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## Hair whorl patterns are related to age at puberty and milk-production traits in dairy cattle

S.K. YOUNG, L.R. MCNAUGHTON and R.J. SPELMAN

LIC, Hamilton

### ABSTRACT

The objective of this study was to measure facial hair whorl characteristics of Friesian-Jersey crossbred cows ( $n=658$ ) and to investigate their association with measures of milk production, fertility and behaviour. Cows had 1 ( $n=581$ ), 2 ( $n=10$ ), 3 ( $n=1$ ) or no facial hair whorls ( $n=66$ ). Of those cows with one whorl, 66% had whorls in the middle of the head, whereas 21% had whorls low on their head and 13% high on their forehead. Round whorls were present on 77% of cows, while 23% had non-round whorls. Fifty five percent of cows with round whorls were recorded as having anticlockwise rotation and 16% of cows as clockwise rotation. Cows with high hair whorls tended to reach puberty earlier on average than cows with lower whorls ( $P=0.07$ ). Cows with higher non-round whorls also produced lower total milk and total solid yields, than cows with low whorls ( $P=0.01$ ). No relationship was found between hair whorl characteristics and behaviour in this study.

**Keywords:** hair; whorl; pattern; bovine; cow; fertility; puberty; production.

### INTRODUCTION

Human hair whorl patterns have been linked to the occurrence of developmental disorders such as Down's syndrome and Prader-Willi (Smith & Gong, 1973; 1974), handedness (Klar, 2003) and sexual preferences (Klar, 2004). These links have been attributed to the simultaneous development of the hair patterns and the brain in the foetus (Smith & Gong, 1974). Patterning of hair follicles occurs at 10 to 18 weeks after fertilisation (Meola *et al.*, 2004).

In cattle, facial hair whorl position has been shown to be associated with temperament and behaviour (Tanner *et al.*, 1994; Grandin *et al.*, 1995; Randle, 1998; Lanier *et al.*, 2001) and bull semen quality (Meola *et al.*, 2004).

Hair whorl characteristics may also be associated with fertility traits based on the fact that it has been shown that the patterning of hair follicles coincides with testicular development (Smith & Gong, 1974; Gilbert, 2000). The differentiation of the gonads into the ovaries and the testes, has been shown to occur at the same time in monkeys (Fouquet & Dang, 1980). In cattle, sex differentiation of the ovaries takes place in 45-day-old female embryos (Kurilo *et al.*, 1987), coinciding with the development of the first hair follicles on the muzzle and above the eye (Currie, 1988). This suggests that the development of the ovaries in bovines occurs at the same time as hair follicle development.

The objectives of this study were to characterise hair whorls in Friesian Jersey crossbred cows and to determine relationships among hair whorl characteristics and fertility, behaviour and milk-

production traits.

If hair whorl patterns are related to measures of fertility, behaviour and production, this could be a useful tool when evaluating young calves as replacement heifers.

### MATERIAL AND METHODS

#### Animals

Hair Whorl dimensions were measured in a population of 658 F<sub>2</sub> Friesian x Jersey cows. These animals were the progeny of 6 F<sub>1</sub> Friesian x Jersey sires and F<sub>1</sub> Friesian x Jersey dams and were bred for a Quantitative Trait Loci (QTL) mapping experiment (FJXB trial) (Spelman *et al.*, 2001). Animals were born over two years, 2000 (Cohort one) and 2001 (Cohort two), and were in their fourth and third lactation respectively, when they were phenotyped for hair whorls. These FJXB trial animals were chosen, as the genetics associated with hair whorl characteristics will be examined as part of a bigger study.

#### Whorl Characterisation

Two people measured and recorded hair whorl data. Each recorder documented the number, position, shape and rotation of each cows whorl(s). To ensure that the two recorders used the same methods and were consistent, both recorders recorded the first fifteen cows together on each of the three days. Any cows that had unusual whorls (*e.g.* no whorls or three whorls) were re-scored by the other recorder. The recorder of each cow was not noted, so this was not added as an effect in the data analysis.

Animals were recorded as having no whorls, a

single whorl, two whorls or three whorls. Only animals with single whorls had the position, asymmetry, shape and rotation evaluated. The position of the whorl was evaluated from the central point of the whorl as described by Meola *et al.* (2004).

Whorl height and asymmetry were classified on a vertical and horizontal five-point scale (Figure 1), described by Evans *et al.* (2005). Whorl shape was classified as: round or non-round. A cow was classified as having a non-round whorl if the epicentre of the whorl was not round. If whorls were classified as round, they were further classified as having either clockwise or anticlockwise rotation.

### Phenotypic Characteristics

As part of the QTL experiment, a range of phenotypic traits were measured. The following phenotypes were analysed to investigate whether there was any correlation with hair whorl characteristics.

**Age at puberty:** This was determined by analysing blood progesterone concentrations fortnightly in animals that were 240 days of age or weighed at least 120 kg. Animals were considered to have reached puberty when progesterone concentrations were >1ng/ml in 2 out of 3 consecutive samples (McNaughton *et al.*, 2005).

**Pregnant within 42 days of the start of the breeding period (P42):** This was evaluated for each cohort's second lactation; 2003 for cohort one, and 2004 for cohort two. P42 was evaluated from artificial insemination data, progesterone profiles (measured twice a week throughout the mating period), pregnancy diagnosis results and subsequent calving dates (McNaughton *et al.*, 2007).

### Behaviour

**Adaptability to milking:** this trait describes how soon each heifer settled into the milking routine after calving in its first lactation. Animals were assessed on a 1-9 behavioural scale, with 1 being slow to adapt and 9 being quick to adapt to milking (Spelman *et al.*, 1999).

**Shed temperament:** describes the temperament of the heifer in the farm dairy while being handled and milked. This trait was assessed once animals have settled into the milking routine in their first lactation, and is based on a 1-9 scale, with 1 being an animal with a nervous temperament, and 9 being a placid animal (Spelman *et al.*, 1999).

**Farmer opinion:** this trait describes the farmer's overall acceptance of the animal as a herd member. This trait is assessed on a 1-9 scale, with 1 being an undesirable animal, and 9 being a desirable herd

member (Spelman *et al.*, 1999).

### Milk-production traits

Milk volume was recorded daily and fat and protein concentrations evaluated in fortnightly milk samples. The second lactation for each cohort was modelled to estimate 270-day yields for fat, protein, milk and total solid yields. Total solids yield, was a combination of fat, protein and lactose.

### Statistical analysis

Data was analysed in JMP (JMP version 5.1, SAS Institute, Cary, NC) by fitting a linear model with whorl height, asymmetry, shape, sire and cohort as fixed effects. Cows with no facial whorls (n=66) or more than one facial whorl (two whorls n=10; three whorls n=1), were not included in the analysis.

## RESULTS

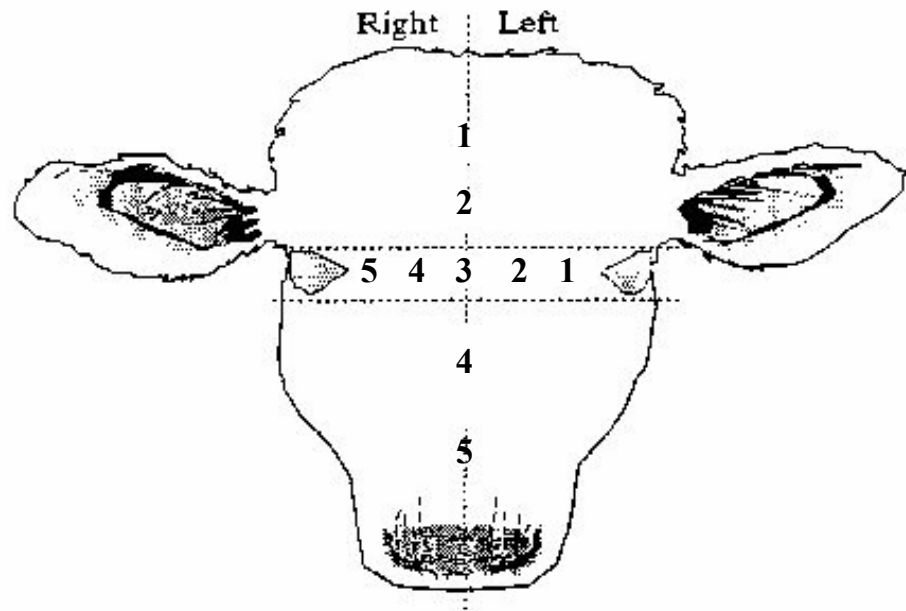
### Whorl Characteristics

The distribution of animals according to their combinations of whorl height and asymmetry scores are shown in Figure 2. Cows had 1 (n=581), 2 (n=10), 3 (n=1) or no facial hair whorls (n=66). Of those individuals that had one whorl, the majority had hair whorls placed in the middle of their forehead (65%), or low on their forehead (22%). In terms of asymmetry, 72% of whorls were centred, 16% were located on the animals left side of the face, whereas only 12% were located on the right side of the animals face. A large proportion of the whorls were placed along the two centrelines (height and asymmetry) with 72% of all whorls occurring along the vertical centreline of the face and a total of 91% of all whorls were described as sitting along both the vertical and horizontal centrelines (as illustrated in Figure 2). Seventy-seven percent of animals had round shaped whorls and of these, 55% had anticlockwise rotation. Of the 66 animals that had no whorl, 35% (n=23) were offspring of sire B, and 42% (n=28) were offspring of sire E (Table 1).

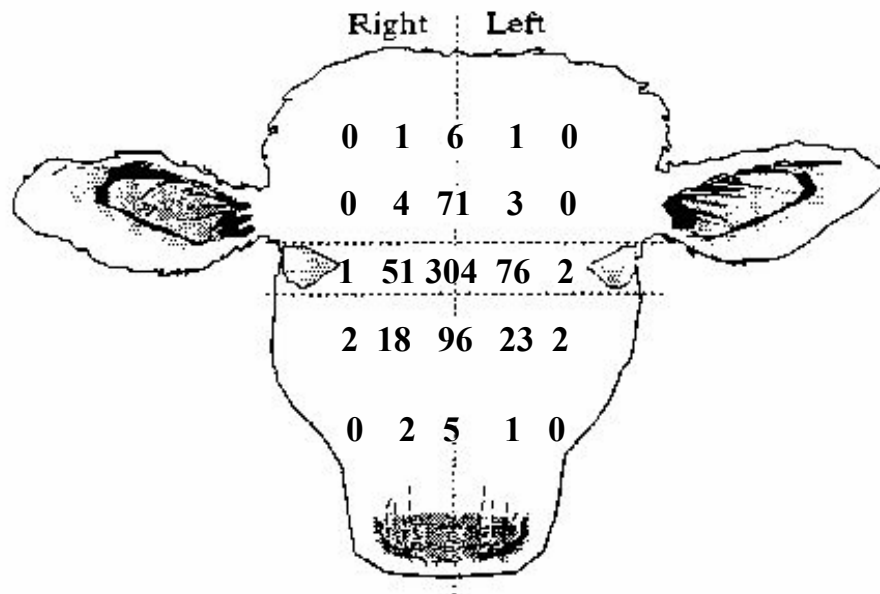
### Fertility, Behaviour and Milk-Production Characteristics

An analysis of whorl height showed that cows with whorls positioned higher on their forehead tended to reach puberty earlier (Table 2) (P=0.07). Furthermore, animals with high whorls and non-round whorls tended to have lower fat (P<0.01), milk (P<0.01), protein (P=0.05), and total solid yields (P<0.05). No significant relationship was found between hair whorl characteristics and P42.

**Figure 1:** Method for determining the position of hair whorls on an animals face. The centre of the hair whorl was used as the reference point to determine whorl height and asymmetry. Whorl height and asymmetry were classified using the two five-point scales (points 1-5) shown in this figure. Height was measured on the vertical scale, whilst asymmetry was measured using the horizontal scale. Described by Evans *et al.* (2005).



**Figure 2:** The relative frequency of the location of the central point of the hair whorl, in relation to the five-point scale described in Figure 1.



The least square mean estimates for each category for hair whorl characteristics on fertility and milk-production traits are presented in Table 3. This table shows that animals with whorls positioned high on their head reached puberty earlier, and produced less fat, milk, protein and total solids yields. The same pattern occurred in relation to the shape of the hair whorl. Animals with non-round whorls tended to reach puberty earlier, and also produced less fat, milk, protein, and total solid yields.

**Table 1:** Percentage of cows with 0, 1, 2, or 3 hair whorls in relation to the bull they were sired by. All cows were sired by one of six bulls (A-F). The total number of cows sired by each bull is indicated by n.

| Sire | Number of whorls |    |   |   | Total number of cows sired by each bull<br>n |
|------|------------------|----|---|---|--|
|      | 0                | 1  | 2 | 3 |  |
| A    | 2                | 97 | 1 | 0 | 124  |
| B    | 18               | 80 | 2 | 0 | 127  |
| C    | 4                | 94 | 2 | 0 | 103  |
| D    | 5                | 93 | 1 | 1 | 121  |
| E    | 21               | 78 | 1 | 0 | 135  |
| F    | 6                | 93 | 1 | 0 | 143  |

## DISCUSSION

The analysis indicates that hair whorl patterns are correlated with age at puberty, and milk-production traits in Friesian Jersey crossbred dairy cows. The relationship between hair whorl height and shape in relation to age at puberty and milk-production traits may possibly be explained by the fact that hair patterning occurs in the foetus at the same time as testicular development (Meola *et al.*, 2004). As a consequence of this relationship, bulls with round hair whorls have been shown to produce a higher percentage of normal spermatozoa (Meola *et al.*, 2004). It is, therefore, possible that the development of the ovaries at this same stage of development could be responsible for the relationships among hair whorl patterns and age at puberty and milk-production found in this study. It has been shown that in humans, handedness and hair whorl direction of rotation are related (Klar, 2003). In addition, Meola *et al.* (2004) showed that bull hair whorl patterns are related to sperm morphology. These studies are further evidence that hair whorl characteristics are related to other phenotypic characteristics.

**Table 2:** Significance levels determined from fitting a linear model estimating the effect of hair whorl characteristics, sire and cohort on fertility (age at puberty and the pregnancy status of cows, 42 days after the start of mating (P42)) and milk-production traits (270-day yields for fat, protein, milk and total solid yields). Results presented when (P<0.1).

|             | Age at Puberty | P42 | Fat Yield | Milk Yield | Protein Yield | Total Solid Yield <sup>1</sup> |
|-------------|----------------|-----|-----------|------------|---------------|--------------------------------|
| Height      | 0.07           | NS  | 0.012     | 0.01       | 0.051         | 0.01                           |
| Shape       | NS             | NS  | <0.001    | 0.011      | 0.0004        | 0.0002                         |
| Asymmetry   | NS             | NS  | NS        | NS         | NS            | NS                             |
| Orientation | NS             | NS  | NS        | NS         | NS            | NS                             |
| Sire        | <0.0001        | NS  | 0.018     | <0.0001    | 0.006         | 0.05                           |
| Cohort      | <0.0001        | NS  | <0.0001   | <0.0001    | 0.0002        | <0.0001                        |

<sup>1</sup>Total solids yield, was a combination of fat, protein and lactose.

**Table 3:** Least Square Mean ± s.e. (lsmean) estimates for each category of hair whorl characteristics on fertility and milk-production traits. Different superscripts indicate a significant difference within columns (P<0.05).

|               | Age at Puberty (days)  | Fat Yield (kg)         | Milk Yield (kg)          | Protein Yield (kg)    | Total Solid Yield <sup>1</sup> (kg) |
|---------------|------------------------|------------------------|--------------------------|-----------------------|-------------------------------------|
| <b>Height</b> |                        |                        |                          |                       |                                     |
| 1             | 264 ± 25 <sup>b</sup>  | 178 ± 10 <sup>c</sup>  | 3376 ± 199 <sup>b</sup>  | 127 ± 7 <sup>b</sup>  | 499 ± 27 <sup>b</sup>               |
| 2             | 335 ± 8 <sup>a</sup>   | 194 ± 3 <sup>bc</sup>  | 3541 ± 65 <sup>b</sup>   | 137 ± 2 <sup>b</sup>  | 533 ± 9 <sup>b</sup>                |
| 3             | 320 ± 4 <sup>a</sup>   | 200 ± 2 <sup>ab</sup>  | 3654 ± 31 <sup>b</sup>   | 139 ± 1 <sup>b</sup>  | 548 ± 4 <sup>b</sup>                |
| 4             | 325 ± 6 <sup>a</sup>   | 205 ± 3 <sup>a</sup>   | 3791 ± 52 <sup>a</sup>   | 143 ± 2 <sup>a</sup>  | 565 ± 7 <sup>a</sup>                |
| 5             | 329 ± 22 <sup>ab</sup> | 194 ± 9 <sup>abc</sup> | 3466 ± 173 <sup>ab</sup> | 134 ± 6 <sup>ab</sup> | 526 ± 24 <sup>ab</sup>              |
| <b>Shape</b>  |                        |                        |                          |                       |                                     |
| Round         | 317 ± 7 <sup>a</sup>   | 199 ± 3 <sup>a</sup>   | 3652 ± 114 <sup>a</sup>  | 139 ± 2 <sup>a</sup>  | 548 ± 8 <sup>a</sup>                |
| Non-round     | 312 ± 8 <sup>a</sup>   | 189 ± 3 <sup>b</sup>   | 3479 ± 131 <sup>b</sup>  | 132 ± 2 <sup>b</sup>  | 520 ± 9 <sup>b</sup>                |

<sup>1</sup>Total solids yield, was a combination of fat, protein and lactose.

No relationship was found between hair whorl characteristics and P42, or behaviour. This temperament result contrasts with the results of other studies (Grandin *et al.*, 1995; Randle, 1998), which showed a significant relationship between hair whorl and temperament. As all animals in this study were in either their third or fourth lactation when they were phenotyped for hair whorls, it is likely that any animals with poor temperament, or poor fertility had already been culled from the herd. Data from the FJXB database suggests that approximately 40% of animals culled from the trial were as a result of poor fertility, however there were no specific records of animals being culled based on temperament. Animals may, however, have been culled due to injuries as a result of poor temperament, making it difficult to separate out temperament related culls. In addition, temperament is most easily observed in cattle that are not accustomed to daily, close contact with people (Grandin *et al.*, 1995). In this study, the animals have been frequently handled since birth, for science-related activities such as blood sampling and weighing.

The biological relationship between hair whorl height and shape and milk-production may be due to the mammary gland beginning to form in the bovine foetus around day 30 of gestation, with early teat formation occurring at 65 days post fertilisation (Akers, 2002), and teats are formed by day 80 of gestation (Currie, 1988). This formation coincides with the patterning of the hair follicle, which occurs around 10 to 18 weeks after fertilisation (Meola *et al.*, 2004).

Marked sire differences for each of the phenotypes were found. The design of this particular QTL experiment is not suitable for the calculation of accurate heritability estimates, however, hair whorl position has been shown to be highly heritable in Konik horses, with an estimated heritability of 0.84 (Gorecka *et al.*, 2006).

If hair whorl patterns are related to measures of fertility and production, as this study suggests, this could be a useful tool when evaluating young calves as replacement heifers.

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