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Body condition score as a selection tool for Targeted Selective Treatment-based nematode control strategies in Merino ewes

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Abstract:

Sheep nematode control utilising refugia-based strategies have been shown to delay anthelmintic resistance, but the optimal indices to select individuals to be left untreated under extensive sheep grazing conditions are not clear. This experiment tested the hypothesis that high body condition can indicate ability of mature sheep to better cope with worms and therefore remain untreated in a targeted treatment program. Adult Merino ewes from flocks on two private farms located in south-west Western Australia (Farm A, n=271, and Farm B, n=258) were measured for body condition score (BCS), body weight and worm egg counts (WEC) on 4 occasions between May and December (pre-lambing, lamb marking, lamb weaning and post-weaning). Half of the ewes in each flock received anthelmintic treatments to suppress WEC over the experimental period and half remained untreated (unless critical limits were reached). Response to treatment was analysed in terms of BCS change and percentage live weight change. No effect of high or low initial WEC groups was shown for BCS response, and liveweight responses were inconsistent. A relatively greater BCS response to treatment was observed in ewes in low BCS pre-lambing compared to better-conditioned ewes on one farm where nutrition was sub-optimal and worm burdens were high. Sheep in low body condition pre-lambing were more than 3 times more likely to fall into a critically low BCS (<2.0) if left untreated. Recommendations can be made to treat ewes in lower BCS and leave a proportion of the higher body condition sheep untreated in a targeted selective treatment program, to provide a population of non-resistant worms to delay the development of resistance.

Keywords:

Targeted selective treatment
Refugia
Anthelmintic
Nematodes
Sheep

Introduction

Internal parasites remain a major constraint on the health and productivity of sheep (Sutherland and Scott, 2010). *Trichostrongylus spp.* and *Teladorsagia circumcincta* are the predominant gastrointestinal nematodes in southern regions of Australia and have been associated with reduced growth rate or bodyweight, reduced wool growth and increased risk of fly strike associated with diarrhoea and faecal fleece soiling (Sutherland and Scott, 2010). The effectiveness of worm control is increasingly compromised because of widespread and increasing resistance to anthelmintics (Besier, 2012; Kenyon and Jackson, 2012), including in Australia (Playford et al. in press).

On-going investigations into sustainable control strategies have focused on the "refugia" strategy which aims to minimise the development of resistance by ensuring the survival of sufficient nematodes of susceptible genotypes in the total population on a property to dilute resistant individuals surviving anthelmintic treatment (Van Wyk, 2001; Besier and Love, 2003; Kenyon et al. 2009, Leathwick et al., 2009). 'Targeted selective treatment' (TST) is a refugia-based approach by which anthelmintic treatments are restricted to animals judged likely to suffer significant production loss or health effects if not treated, while treatment to others in the group is avoided (Kenyon et al., 2009; Leathwick et al., 2009; Besier, 2012; Kenyon and Jackson 2012). The concept that some individual animals exhibit greater resilience to parasites, seen as fewer signs of ill-health or better production in some individuals, can be exploited by TST strategies to ensure that a proportion of a worm population remains in refugia from anthelmintic exposure (Van Wyk, 2001) with additional benefits such as reductions in the costs of anthelmintics and labour (Besier, 2012).

The TST concept has been successfully utilised for some time through the FAMACHA test for the sustainable control of *Haemonchus contortus* in sheep and goat flocks (Vatta et al., 2001; van Wyk and Bath, 2002). More recent investigations have extended the TST concept for small ruminants to non-haematophagous nematodes (principally *Tel. circumcincta* and *Trichostrongylus spp.*), mostly using animal production indices to indicate which individuals in a flock are likely to benefit from anthelmintic treatment (for example, Hoste et al., 2002; Cabaret et al 2006; Leathwick et al., 2006; Cringoli et al., 2009; Stafford et al. 2009; Besier et al., 2010; Gaba et al., 2010; Greer et al., 2010).

However, a key factor that has delayed utilization of TST for trichostrongylids other than *H. contortus* is the absence of a convenient and accurate method for identifying animals that are likely to suffer compromised health, productivity and welfare if left untreated (van

Wyk et al., 2006; Besier, 2012). The approaches used in the investigations cited were based on repeated measurements of production indices (for example body weight, worm egg count, ocular membrane inspection) in animals under parasite challenge as an indicator of resilience, but these require investment in labour and/or equipment that may limit their application on a large scale (van Burgel et al. 2011). Body condition score (BCS) is a practical and low-technology measure that is accepted as an indicator of general condition and body reserves (van Burgel et al., 2011) and therefore may act as an indicator of resilience to nematode infections.

The need to develop a more practicable basis for individual animal treatment for use in large flocks or where labour is scarce led to the hypothesis that mature sheep of lower BCS would generally suffer greater production loss due to worm infections than would sheep of higher scores, and that BCS may therefore provide a suitable selection basis (Leathwick et al., 2006; Besier et al., 2010). The aims of the experiment were, firstly, to investigate whether mature sheep in poorer body condition suffer proportionately greater production loss due to trichostrongylid infection than those in better condition when BCS is used as an index of the relative need for anthelmintic treatment. Secondly, the experiment investigated which parameter (BCS, bodyweight or faecal worm egg counts) provides the most appropriate indication of a reduced resilience to trichostronglid infection (significant magnitude of response to anthelmintic treatment) in mature sheep.

Materials and methods

The experiment was conducted according to the guidelines of the Australian Code of Practice for the Use of Animals for Scientific Purposes, with approval from the Animal Ethics Committees of the Department of Agriculture and Food Western Australia and Murdoch University (R2329/10).

Experimental sites

The experiment was conducted in 2010 on two commercial farming properties located near Woodanilling (Farm A) and Kojonup (Farm B), approximately 265km and 260km southeast of Perth, Western Australia, respectively. The region has a Mediterranean climate characterised by hot, dry summers and cool, wet winters. The mean annual rainfall for Farm A and Farm B is 460mm/annum and 530 mm/annum respectively, but 2010 was widely considered a drought year and the two farms received only 234mm and 350mm of rainfall respectively.

Experimental design and animal management

Merino ewes were selected at Farm A (n=271, aged 3 years) and Farm B (n=258, aged 4 years). Ewes were individually identified with numbered ear tags. All ewes at Farm B carried single pregnancies, indicated by transabdominal ultrasound scanning. Ewes at Farm A were not pregnancy-scanned so the parity status was not known. The possible effect of unknown ewe parity on response to parasitism at this experimental site is detailed in the discussion. Ewes were stratified on the basis of BCS using a range from one (thin) to five (fat) scale (Thompson and Meyer, 1994), liveweight and worm egg count (WEC) at the pre-lambing assessment. BCS was assessed by a single trained operator. Ewes were categorised to 4 initial (pre-lambing) BCS groups: <2.7, 2.7, 3.0 and >3.0. Within each BCS group, ewes were allocated randomly to two treatment sub-groups (worm-suppressed or non-worm-suppressed) with equivalent numbers in each. The mean pre-lambing liveweight and BCS was 55.0kg (range 39.6kg - 68.2kg) and BCS 2.9 (2.3 - 3.5) at Farm A and 62.0kg (46.2kg - 80.8kg) and BCS 3.0 (2.3 - 3.7) at Farm B. There was no significant difference in WEC between BCS groups or treatment groups at the start of the study for either site. Lambing commenced in June for both properties.

Ewes were grazed as a single group at each site in paddocks with predominantly annual rye-grass (*Lolium* spp.), subterranean clover (*Trifolium subterraneum*) and capeweed (*Arcotheca calendula*). Over the course of the experiment, pasture growth (assessed visually; Ferguson et al. 2011) was poorer at Farm A than Farm B and this necessitated a greater level of supplementary feeding at this site. Supplementary feeding of concentrate grain-based pellets (11.0 MJ/kg DM, 14.5% CP; EasyOne, Milne Feeds, Welshpool, Australia) commenced at Farm A in July 2010 at a rate of 700g/hd/day to ensure the ewes did not fall to unacceptably low weights or body condition.

Measurements

Ewes were weighed, assessed for BCS and faecal sampled on 4 occasions between May and December 2010 that coincided with yarding for routine management operations (Table 1). BCS were measured by palpation of the lumbar vertebrae and associated soft tissue using a scale of one (thin) to five (fat) scale with sub-categories where appropriate (eg. 2.3, 2.5 and 2.7 for scores in between 2 and 3) (Thompson and Meyer, 1994). Faecal samples were collected directly from the rectum of all sheep at each sampling occasion. Faecal worm egg counts (WEC) were performed using a modified McMaster technique whereby 2.0g of faeces were used from each sample and each egg counted represented 50 eggs per gram (epg) of faeces (Hutchinson 2009). The genera of trichostrongylid nematodes present was determined using larval culture and differentiation performed on faecal samples pooled for each BCS and treatment group (Lyndal-Murphy, 1993; Hutchinson 2009).

Anthelmintic treatments

The sheep in the worm-suppressed groups were treated at each visit (ie at 26-90 day intervals) with 1mg/kg liveweight long-acting injectable moxidectin (Cydectin LA™, Virbac, Australia). Sheep in the non-worm suppressed group received no treatment unless BCS fell under 2.0, in which case individual sheep were treated with 0.2mg/kg oral abamectin

(Ovimectin, Norbrook, Australia). Any ewes with BCS <2.0 at any sampling occasion were treated with abamectin and removed from the experiment. All ewes at Farm A were treated with moxidectin at the lamb weaning sampling due to sharp increases in WEC, falling BCS and a high proportion of ewes with BCS <2.0. Monitoring of ewes continued until the post-weaning sampling, but comparison of BCS and weight between the suppressed and non-suppressed groups were not made at post-weaning for Farm A.

Statistical Analysis

Data were analysed using SPSS Statistics version 22.0 (IBM Corporation, Ireland).

Ewes were categorised into WEC and BCS groups corresponding to distribution within each flock and biologically-relevant categories. WEC groups were based on initial (pre-lambing) counts according to the WEC distribution and potential for pathogenic effects within the flock: high (>400epg), mid (151-400epg) and low (0-150epg). Ewes were categorised as BCS <2.0 or ≥2.0 at each sampling occasion as an indication of falling into BCS category (<2.0) associated with increased risk of production loss, mortality and compromised welfare (Curnow et al. 2011).

Liveweight change between sampling occasions was analysed as % change based on % liveweight change relative to starting bodyweight at start of each experimental period (ie. pre-lambing to lamb marking, lamb marking to lamb weaning, lamb weaning to post-weaning; Table 1). At Farm A, all ewes were treated with an anthelmintic at the weaning sampling therefore comparisons between suppressed and non-suppressed ewes were not made for the post-weaning period. Worm egg count data was log transformed for analyses using Log(WEC+25), and backtransformed for discussion of the results.

Univariate general linear models with least square difference post-hoc tests were used to examine differences between condition score groups and treatment groups for bodyweight, BCS and worm egg counts at sampling plus weight change and BCS change between sampling occasions. Odds ratios were used to calculate relative risk for ewes in different starting BCS categories falling below BCS 2.0 after lambing relative to ewes that were BCS ≥3.0 pre-lambing. Regression analysis was conducted using linear regression to examine relationships between BCS and WEC, and similarly with liveweight and WEC. Pre-lambing sample was excluded as sheep were stratified for inclusion in the study such that WEC, liveweight and BCS were not significantly different between groups. Where specified, regression analyses were performed separately for worm suppressed and non-worm suppressed groups.

Results

Worm egg counts and larval differentiations

Ewes in the "non-worm suppressed" groups (ewes not treated with long acting moxidectin and only treated with abamectin if BCS fell below 2.0) had higher WEC at Farm A compared with Farm B (P=0.002) with means over the experimental period of 522 epg and 170 epg respectively (Table 2).

Treatment with long-acting moxidectin maintained low WEC in the worm suppressed groups at both Farm A (25 epg) and Farm B (8 epg) over the observation period (Table 2). The WEC reduction in treated animals was >99% at both sites suggesting that moxidectin was fully effective on both farms at the time of the experiment.

Faecal cultures and larval differentiations indicated the predominant species for the non-worm suppressed groups to be *Trichostrongylus spp.*, *Tel. circumcincta* and *Chabertia ovina*, in the mean proportions across all observation times of 73%, 22%, and 5% (Farm A), and 45%, 52% and 3% (Farm B).

Effect of initial WEC on response to treatment

Ewes in the highest WEC category (>400epg) at the start of a period had no greater response to treatment in terms of BCS change than those in the lowest WEC category at the start of the same period (P>0.100). While differences were observed in liveweight change (%), these results were inconsistent between sampling periods and sites, with instances where lower WEC groups showed a greater treatment response.

At Farm A, over the whole period (pre-lambing to lamb weaning), all worm suppressed WEC groups (low, mid and high) had a significant response to treatment in percentage liveweight change (P=0.002, P=0.001 and P=0.004 respectively), losing less weight than non-worm suppressed sheep. However, while from pre-lambing to lamb marking the sheep in the high (>400epg) initial WEC groups had a significantly greater response to treatment (P=0.028) than lower WEC categories, from lamb marking to lamb weaning the reverse applied with low (0-150epg) and mid (>150-400epg) initial WEC groups showing a significant response to treatment (P=0.029 and P=0.028 respectively).

Similarly, at Farm B, over the whole period all initial WEC groups (low, mid and high) showed a positive response to treatment (P<0.001, P=0.017 and P=0.047 respectively) in percentage liveweight change, but with differences between periods. Between pre-lambing and lamb marking both the low and the high initial WEC groups had a significant response to treatment (P=0.015 and P=0.044 respectively), but there were no significant responses from lamb marking to lamb weaning, or lamb weaning to post-lamb weaning.

Body condition score response to treatment

Over the whole experimental period the non-worm suppressed ewes lost more condition than the worm suppressed ewes in the two lowest BCS groups; ≤2.5 (*P*<0.001) and 2.7 (*P*=0.044) at Farm A and similarly at Farm B; ≤2.5 (*P*=0.001) and 2.7 (*P*=0.014; Table 3).

Between pre-lambing and lamb marking, a response to anthelmintic treatment was observed only in the lowest BCS group (≤2.5) and only at Farm A where non-worm suppressed sheep lost more condition than worm suppressed sheep (*P*=0.012; Table 3). Similarly, between lamb marking and weaning a response to treatment was also observed only in the lowest BCS groups at Farm A, specifically BCS ≤2.5 (*P*=0.013) and 2.7 (*P*=0.015) with worm suppressed sheep gaining more condition than non-worm suppressed sheep (Table 3).

A response to treatment was observed in the lowest BCS group (≤2.5) between weaning and post weaning at Farm B where non-worm suppressed ewes lost more BCS than worm suppressed ewes (p=0.049; Table 3). The response to treatment could not be measured for ewes at Farm A for this period because all ewes were treated at weaning.

Live weight response to treatment

Liveweight responses to treatment were inconsistent between the two sites. Over the whole experimental period the non-worm suppressed ewes lost more weight than the worm suppressed ewes in BCS 3.0 group (P=0.001) and BCS >3.0 group (P=0.040) at Farm A, and at Farm B in BCS ≤2.5 group (P=0.011), BCS 2.7 group (P=0.008) and BCS 3.0 group (P=0.002).

Between pre-lambing and marking, non-worm suppressed ewes lost 4.7% more weight than the worm suppressed ewes in BCS 3.0 group at Farm A (*P*<0.001) and 5.4% more weight in the BCS 2.7 group at Farm B (P=0.009; Table 4).

Between lamb marking and weaning, responses to anthelmintic treatment were observed in BCS 2.7 group (*P*=0.030) and BCS >3.0 group (*P*=0.026) at Farm A and BCS 3.0 group at Farm B (*P*=0.019).

A response to treatment was observed between weaning and post-weaning at Farm B only in BCS ≤2.5 group where non-worm suppressed ewes lost 2.6% more weight than worm suppressed ewes (*P*=0.049; Table 4).

Effects of overall worm egg counts on body condition score and live weight in non-worm suppressed ewes

At Farm A there were negative relationships between WEC and BCS ($R^2 = 0.24$, $p<0.001$) and also between WEC and liveweight ($R^2 = 0.21$, $p<0.001$) in non-worm suppressed ewes. These represented a decline in WEC of 812 epg and 795 epg respectively over the range of BCS and live weights observed over the sampling periods subsequent to lambing. Similarly at Farm B, weak negative relationships were observed between WEC and BCS ($R^2 = 0.02$, $p<0.003$) and between WEC and liveweight ($R^2 = 0.02$, $p<0.005$) representing a decline in WEC from 102 epg and 94 epg respectively over the range of BCS and live weights observed over the sampling periods subsequent to lambing.

Effect of pre-lambing body condition score on subsequent body condition and live weight change in non-worm suppressed ewes

In general, ewes that were in poorer body condition pre-lambing tended to lose less or gain more body condition than ewes that were in better body condition pre-lambing, regardless of treatment (Table 3).

A relationship between initial BCS and subsequent BCS change from pre-lambing to lamb marking was observed at Farm A (*P*<0.001) whereby BCS ≤2.5 lost less BCS than all other groups and BCS ≥3.0 ewes lost more condition than all other groups (Table 3). A similar trend was observed at Farm B where there was no general difference in BCS change from pre-lambing to lamb marking between groups, but BCS >3.0 ewes lost more condition than all other groups.

Similarly, a relationship between pre-lambing BCS and subsequent BCS change from lamb marking to lamb weaning was observed at Farm B (*P*<0.018) whereby BCS ≤2.5 gained more BCS than all other groups and BCS ≥3.0 ewes lost more condition than all other groups (Figure 1b). There was no relationship between pre-lambing BCS and BCS change between lamb marking and lamb weaning observed at Farm A.

Between lamb weaning and post-weaning at Farm A, ewes that were BCS ≤2.5 pre-lambing gained more condition than >3.0 ewes (*P*=0.036).There was no effect of pre-lambing BCS on BCS change between lamb weaning and post-weaning at Farm B.

There was no effect of pre-lambing BCS on subsequent liveweight change (%LWC) from pre-lambing to lamb marking, lamb marking to lamb weaning or lamb weaning to post weaning at either Farm A or Farm B.

Risk of ewes falling below critical condition level

The risk of sheep falling below BCS 2.0 during the experiment was increased for ewes in poorer BCS before lambing, despite losing less BCS than better condition score ewes (Table 5). At Farm A, all ewes regardless of treatment that were BCS<2.5 pre-lambing subsequently had a BCS <2.0 on at least one occasion (Table 5).

The increase in risk associated with lower initial BCS was evident for non-worm suppressed ewes but not for worm suppressed sheep at Farm B (Table 5). In contrast, the risk of falling below BCS 2.0 was increased for ewes BCS<3.0 pre-lambing in both worm suppressed and non-worm suppressed groups at Farm A (Table 5).

Discussion

This experiment compared the effect of naturally acquired trichostongylid infections (predominantly *Trichostrongylus spp.* and *Tel. circumcincta*) on the degree of weight change and body condition change of mature Merino ewes of different body condition status prior to lambing. The most important finding was that ewes in poorer starting body condition showed a greater relative BCS response to anthelmintic treatment (ie BCS difference between worm suppressed and non-worm suppressed groups) than those of higher starting BCS (Table 3), suggesting that BCS offers promise as a selection index for identifying Merino ewes most likely to benefit from anthelmintic treatment in TST-based nematode control programs. This response was observed consistently at Farm A which was characterised by poorer nutritional conditions (pasture availability), lower mean flock body condition and higher mean flock WEC in non-worm suppressed ewes compared with the Farm B site. However, the differential effect of anthelmintic treatment in low BCS sheep was not consistently observed when body weight was used as the response index.

Although factors other than trichostrongylid parasites may have affected changes in liveweight and condition between BCS groups such as differences in feed intake and partitioning of nutrients into the conceptus (pre-lambing), lactation (post-lambing) and body reserves, these are unlikely to explain the results as the sheep were selected for BCS groups after stratification for WEC and weight, then random allocation to treatment groups. Further supporting the notion that BCS can be used to identify sheep more likely to benefit from treatment, the untreated ewes in poorer body condition (BCS <3.0) pre-lambing at both experimental sites were more than 3 times more likely to fall below BCS 2.0 after lambing and ewes in very poor condition (BCS <2.0) more than 230 times more likely to have BCS <2.0 after lambing, which indicates that they are likely to be at increased risk of production losses, reduced milk production (affecting growth of offspring) and increased ewe mortalities

(Ferguson et al., 2011). The weight and body condition response of breeding ewes to anthelmintic treatment are largely moderated by factors including pre-lambing BCS, larval challenge, genetics and the supply of dietary nutrients (Kahn 2003).

Parameters including BCS, body weight, weight change and WEC were recorded in this experiment. Of these, BCS showed the greatest promise as a selection index under commercial farming conditions for determining which animals should be left untreated in order to provide a source of refugia without compromising flock productivity. BCS assessment is fast to perform and apart from a trained operator, does not require specialised equipment. Other studies have demonstrated that BCS measurement can be used to identify ewes at risk of reduced productivity and increased mortality (van Burgel et al. 2011). Furthermore, BCS can also be used to identify where nutritional intervention for ewes is likely to have lifetime impacts on the productivity of the offspring (Oldham et al. 2011).

In contrast, weight or weight change requires specialised equipment (scales). Modern electronic scales and drafting equipment can speed up the process, but the equipment is costly and requires some expertise to operate and maintain. There are also important limitations to the use of weight change to assess productivity and effects of parasitism on ewes. Live weight and weight change may not accurately reflect change or difference in body reserves because liveweight measurement does not differentiate body reserves (muscle and fat) from weight of viscera, gastrointestinal content, wool and conceptus tissue (van Burgel et al. 2011).

Sheep with high WECs at the commencement of observations did not show a greater BCS response to treatment than those with low WECs, and the response in terms of liveweight change was inconsistent. Correlations between WEC and bodyweight were noted, but while statistically significant at both experimental sites, the correlations were weak (low

R^2), suggesting that WEC explained only 1-20% of the variation in weight and BCS observed in the flock. This finding was consistent with previous studies (Larsen and Anderson, 2009) in which mean WECs from ewes in high and low body weight groups were not significantly different. In addition, the practicality of implementation of TST strategies is a significant factor in large flocks (Besier 2012), and it would rarely be feasible to conduct individual worm egg counts prior to a treatment decision.

Untreated sheep in higher starting body condition groups (3.0 and >3.0) pre-lambing tended to lose more and gain less condition over the measurement periods over the two experimental sites than ewes in lower starting BCS groups (≤2.5), but no differences in liveweight change were observed. Some subsequent responses to treatment in terms of liveweight change were observed in ewes in better pre-lambing body condition (BCS ≥3.0), although these responses were inconsistent between the 2 sites and 3 measurement periods. While a positive association between liveweight change and body condition change has been reported (CSIRO 2007; van Burgel et al., 2011), this association was not apparent in these experiments, presumably due to changes in weight of the conceptus, fleece and gut contents between sampling occasions. The ewes at Farm B were diagnosed as pregnant with single foetus using transabdominal ultrasound. Pregnancy diagnosis was not conducted at Farm A, so individual ewe weights at this site could have included ewes carrying from zero to three conceptus at pre-lambing measurement. As anthelmintic treatments and the measurement of weight and condition took approximately 4 hours at each visit, the variable time spent off feed and water for individuals is likely to have affected gastrointestinal content weights, whereas the use of BCS to assess body reserves is not affected by these factors.

Apart from effects on the breeding ewe, low BCS in pregnancy also has important implications for the progeny, including reduced lamb birth weight and survival, reduced lamb growth rate to weaning, reduced fleece weight and increased fibre diameter over lifetime of the progeny (Oldham et al., 2011; Thompson et al., 2011). As well as the association with important health, production and welfare parameters for ewes and offspring, BCS offers advantages over liveweight as a measure of body reserves because the proportion of viscera to carcass may increase in sheep with helminth (Liu et al., 2005; Jacobson et al., 2009) and gastrointestinal protozoan (Sweeny et al., 2011) infections, thus the measurement of liveweight is therefore likely to underestimate the effect of infection on carcass productivity and body reserves.

This experiment had a number of limitations. Firstly, the condition scores of the ewes in the two flocks in this experiment covered the critical range regarding reproduction and general health (BCS 2-3.5), but as ewes with BCS <2.0 were treated and removed from the experiment due to unacceptable risks to welfare, the effects in ewes with very low BCS could not be determined. In addition, ewes were grazing pasture and nutrition was not standardised between the two sites. Pasture availability was lower at Farm A compared with Farm B and ewes at Farm A required supplementation with a commercial pelleted feed to prevent BCS in ewes from falling to a level were health, productivity and welfare was likely to be compromised. Differences in nutrition between the two experimental sites may have contributed to differences in the effects of parasitism and also response to treatment. Nonetheless, the pasture availability and level of supplementary feeding on both properties was typical for commercial sheep farms in this region in years with below average rainfall and subsequent reduced pasture growth. Secondly, untreated and treated ewes were grazing together, thus treated ewes were subjected to larval challenge originating from untreated ewes. This probably resulted in underestimation of the response to deworming relative to scenarios where all animals are treated and grazing pasture with low larval contamination. Production responses to larval challenge are likely to be impacted by a number of factors including the degree of larval challenge and the host (ewe) immune response to larvae which in turn is impacted by host genetic variation with evidence that ewes with increased genetic resistance to trichostrongylids may experience greater production losses in response to larval challenge. Genetic variation in trichostrongylid immunity in sheep can be estimated with estimated breeding values and Australian Sheep Breeding Values based on WEC (Karlsson and Greeff 2006), but these were not known for ewes at either site in this experiment. Notwithstanding this, the WEC (and likely associated level of pasture contamination observed) were typical for lambing ewe flocks in this region and other studies have shown minimal effect on production in sheep treated with long acting anthelmintics (sustained-release anthelmintic capsules) whilst grazing contaminated pasture (Kelly et al 2012). Thirdly, there may be an observational bias of the BCS recordings, as we did only a single estimation of BCS at each time, but a single highly-experienced observer performed all BCS observations and sheep were presented in random order.

The results of this experiment suggest that not treating ewes in good pre-lambing BCS is potentially a viable tactic to allow worm burdens to remain in some animals in a flock, as this did not significantly reduce subsequent body condition change of ewes during lactation and in the period immediately post weaning. In this experiment, any responses to treatment in terms of liveweight that were subsequently observed in the ewes in better body condition pre-lambing was not reflected in demonstrable changes in body condition and reserves. Previous experiments in Western Australia have demonstrated that neither sheep production nor reproductive results suffered when targeted selective treatment using a BCS index was applied in ewes, with the proportion left untreated based on an assessment of initial flock parasitism (Besier et al. 2010).

Conclusion

This experiment supported the hypothesis that ewes in poorer body condition prior to lambing are more likely to benefit from anthelmintic treatment than their better-conditioned counterparts. Untreated ewes in better body condition pre-lambing tended to subsequently lose more or gain less body condition when exposed to the same level of challenge, although this was not reflected in differences in liveweight changes in these ewes, nor were improvements in body condition change or consistent weight responses to treatment observed. Better conditioned ewes were also less likely to fall to a critically low body condition level where the risk of compromised productivity and welfare is increased. The findings from these flocks therefore suggest that under a TST strategy, pre-lambing treatments should be given to ewes in poorest BCS, while untreated ewes in better body condition (BCS >3.0) may be used as a source of refugia for worms of lower anthelmintic resistance status, with no effect on subsequent weight or BCS change relative to untreated ewes with similar pre-lambing BCS.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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Table 1

Sampling schedule for ewes at the Farm A and Farm B properties.

		Farm A			Farm B		
Sampling Occasion	Timing relative to start of lambing	Study day	Date	Ewes sampled (n)	Study day	Date	Ewes sampled (n)
Pre-lambing	-3 weeks	0	12 May 2010	271	0	13 May 2010	258
Lamb marking	7-10 weeks	72	23 July 2010	245	90	11 Aug 2010	251
Lamb weaning	14-19 weeks	120	9 Sep 2010	114	152	12 Oct 2010	242
Post-weaning	28 weeks	146	5 Oct 2010	84	216	15 Dec 2010	255

Table 2

Worm egg counts at different sites and times for different treatment groups

	Farm A				**Farm B**			
	Non-worm suppressed		**Worm suppressed**		**Non-worm suppressed**		**Worm suppressed**	
	Mean ± SE	*Range (n)*	*Mean ± SE*	*Range (n)*	*Mean ± SE*	*Range (n)*	*Mean ± SE*	*Range (n)*
Pre-lambing	399 ± 26^{A}	0-1250 (134)	396 ± 26*	0-1350 (137)	188 ± 15	0-800 (128)	192 ± 15*	0-900 (129)
Lamb Marking	822 ± 82^{B}	0-4750 (134)	33 ± 20	0-2300 (137)	185 ± 25	0-1900 (123)	8 ± 3	0-400 (128)
Lamb Weaning	311 ± 55^{A}	0-2300 (89)	34 ± 30	0-750 (25)	142 ± 22	0-1300 (121)	10 ± 7	0-650 (121)
Post-weaning	3 ± 2^{C}**	0-50 (39)	0 ± 0	0 (45)	163 ± 21	0-1200 (127)	5 ± 3	0-300 (128)

Values in columns with different superscripts are significantly different ($p<0.05$)

* before treatment

** treated at weaning with moxidectin

Table 3

BCS change (mean ± standard error) in ewes during different treatment periods.

Time period	Initial BCS	Farm A (Higher WEC)			Farm B (Lower WEC)		
		Worm suppressed	Non-worm suppressed	P value	Worm suppressed	Non-worm suppressed	P value
Over whole experimental period*	≤2.5	-0.42 ± 0.05	-0.71 ± 0.04	<0.001	0.31 ± 0.06	0.02 ± 0.06	0.001
	2.7	-0.71 ± 0.04	-0.86 ± 0.06	0.044	0.19 ± 0.04	0.00 ± 0.06	0.014
	3.0	-0.95 ± 0.05	-1.05 ± 0.04	ns	-0.05 ± 0.04	-0.10 ± 0.04	ns
	>3.0	-1.18 ± 0.08	-1.24 ± 0.07	ns	-0.28 ± 0.06	-0.39 ± 0.05	ns
Pre-lambing to Lamb marking	≤2.5	-0.83 ± 0.04	-1.00 ± 0.05	0.012	-0.30 ± 0.05	-0.33 ± 0.06	ns
	2.7	-1.08 ± 0.04	-1.15 ± 0.05	ns	-0.22 ± 0.05	-0.35 ± 0.07	ns
	3.0	-1.24 ± 0.05	-1.36 ± 0.04	ns	-0.32 ± 0.04	-0.37 ± 0.05	ns
	>3.0	-1.45 ± 0.08	-1.50 ± 0.06	ns	-0.39 ± 0.05	-0.53 ± 0.06	ns
Lamb marking to Weaning	≤2.5	0.41 ± 0.04	0.29 ± 0.03	0.013	0.76 ± 0.06	0.68 ± 0.06	ns
	2.7	0.37 ± 0.03	0.27 ± 0.03	0.015	0.68 ± 0.05	0.65 ± 0.06	ns
	3.0	0.30 ± 0.03	0.31 ± 0.02	ns	0.52 ± 0.04	0.50 ± 0.05	ns
	>3.0	0.27 ± 0.04	0.26 ± 0.04	ns	0.46 ± 0.04	0.45 ± 0.06	ns
Weaning to Post-weaning	≤2.5	na	na	-	-0.16 ± 0.06	-0.36 ± 0.08	0.049
	2.7	na	na	-	-0.27 ± 0.05	-0.31 ± 0.04	ns
	3.0	na	na	-	-0.25 ± 0.04	-0.23 ± 0.05	ns
	>3.0	na	na	-	-0.34 ± 0.05	-0.30 ± 0.05	ns

ns = not significant (p>0.05)

na – not available – all ewes treated with moxidectin at weaning

*For Farm A the ‘whole experimental period’ refers to Pre-lambing to Weaning and for Farm B refers to Pre-lambing to Post-weaning

Table 5

Relative risk for non worm suppressed ewes falling BCS <2.0 after lambing relative to ewes BCS ≥3.0 pre-lambing

	Relative risk (95% confidence interval) p-value for 2-sided Pearson Chi-square test					
Pre-lambing BCS	**All ewes**		**Worm suppressed ewes only**		**Non-worm suppressed ewes only**	
	Farm A	Farm B	Farm A	Farm B	Farm A	Farm B
<2.5	* P=0.006	62.4 (9.2, 424.3) P=<0.001	* P=0.027	ns	* ns	231.0 (11.5, 4650.0) P=<0.001
≤2.5	9.8 (2.3, 42.1) P=<0.001	18.0 (3.7, 86.7) P=<0.001	5.6 (1.2, 26.0) P=0.017	ns	* P=0.003	31.7 (3.7, 274.9) P=<0.001
<3.0	4.2 (2.1, 8.4) P=<0.001	9.3 (2.0, 43.0) P=0.001	3.6 (1.5, 8.8) P=0.003	ns	5.5 (1.8, 17.0) P=0.001	16.1 (2.0, 131.5) P=0.001

*All the sheep in pre-lambing BCS group fell below BCS 2.0 after lambing

Highlights for *"Body condition score as a selection tool for Targeted Selective Treatment-based nematode control strategies in Merino ewes"*

- Showed body condition score can be used as a practical and effective selection index for Targeted Selective Treatment strategies
- Parameters including body condition score, body weight, weight change and worm egg count were recorded in this experiment. Body condition score showed the greatest promise as a selection index under commercial farming conditions for determining which animals should be left untreated in order to provide a source of refugia without compromising flock productivity
- Ewes in better body condition gained less and lost more weight after lambing, but sheep in poor condition were likely to fall below critical levels where compromised productivity and welfare was more likely

Table 4

Live weight change (%) (mean ± standard error) in ewes during different treatment periods.

Time period	**Initial BCS**	**Farm A (Higher WEC)**			**Farm B (Lower WEC)**		
		Worm suppressed	Non-worm suppressed	P value	Worm suppressed	Non-worm suppressed	P val
Over whole experimental period*	≤2.5	-8.08 ± 0.99	-10.4 ± 0.93	ns	2.87 ± 0.98	-0.99 ± 1.07	0.01
	2.7	-9.99 ± 0.74	-11.8 ± 0.73	ns	1.30 ± 1.00	-2.13 ± 0.80	0.00
	3.0	-10.1 ± 0.74	-13.3 ± 0.49	0.001	-0.82 ± 0.46	-3.47 ± 0.67	0.00
	>3.0	-10.5 ± 1.33	-13.9 ± 0.82	0.040	-2.49 ± 0.70	-4.11 ± 0.64	ns
Pre-lambing to Lamb marking	≤2.5	-28.7 ± 1.60	-31.1 ± 1.23	ns	-0.66 ± 1.43	-3.17 ± 1.86	ns
	2.7	-29.6 ± 1.16	-34.9 ± 2.66	ns	-1.15 ± 1.54	-6.53 ± 1.28	0.00
	3.0	-28.5 ± 0.98	-33.2 ± 0.77	<0.001	-5.56 ± 0.97	-6.57 ± 0.92	ns
	>3.0	-28.4 ± 2.53	-31.5 ± 1.08	ns	-4.67 ± 0.98	-7.61 ± 1.12	ns
Lamb marking to Weaning	≤2.5	19.7 ± 1.21	16.7 ± 1.54	ns	19.0 ± 1.19	16.51 ± 1.51	ns
	2.7	17.6 ± 1.34	13.5 ± 1.27	0.030	17.0 ± 0.82	17.3 ± 1.22	ns
	3.0	15.2 ± 0.99	14.6 ± 1.02	ns	18.4 ± 0.84	15.2 ± 1.07	0.01
	>3.0	15.6 ± 1.31	11.5 ± 1.23	0.026	15.4 ± 0.96	-12.1 ± 0.78	ns
Weaning to Post-weaning	≤2.5	na	na	-	-10.9 ± 0.78	-13.5 ± 0.98	0.04
	2.7	na	na	-	-11.1 ± 0.59	-12.3 ± 0.87	ns
	3.0	na	na	-	-11.4 ± 0.64	-11.8 ± 0.68	ns
	>3.0	na	na	-	-12.1 ± 0.78	-12.1 ± 0.62	ns

ns = not significant (p>0.05)

na – not available – all ewes treated with abamectin at weaning

*For Farm A the ‘whole experimental period’ refers to Pre-lambing to Weaning and for Farm B refers to Pre-lambing to Post-weaning