Development of fibre and follicle characteristics related to wool bulk in Perendale sheep over the first year of life

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ABSTRACT

The pattern of wool fibre and follicle development was monitored for 20 Perendale lambs from lines selected for or against wool bulk. There was no significant difference in characteristics associated with wool bulk between selection lines at birth. These characteristics followed a curvilinear pattern of development with most of the change taking place between birth and 14 weeks of age then reaching a plateau by 35 weeks. The different rate of developmental change for each bulk line meant that by 14 weeks the high line had a greater follicle curvature grade, shorter follicle length, shallower follicle depth, more para-meso cortex and a higher fibre curvature. Together fibre curvature, fibre diameter and fibre diameter standard deviation explained around 70% of the variation in hogget wool bulk from 25 weeks of age. From these results it is suggested that the potential of a sheep to produce high bulk wool can be assessed using fibre curvature and fibre diameter from 6 months of age which allows hogget mating and/or early culling to be practised.

Keywords: wool bulk; development; fibre curvature; follicle characteristics; Perendale.

INTRODUCTION

Wool bulk is an important characteristic for the superior performance of many end products produced from Romcross type wool (Sumner *et al.*, 1991). Bulk is strongly inherited and controlled by relatively few genes (Sumner *et al.*, 1995; Wuliji *et al.*, 1995). Consequently wool bulk can be improved quickly through selective breeding in flocks containing genes for high wool bulk. To maximise rate of genetic gain it is desirable to mate sheep as hoggets. However, there is a weak relationship between wool bulk of a fleece at three months of age (lamb shearing), and wool bulk from 12 months (hogget shearing) throughout the remainder of the sheep's life (Sumner *et al.*, 1986; 1989). The principal follicle and fibre characteristics associated with wool bulk of Romcross type wool have been shown to be follicle curvature, staple crimp frequency, staple length and proportion of para-meso cortex within the fibre (Sumner *et al.*, 1993; Dick and Sumner, 1995). These characteristics are considered to influence variations in wool bulk through their associations with fibre crimp conformation (Stobart and Sumner, 1991).

This study investigated the development of follicle and fibre characteristics associated with bulk between birth and 13 months of age to identify possible early life indicators of a sheep's ability to produce high bulk wool as an adult.

MATERIALS AND METHODS

Midside wool patch and skin samples were taken at two monthly intervals, from birth until hogget shearing, from all sheep born in 1994 within a Perendale flock containing lines selected for or against wool bulk. The flock has been maintained at Whatawhata Research Centre since 1989 (Sumner *et al*., 1995). Samples were analysed from twenty of these sheep selected by restricted randomisation to balance for high and low bulk line, sex and birth rank. Sheep were weighed at birth (late August 1994), lamb shearing (29 November 1994), and before hogget shearing (16 August 1995 for rams and 19 September 1995 for ewes).

Wool measurements

Midside wool samples were taken at lamb and hogget shearing, and individual fleece weights recorded at hogget shearing. Core bulk (Standards Association of New Zealand, 1994), fibre diameter and fibre curvature (Edmunds, 1995) were measured for both sets of samples. Staple length and total number of crimps along the staple were measured for the hogget samples and crimp frequency calculated. Immediately following lamb shearing (14 weeks) a right midside patch of approximately 10cm x 10cm was clipped with oster clippers and reclipped on 20 February 1995 (26 weeks), 19 April 1995 (34 weeks), 27 June 1995 (44 weeks) and either 16 August 1995 (51 weeks) for the rams or 19 September 1995 (56 weeks) for the ewes. The patch samples were washed and clean wool growth rate estimated (Sumner *et al.*, 1994). The birth coat region, approximately the outermost 20% of the staples, was cut with scissors from a subsample of the lamb midside fleece sample. These two portions of the lamb fleece and subsequent clipped patch samples were measured for fibre diameter, fibre diameter standard deviation and fibre curvature by optical fibre diameter analyser (OFDA) (Edmunds, 1995).

Skin measurements

A snip skin biopsy was taken from the left midside at birth, then both a snip skin biopsy and a 12mm trephine skin biopsy were taken from the left midside at patch clipping in November 1994 and February, April, August and September of 1995 and fixed in buffered 10% formalin. Longitudinal sections (2mm) were cut from the snip biopsy samples, stained with 0.25% nile blue sulphate and graded for follicle curvature (Dick and Sumner, 1995). Curved length of a follicle and vertical depth from the skin surface to the base of the dermal papilla were measured for 12 follicles in each sample by image analysis. Each trephine biopsy sample was processed through an ethanol gradient, embedded in wax, cut in transverse sections (7μm) and stained with 0.1% janus green (Dick and Sumner, 1995). Follicle density and ratio of secondary to primary follicles (S/P ratio) were calculated from four fields covering a total of approximately 300 follicles. Stereological methods of Gundersen *et al.* (1988), were used to measure the area of sections, to define follicles for counting and to calculate tissue shrinkage, follicle density and S/P ratio. Proportion of para-meso cortex of total fibre cortex and fibre diameter were calculated by image analysis (Dick and Sumner, 1995).

Statistical analysis

Individual measurement data were analysed by least square regression analysis fitting effects of sex, birth rank and selection line. Variables repeatedly measured through time were analysed for selection line effects by Bayesian smoothing (Upsdell, 1994). As the measured fibre and follicle characteristics associated with core bulk are themselves interrelated, their effect on core bulk was assessed by multiple regression using GENSTAT (Lawes Agricultural Trust, 1993). Initially the effect of step-wise adjustment to include each characteristic was evaluated based on the change in residual mean square. The critical F-statistic for variate selection was set at F = 2. The multiple regression analysis was then repeated for each characteristic individually.

RESULTS

Sex and birth/rearing rank effects were not significant for any of the measured characteristics and will not be further discussed. There was no significant difference between bulk lines for birth weight (4.8 ± 1.4kg) (±SD), weaning weight (21.0 ± 5.9kg) or pre-shear hogget live weight (33.0 ± 4.9kg). Least square means for measured wool characteristics at lamb and hogget shearing are given in Table 1. Core bulk values for the lamb fleeces were more variable in the high bulk line (SD = 2.4cm^3/g) than the low bulk line (SD = 0.6cm^3/g) with two (20%) of sheep in the high line having lower core bulk values than the highest values in the low line. The mean of the within line correlations between core bulk of individual samples at lamb and hogget shearing was r = 0.5, which was not significant on account of the small sample size. Six sheep differed in core bulk by more than 4cm^3/g between lamb and hogget samplings. At hogget shearing fleeces from the high bulk line were lighter and shorter, with a higher crimp frequency and greater fibre curvature than fleeces from the

TABLE 1: Least square means of lamb and hogget fleece wool characteristics.

Characteristic	High line	Low line	SED[1]	Significance
Number of sheep	10	10	-	-
Lamb fleece:				
Core bulk (cm^3/g)	27.3	23.6	0.8	***
Fibre diameter (mean) (μm)	28.1	29.1	0.9	NS
Fibre diameter (SD)(μm)	6.5	6.5	0.3	NS
Fibre curvature (deg/mm)	63.8	51.6	3.1	***
Hogget fleece:				
Clean fleece weight (kg)	1.36	1.66	0.12	**
Core bulk (cm3/g)	31.5	23.6	0.7	***
Staple length (mm)	84	113	5.9	**
Fibre diameter (mean) (μm)	30.2	30.3	1.0	NS
Fibre diameter (SD)(μm)	7.1	7.0	0.3	NS
Staple crimp frequency (crimps/cm)	2.3	1.3	0.1	***
Fibre curvature (deg/mm)	72.5	57.7	2.6	***

[1] Standard error of difference.

low bulk line (Table 1). Within samples the mean and standard deviation of fibre diameter were not significantly different between wool bulk lines.

Wool growth rate followed a shallow seasonal trend, as previously reported in Perendale lambs (Bigham *et al.*, 1978), with insufficient data points for the seasonal pattern to be significantly curvilinear (Fig. 1). Wool growth rate of the low wool bulk line was significantly greater than that of the high wool bulk line from May (approximately 36 weeks) onwards.

There was no significant difference between the high and low wool bulk lines for mean fibre diameter which followed a similar seasonal pattern to that for wool growth rate (Fig. 1) of 25.6 ± 1.5, 28.6 ± 2.0, 30.4 ± 1.8, 29.5 ± 2.0, 30.7 ± 2.5, 30.1 ± 3.2 and 27.8 ± 2.5μm for samples taken at 0, 14, 26, 34, 44, 51 and 56 weeks of age respectively. Mean fibre diameter in skin sections measured by image analysis and mean fibre diameter of wool patch samples measured by OFDA were not significantly different. From

FIGURE 1: Mean values for wool growth rate. Open symbols are low wool bulk selection line group and solid symbols are high wool bulk selection line group. Plotted lines are significantly different at 5% level where shaded areas do not overlap.

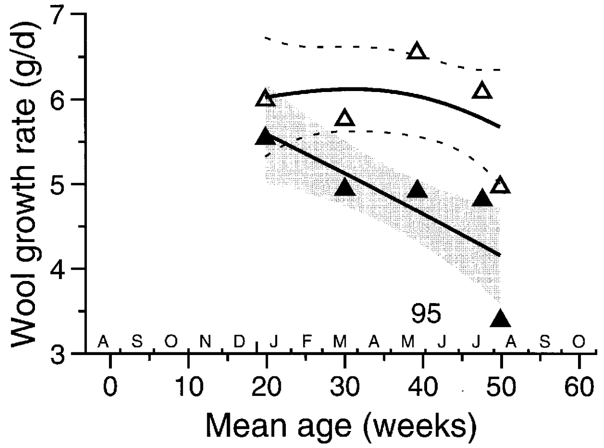
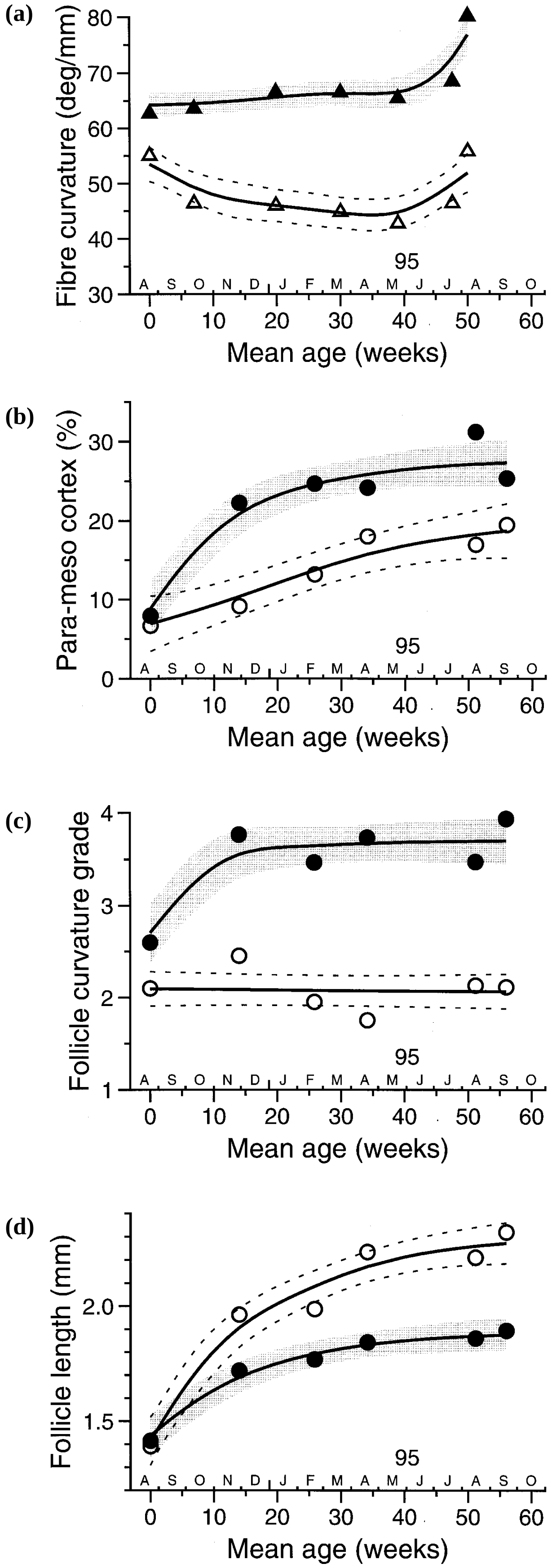
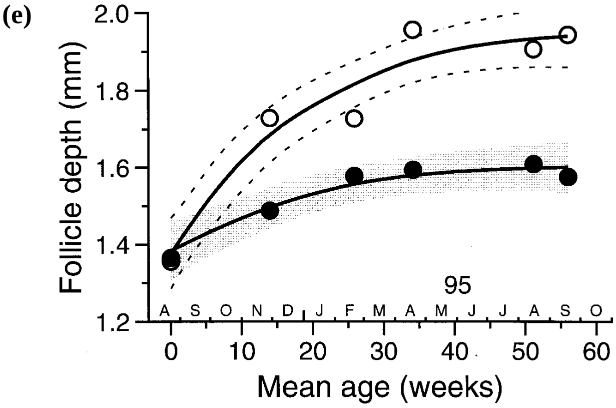


FIGURE 2: Mean values for (a) fibre curvature, (b) proportion of para-meso cortex, (c) follicle curvature grade, (d) follicle length, and (e) follicle depth, over time. Open symbols are low wool bulk selection line group and solid symbols are high wool bulk selection line group. Plotted lines are significantly different at 5% level where shaded areas do not overlap.





birth until the end of the following June the difference in fibre curvature between the high and low wool bulk lines gradually increased as fibres of the low line became less curved than the original birth coat (Fig. 2a). The increased fibre curvature of wool grown during late winter, in August, coincided with a decreased seasonal wool growth rate and an associated reduction in mean fibre diameter. The proportion of para-meso cortex within the wool fibres increased curvilinearly to a plateau by about 25 weeks of age in the high line and had not plateaued by 50 weeks in the low bulk line (Fig. 2b). From 14 weeks of age wool grown by sheep in the high bulk line consistently contained a higher proportion of para-meso cortex than that of the low bulk line.

Follicle curvature grade for the high wool bulk sheep increased curvilinearly appearing to plateau by about 25 weeks of age whereas curvature grade did not change significantly after birth in sheep of the low wool bulk line (Fig. 2c). Both follicle length and follicle depth increased curvilinearly with time appearing to plateau by 50 weeks of age (Fig. 2d & 2e). Follicles in sheep producing high bulk wool were shorter and shallower by approximately 0.35mm (19%) than follicles in sheep producing low bulk wool from 35 weeks of age. Within sheep the mean ratio of follicle length/follicle depth ranged from 1.0 to 1.7 but was not significantly different between the high and low wool bulk lines.

Rate and extent of follicle development was not significantly different between the wool bulk lines as indicated with no difference between lines in S/P ratio and total follicle density at any time point. Mean S/P ratio at birth was 3.05 ± 0.75 increasing to a mean of 4.93 ± 0.95 by lamb shearing. Mean follicle density at lamb shearing was 22.7 ± 3.5 follicles/mm^2 and decreased as skin surface area increased with growth to 15.0 ± 3.0 follicles/mm^2 at hogget shearing.

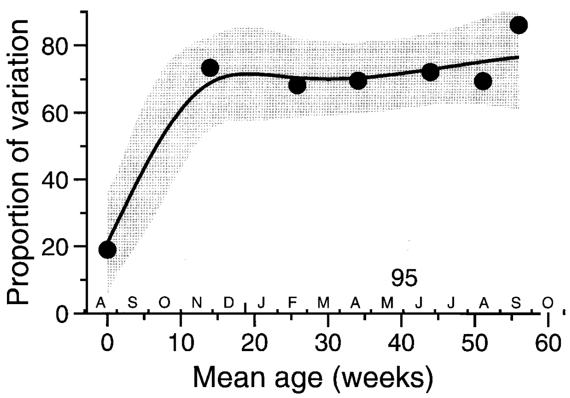
Stepwise multiple regression to include each measured characteristic found crimp frequency explained 81.8% of the variation in core bulk with the addition of no other characteristic resulting in a significant reduction in the total variation present. A summary of the proportion of total variation in core bulk explained by each characteristic individually, in order of decreasing importance, and the residual mean square is given in Table 2.

TABLE 2: Proportion of variation in core bulk measured at hogget shearing explained by individual fibre and follicle characteristics measured at hogget shearing and the mean residual standard deviation for core bulk remaining.

Characteristic	Proportion of variation explained (%)	Residual standard deviation (cm^3/g)
Crimp frequency	81.8	1.8
Follicle curvature	78.0	2.0
Fibre curvature	65.6	2.5
Follicle length	56.2	2.8
Staple length	52.2	2.9
Follicle depth	46.1	3.1
Proportion of para-meso cortex	31.3	3.5
Fibre diameter (SD)	0.0	4.2
Fibre diameter (mean)	0.0	4.3

In considering objective measurements that can be easily measured on fibres, fibre curvature of hogget midside samples explained 65.6% of the variation in hogget core bulk. Including fibre diameter standard deviation increased this to 72.3% while fibre curvature, fibre diameter standard deviation and fibre diameter together explained 73.0% of core bulk. The proportion of variation in hogget core bulk explained by the combination of these three measurements, for clipped samples taken between birth and hogget shearing, is plotted in Fig. 3. From 25 weeks of age values for the explained variation plateaued at around 73% and had a narrower confidence interval than weeks 12-25 over which time the characteristics reached maturity.

FIGURE 3: Proportion of variation in core bulk at hogget shearing explained by the combination of fibre curvature, fibre diameter and fibre diameter standard deviation measured on patch samples clipped between birth and hogget shearing. The shaded area covers the 95% confidence interval for the line.



DISCUSSION

The large variation in core bulk values of lamb fleeces in the high wool bulk line and the weak repeatability of individual core bulk values between lamb and hogget fleeces is consistent with the poor predictability of the lamb fleece as an indicator of adult wool bulk found by Sumner *et al.* (1989). This study confirms previous findings of the effects on fibre and follicle characteristics from selecting Perendale sheep for high wool bulk (Sumner *et al.*, 1993). These effects were a lighter fleece weight, shorter staple length, higher staple crimp frequency, more para-meso cortex, increased follicle curvature and no difference in fibre diameter in the high compared to the low selection line. In this study high wool bulk sheep have distinctly shorter and shallower follicles than low wool bulk sheep. This difference was greater than that reported between these selection lines by Sumner *et al.* (1993). This could be due to changes in the measurement technique. In this study individual follicles were measured whereas Sumner *et al.* (1993) estimated an average follicle depth across a row of follicles lying in longitudinal section. The ratio of follicle length/follicle depth did not differ between high and low wool bulk selection lines and is therefore not suitable for use as an objective measure of follicle curvature to replace the present subjective grading system.

Here, and previously, wool bulk has been linked to aspects of fibre and follicle morphology, particularly staple crimp and follicle curvature, which are thought to be interrelated with individual fibre crimp (Sumner *et al.*, 1991; 1993; Dick and Sumner, 1995). Until recently no objective measurements for parameters of crimp on individual fibres have been available. Recent technological developments in image analysis now allow measurement of the extent of fibre curvature across 0.2mm snippets of individual fibres using OFDA (Edmunds, 1995). This measure of fibre curvature, in association with a measure of fibre diameter, appears to be a key factor in the compressional properties of a mass of wool fibres. Swan (1994) found fibre curvature and fibre diameter together explained 85% of the variation in wool bulk across a range of Merino wools and some coarser crossbred wools which covered a wide range in mean fibre diameter. The relationships presented in Table 2 are the first reported between fibre curvature and wool bulk for a New Zealand Romcross wool type. This study found fibre curvature and fibre diameter measurements from hogget fleece midside samples explained 73% of core bulk in the same samples. The relatively small increase made by adding fibre diameter components to the proportion of bulk explained, over the 65.6% explained by fibre curvature, was probably due to the small range of fibre diameter values covered in this study. It should be noted that fibre curvature as measured by OFDA is a 2-dimensional measurement whereas fibre crimp within a fibre mass acts in 3 dimensions. This may be the major reason why 27% of the variation in core bulk remains unexplained.

Changes in developing fibre and follicle characteristics of young sheep cause variability in the morphology of growing wool. Hence bulk measured from fleece samples taken earlier than hogget shearing is not a reliable indicator of bulk of wool from adult sheep. The greatest change in fibre curvature occurs between birth and 14 weeks but there is an increasing difference between lines that continues throughout the first year of life (Fig. 2a). This study has shown proportion of para-meso cortex, follicle length and follicle depth all exhibit curvilinear developmental trends with the greatest changes occurring from birth to 14 weeks (lamb shearing), slowing to a plateau in all characteristics by 35 weeks of age (Fig. 2). Follicle curvature development was curvilinear in the high wool bulk line while in the low line it did not change from birth (Fig. 2c). Thus measurement of key fibre and follicle characteristics affecting bulk, grown around 35 weeks of age or later, will provide a relative indication of the likely wool bulk of the sheep as an adult.

Bulk and crimp frequency can only by measured on full length wool after shearing. To facilitate early culling and hogget mating it is therefore important to identify an early indicator of adult wool bulk. Of the measured characteristics which were closely related to core bulk many are unsuited for routine use to select flock sheep on a farm as they are either subjective assessments or expensive to measure. For example, follicle curvature, which previous studies have found to be the characteristic most closely linked to bulk, is a labour intensive subjective measurement (Sumner *et al.*, 1993; Dick and Sumner, 1995). It is notable that of the characteristics measured in this trial, follicle curvature and fibre curvature are the earliest to develop significant differences between bulk lines (Fig. 2a & 2c). While fibre curvature of the lamb birth coat and follicle curvature at birth are poor indicators of adult wool bulk line (Fig. 2a & 2c), both of these characteristics measured after lamb shearing at 14 weeks of age provide an indication of adult wool bulk. Of the characteristics measured in this study, fibre curvature, fibre diameter and fibre diameter variation are objective measurements that can be measured at the same time by OFDA and together provide the most practical indicator of adult wool bulk for on farm use.

Use of these three characteristics measured in wool grown over late summer/early autumn, when hoggets are 6 to 8 months old, will enable wool growers producing speciality high bulk wool to select for wool bulk at an earlier age than previously possible. This has potential benefits of enabling growers to undertake hogget mating and/or reduce numbers of over wintered hoggets without compromising potential genetic gains for wool bulk.

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