth at the GR site was measured on the hot carcasses by two experienced operators using standard GR knives (Shands *et al*. 2009).

Experiment 2: alternative methods for estimating nutritional wellbeing

The experiment was repeated in New South Wales with 50 fine-wool Merino, 44 medium-wool Merino and 48 first-cross Border Leicester × Merino mature-aged ewes selected to represent a range of fat scores. For 6 weeks before slaughter the medium-wool and first-cross groups were split into two groups (fat score 1–3 and 4–5) and fed a maintenance ration. The fine-wool group arrived 4 weeks before slaughter and were between fat score 1 and 3. The measurements from Experiment 1 were again assessed by the same number of operators and in the same way, this time twice by each of the experienced operators, with the two ultrasound operators, two condition score operators, one fat score operator and one GR knife operator common to both experiments.

Statistical analyses

To ensure consistency and to provide more accurate estimates, the calculation of the difference in liveweight and corresponding change in condition score was based on the average of estimates taken between Day 100 and about Day 140 of pregnancy. The standard reference weight was calculated for the ewes in each of the 15 experiments reported in Table 1 as the fitted conceptus and fleece-free liveweight at condition score 3 from a linear regression of liveweight and condition score measurements ($n \sim 600$) taken between Days 0 and 100 of pregnancy. The ratio relative to a standard reference weight was compared with the published figure (CSIRO 2007) using a *t*-test.

For the two experiments examining condition score and fat score, repeatability was calculated as the average absolute difference between assessments on the same sheep by the same operator. Bias was examined by fitting a smoothing spline through the average operator scores when regressed against measured tissue depth at the GR site for fat score or eye muscle depth at the C site for condition score using GENSTAT (Payne 2009). Other relationships between the different scores and measures were done using linear or non-linear regression models as appropriate.

Results

Relationship between liveweight and condition score

The relationship between change in liveweight and change in condition score was calculated from the Lifetimewool plot- and paddock-scale experiments (Table 1). The average change in liveweight per unit change in condition score was 9.2 ± 0.5 (mean ± s.e.m.) with a range of 6.3 and 11.3 between experiments. The average ratio was 0.19 ± 0.01 (mean ± s.e.m.) times the standard reference weight with a range of 0.11–0.26. There was little correlation between the ratios of liveweight to condition score and the standard reference weight of the animals. The average standard reference weight of the ewes between experiments was 48 ± 1.8 (mean ± s.e.m.) with a range of 38–60 kg.

Repeatability of assessments of carcass characteristics

There was high repeatability for all operators assessing condition score or fat score (Table 2). The difference between repeat assessments on the same sheep for the most repeatable condition score operator CS_6 was ≤0.25 of a condition score 98% of the time. Likewise the most repeatable fat score operator FS_5 in repeat assessments on the same sheep differed by <3 mm assessed GR tissue depth 95% of the time. The estimate of repeatability omitted the low-fed group in Experiment 1 because these sheep only ranged from 1 to 3 mm in measured tissue depth at the GR site and thus were inappropriate for measuring repeatability.

There was also good agreement between operators for the objective measures of eye muscle and fat depth at the C site and tissue depth at the GR site. The average absolute difference between the assessment (averaged over the two replicates) by different operators on the same sheep was 3.7 mm (17%) for eye

Table 1. Standard reference weight (SRW; kg), difference in liveweight (LW; kg) and condition score (CS) in late pregnancy between the highest and lowest nutritional treatments from the plot-scale experiments and the high and low groups at paddock-scale experimental sites, and the ratio between changes in LW per unit change in CS and its relationship to SRW for each experiment

Typically 600 ewes contributed to each ratio for each experiment. Standard errors are given in parentheses

Experiment (site, year)	SRW	Treatment differences LW	Treatment differences CS	Ratio kg LW: 1 CS	Ratio % SRW
Plot scale					
Hamilton Vic., 2001	47	7.8	0.8	10.3	0.22 (0.02)
Hamilton Vic., 2002	43	10.5	1.1	9.9	0.23 (0.02)
Hamilton Vic., 2003	43	15.9	1.8	8.9	0.21 (0.01)
Kendenup WA, 2001	47	10.2	1.4	7.2	0.16 (0.02)
Kendenup WA, 2003	54	14.3	1.5	9.8	0.18 (0.01)
Paddock scale					
Kingston Vic., 2004	49	7.5	0.7	10.9	0.22 (0.02)
Deniliquin NSW, 2003	48	9.5	1.5	6.4	0.13 (0.01)
Kojonup WA, 2003	57	6.2	1.0	6.3	0.11 (0.01)
Kojonup WA, 2004	54	10.9	1.0	11.3	0.21 (0.01)
Seymour Vic., 2003	40	9.9	0.9	10.4	0.26 (0.03)
Lismore Vic., 2004	42	9.2	0.8	11.1	0.26 (0.02)
Darkan WA, 2003	55	6.5	0.7	8.8	0.16 (0.01)
Penshurst Vic., 2003	42	7.1	0.8	8.4	0.20 (0.02)
Balmoral Vic., 2003	38	6.1	0.9	6.9	0.18 (0.01)
Brookton WA, 2003	60	5.3	0.5	11.3	0.19 (0.02)
Average	48 (1.8)	–	–	9.2 (0.5)	0.19 (0.01)

Table 2. Repeatability of operators as defined by the average difference between condition score (CS) and fat score (FS) assessments on the same sheep by the same operator in Experiments 1 and 2

Experiment 1 (high-fed group n = 43)		Experiment 2 (n = 142)	
Operator	Average difference	Operator	Average difference
CS_1	0.19	CS_1	0.17
CS_2	0.29	CS_2	0.23
CS_3	0.15	CS_5	0.22
CS_4	0.24	CS_6	0.11
FS_1	2.4 mm	FS_1	1.6 mm
FS_2	1.7 mm	FS_5	1.3 mm
FS_3	1.5 mm	FS_6	1.6 mm
FS_4	1.7 mm	FS_7	1.5 mm

muscle depth at the C site, 0.5 mm (17%) for fat depth at the C site and 0.6 mm (8%) for tissue depth at the GR site.

Bias of condition score and fat score

There was considerable bias by the fat score operators when fat score (estimated tissue depth at the GR site) was compared with the measured tissue depth at the GR site (Fig. 1). With the exception of operator FS_1, there was a typical overestimation of ~4 mm for animals with measured tissue depth at the GR site less than 10 mm, and the overestimate varied from 3 to 7 mm at a measured tissue depth at the GR site of 5 mm. In addition, there were differences in bias between operators with an average difference of 5 mm (1 fat score) between the most extreme fat score operators in both experiments, with a greater average bias of 6 mm for sheep with measured tissue depth at the GR site between 6 and 10 mm (fat score 2).

In contrast to fat score, where bias is defined by the difference from measured tissue depth at the GR site, condition score is not defined by measured carcass characteristics. However, because condition score includes estimation of eye muscle fullness, and to capture the range of condition score estimates of operators, we have plotted condition scores against eye muscle depth at the C site in order to estimate bias between operators (Fig. 2). The average difference between the most extreme condition score operators was 0.3 however importantly for the management of nutritional wellbeing the bias is lowest at 0.2 between condition score 2.5 and 3.0.

Relationship between condition score and fat score

The relationship between condition score, averaged across all scores done on each sheep, and measured tissue depth at the GR

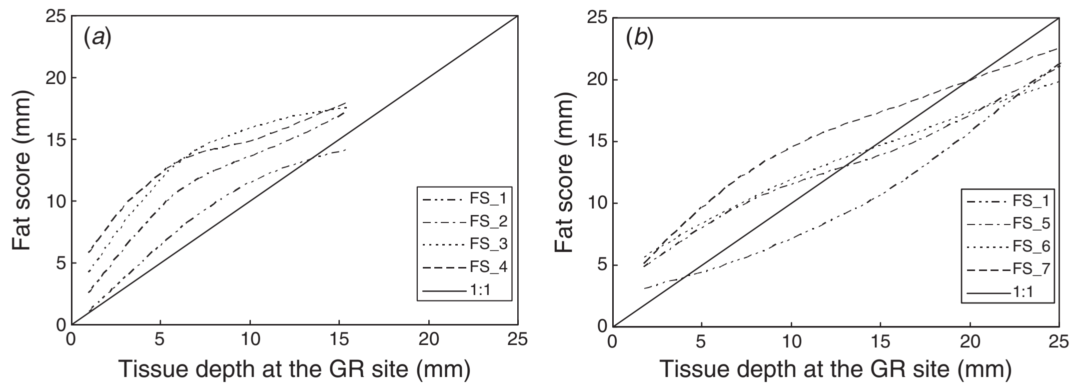

Fig. 1. Fitted curves showing the bias between fat scorers in (*a*) Experiment 1 and (*b*) Experiment 2. The straight line (1:1) indicates perfect agreement with the objective measure of tissue depth at the GR site.

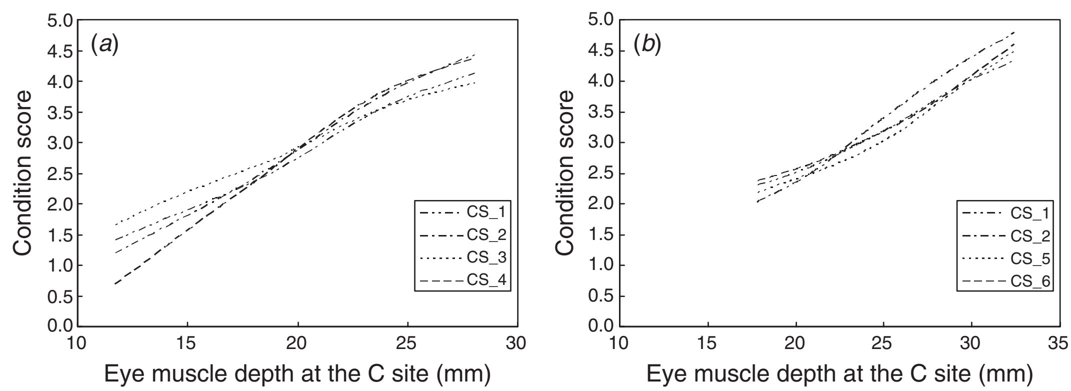

Fig. 2. Fitted curves showing the bias between condition scorers in (*a*) Experiment 1 and (*b*) Experiment 2 for varying levels of eye muscle depth at the C site.

site (unbiased fat score) is presented in Fig. 3. In Experiment 1, the high-fed group showed a linear trend (tissue depth at the GR site = 3.2 + 0.06 × condition score; $R^2 = 0.38$, $P < 0.001$, Fig. 3*a*). However, there was a different relationship for the low-fed group where there was little change in tissue depth at the GR site across the range in condition scores from 1.3 to 2.8. Experiment 2 showed a linear relationship with the same slope (as the high-fed group in Experiment 1) for the medium-wool and first-cross groups but with a lower intercept (tissue depth at the GR site = 2.5 + 0.06 × condition score; $R^2 = 0.75$, $P < 0.001$, Fig. 3*b*) while the leaner sheep from the fine-wool group showed some evidence of a similar departure from this linear trend as seen in Experiment 1.

Eye muscle depth and fat depth at the C site

Both condition score and (unbiased) fat score as defined by measured tissue depth at the C site are highly correlated with measures of muscle and fat at the C site. The relationship between eye muscle depth at the C site and condition score shows a strong linear relationship for both experiments (Fig. 4*a*). Again the slope was the same but the intercept different for Experiment 1 (eye muscle depth at the C site = 6.8 + 4.6 × condition score; $R^2 = 0.92$, $P < 0.001$) compared with Experiment 2 (eye muscle depth at the C site = 9.7 + 4.6 × condition score; $R^2 = 0.74$, $P < 0.001$). The relationship between eye muscle depth at the C site and measured tissue depth at the GR site was curvilinear [eye muscle depth at the C site = 16.3 + 3.6 × $\log_e$(tissue depth at the GR site); $R^2 = 0.80$, $P < 0.001$] and not significantly different between experiments (Fig. 4*b*).

The relationship between fat depth at the C site and condition score (Fig. 5*a*) shows a significantly different exponential relationship for Experiment 1 [fat depth at the C site = 0.29 × exp(0.65 × condition score); $R^2 = 0.88$, $P < 0.001$] compared with Experiment 2 [fat depth at the C site = 0.30 × exp(0.76 × condition score); $R^2 = 0.85$, $P < 0.001$]. The relationship between fat depth at the C site and measured tissue depth at the GR site (Fig. 5*b*) was linear and similar for both experiments (fat depth at the C site = 1.2 + 0.22 × tissue depth at the GR site; $R^2 = 0.87$, $P < 0.001$).

Discussion

The relationship between change in liveweight and condition score of Merino ewes in our data showed a similar range in slopes to that published in the Nutrient Requirements of Domesticated Ruminants (CSIRO 2007). The average ratio was 0.19 times the standard reference weight, which is significantly higher ($P = 0.001$) than the 0.15 published by CSIRO (2007). However, our analysis is based on much larger numbers of animals across a wide range of environments and genotypes and multiple measurement dates. We therefore reject this component of our hypothesis and suggest that 0.19 be adopted as the standard multiplier for calculating the relationship between

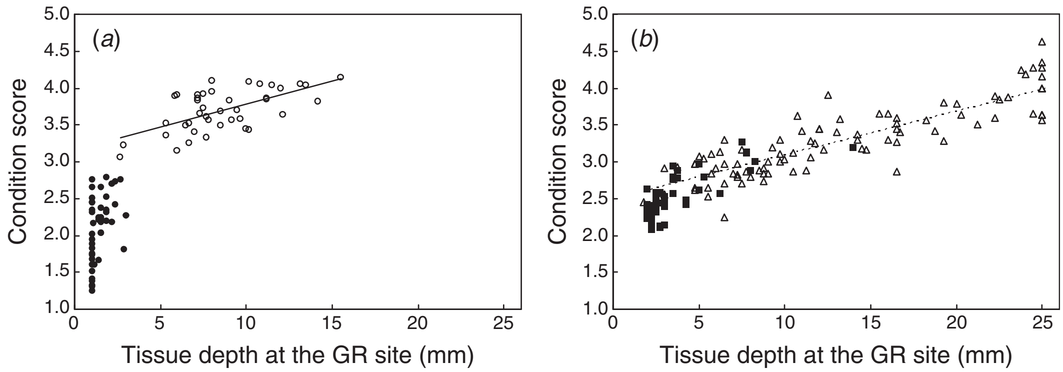

Fig. 3. Relationship between condition score and measured tissue depth at the GR site (unbiased fat score) in (*a*) Experiment 1 and (*b*) Experiment 2. The fitted line in Experiment 1 is based on the high-fed group (open circles), while for Experiment 2 the fitted line is based on the medium-wool and first-cross groups (open triangles). The low-fed (closed circles) and fine-wool (closed squares) groups are also shown.

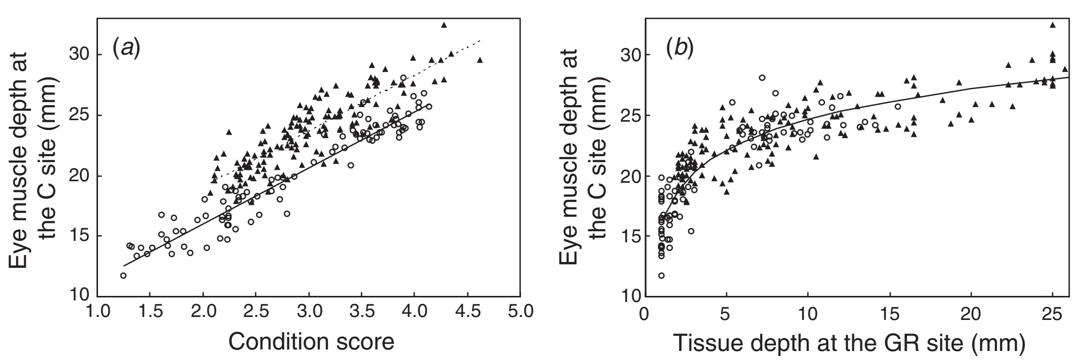

Fig. 4. Relationship between (*a*) condition score and (*b*) tissue depth at the GR site with eye muscle depth at the C site for both Experiments 1 (open circles) and 2 (solid triangles).

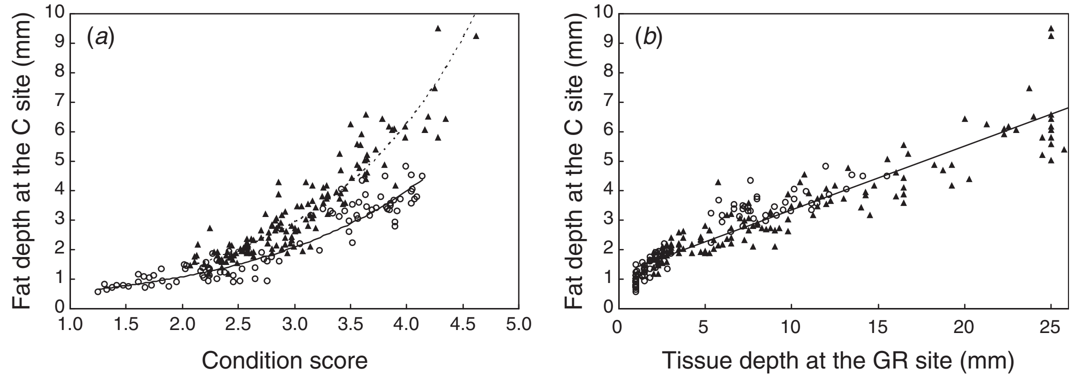

Fig. 5. Relationship between (*a*) condition score and (*b*) tissue depth at the GR site with fat depth at the C site for both Experiments 1 (open circles) and 2 (solid triangles).

standard reference weight and condition score. Ewe and progeny production responses from the Hamilton plot-scale site, reported by Ferguson *et al*. (2011), Oldham *et al*. (2011) and Thompson *et al*. (2011*a*, 2011*b*), were used to establish ewe liveweight profiles to maximise profit and welfare outcomes for different regions and times of lambing (Young *et al*. 2011). As the average ratio of change in liveweight to change in condition score in this data was 10 (Table 1, Hamilton, 2001 and 2002) this conversion factor was used when the guidelines were converted from liveweight to condition score profiles (Curnow *et al*. 2011).

Measured tissue depth at the GR site could not discriminate between sheep when condition score was less than 2.5. Hence if fat score is assessed by an unbiased operator it is a poorer alternative to condition score for managing the nutritional profile of ewes. In Experiments 1 and 2, 95% of sheep below condition score 2.5 had tissue depth at the GR site $\leq$3 mm, by definition equal to fat score 1. In Experiment 1 the measured tissue depth at the GR site for 21 sheep was 1 mm and one operator accurately allocated 1 mm to 18 of these sheep; however, these sheep ranged in eye muscle depth at the C site from 11.7 to 19.8 mm and in condition score from 1.3 to 2.8 demonstrating that these sheep were of different degrees of 'nutritional wellbeing'. This highlights the inability of fat score when done accurately according to measured tissue depth at the GR site to distinguish between lean sheep even if fat score is assessed to the nearest mm. In practice it is often assessed in whole (5 mm) or half (2.5 mm) scores. It is important for producers to be able to discriminate between leaner sheep because the condition score of ewes on commercial properties often fluctuates between scores 2 and 3 and small changes in condition score within this range have considerable impact on animal welfare (Oldham *et al*. 2011) and on whole-farm profitability (Young *et al*. 2011). These results clearly indicate that condition score is able to distinguish between these sheep, while an (unbiased) fat score is not, thus it is a more appropriate alternative to liveweight than is fat score for managing the nutrition of ewes.

Shands *et al*. (2009) using only data from Experiment 2 came to the opposite conclusion that 'fat score is the preferred assessment system to identify subgroups or individual animals that are higher or lower than the mob average as it is more discriminating particularly among leaner animals'. These authors based this on a higher repeatability (although not significant) for fat score compared with condition score in the leaner fine-wool group. The reasoning is that 'the difference in average repeatability was 0.09 in favour of the fat score assessment, which demonstrates the greater ability of the fat score assessors to discriminate between lean animals'. This, however, is a false argument because a measure can be highly repeatable but not able to discriminate well. Fat score for example is highly repeatable but not able to discriminate well for sheep below about condition score 2.5 as these would all typically be assessed fat score 1.0 by an unbiased operator allocating in half scores. Therefore, we cannot agree with the conclusion of Shands *et al*. (2009) that fat score is more discriminating among leaner animals.

Shands *et al*. (2009) also focus on the subjectively assessed fat score rather than measured tissue depth at the GR site. The bias in the subjectively assessed fat score enables the 20 leanest fine-wool animals to be separated into those with fat score = 1 and fat score = 1.5; however, the measured tissue depth at the GR site in these sheep only varied from 2 to 3 mm i.e. they were all fat score = 1. It is understood that some fat score operators when dealing with leaner sheep also assessed away from the GR site which is one possible explanation for the bias and consequent ability to discriminate.

There was considerable bias between fat score operators and it was greater at 6 mm for sheep with measured tissue depth at the GR site between 6 and 10 mm (fat score = 2). By contrast, at the range of condition score 2.5–3.0 typical for a commercial flock, the bias between the most extreme condition score operators in both experiments was lower at 0.2 of a condition score. Repeatability of all operators was high with average differences of ~0.2 of a condition score or 2-mm estimated tissue depth at the GR site between assessments of the same sheep by the same operator. When compared with bias these differences are relatively small, especially for fat score, indicating that bias is the main source of error. This problem of bias needs to be addressed and one option would be the construction of models similar to those that have been successfully used to align many condition score operators across southern Australia (Curnow *et al*. 2011). Kirton *et al*. (1991) came to a similar conclusion when they studied subjective assessment of GR tissue depth in New Zealand. The presence of bias also highlights the importance of training operators to accepted national standards.

For sheep in better condition (above condition score 2.5) both condition score and measured tissue depth at the GR site (unbiased fat score) are able to distinguish between sheep as evidenced for example by their relationships with eye muscle depth and fat depth at the C site. The relationship with eye muscle depth at the C site was linear with condition score compared with curvilinear with tissue depth at the GR site while the reverse was true of the relationships with fat depth at the C site. The strong linear relationship between condition score and eye muscle depth at the C site is consistent with the role of eye muscle in assessing condition score (Jefferies 1961; Russel *et al*. 1969; Delfa *et al*. 1989). Similarly, the strong curvilinear relationship between measured tissue depth at the GR site and eye muscle depth at the C site is consistent with the observed relationship between measured tissue depth at the GR site and condition score in our data. In other words, as sheep recover condition they first replete eye muscle before beginning to lay down fat after they have reached eye muscle depth at the C site of ~20 mm (condition score 2.5). This observation obeys the key rule that muscle growth precedes the deposition of fat as an animal matures or recovers from a period of under nutrition (Dukes 1947).

The relationship between condition score and measured tissue depth at the GR site in both experiments showed that for sheep in good condition a 5-mm increase in tissue depth at the GR site corresponded to an increase of ~0.3 of a condition score. This common slope was encouraging and gives more certainty in relating changes in condition score with changes in measured tissue depth at the GR site (unbiased fat score). However, the condition score at a given tissue depth at the GR site was 0.6 higher in Experiment 1 when calculated using the operators common to both experiments. There were similar differences between experiments in the relationship between condition score and measures of eye muscle depth and fat at the C site. We could not identify a reasonable explanation for these differences.

In conclusion, there is a workable relationship between change in liveweight and change in condition score across a wide range of genotypes and environments. Therefore, given the need to correct liveweight for a range of factors condition score or fat score present as attractive alternatives to liveweight for managing the nutritional profile of ewes. However, as sheep with condition scores below 2.5 are common on farms and condition score is better than fat score at distinguishing between these ewes we conclude that condition score is the most appropriate alternative to liveweight for managing the nutrition of ewes.

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