Body condition score is a critical factor determining the onset of puberty in Blanca Andaluza female goat kids

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Short title: Body condition score is critical at goats' puberty

Abstract

This study examines the effect of body condition score (BCS), independently of body weight (BW), on the onset of puberty in Blanca Andaluza female kids born in Autumn (November). Thirty six female kids were distributed into three groups according to their BW and BCS: low BW and low BCS (LL, N=10), low BW and high BCS (LH, N=10), and high BW and high BCS (HH, N=16). Feeding was adjusted weekly so that the animals would gain about 50 g per day. Oestrus was checked daily using young vasectomized bucks fitted with a marking harness. The ovulation rate was determined by transrectal ultrasonography 10 days after the identification of oestrus. Plasma samples were obtained weekly for progesterone determination. Changes in BW and BCS were also recorded weekly. The BCS had a clear effect on the date of first ovarian activity and first detected oestrus. The HH kids experienced the earliest onset of puberty (31st August±2.4 days) although no significant difference ($P>0.05$) was seen compared with the LH group (19th September±8.7 days). A significant difference was recorded, however, in comparison with the LL group (25th October±7.8 days) ($P<0.001$). No effect of BCS was observed on ovulation rate ($P>0.05$). These results show that, in Blanca Andaluza female kids, the onset of puberty depends strongly upon BCS and is independent of BW. There may be clear benefit in breeding November-born animals if, during the prepubertal period, they can be maintained with a high BCS.

Key words: goat, female, puberty, body condition score, nutrition.

Summary text

The main objective was to determine the role of the body condition score or the live weight on the onset of goat's puberty. We designed an experiment to study the role of the body condition score as modulator of the onset of the puberty independently than the body weight. We used Blanca Andaluza goat kids, an endangered native Spanish breed raised for meat production in extensive or semi-extensive grazing systems. The interest for this kind of systems has been increased amongst Spanish farmers in recent years, more specifically for organic livestock's. These results could support the goat’s farmers.

Introduction

Puberty in female goats can be defined as the age at which oestrus is first detected by a male, followed by characteristic cyclical ovarian activity (Greyling, 2000). In neuroendocrine terms, puberty is the beginning of gonadotrophin releasing hormone (GnRH) secretion by the hypothalamus (Ebling, 2005). As puberty approaches, sensitivity to gonadal steroids decreases to allow GnRH pulse frequency to increase (Foster, 1984; Olster and Foster, 1986; Foster and Jackson, 2006; Valasi et al., 2012). The onset of puberty is influenced by genetic factors, and recent investigations into its neuroendocrine control have revealed the involvement of many genes organized into functional networks (Valasi et al., 2012). Photoperiod, season of birth, nutritional status, body weight (BW), total body fat, growth rate and metabolism, etc., also play their part (Land, 1978). Indeed, in temperate latitudes, the influence exerted by photoperiod is among the strongest of all (Malpaux et al., 1989; Zarazaga et al., 2009, 2011a, 2011b). In goats, only one study has reported the effect of nutrition on the onset of puberty (Zarazaga et al., 2009), while in other species nutritional status has been closely linked to it (Foster and Olster, 1985; Schillo, 1992; Archbold et al., 2012). BW and body composition are reported to have an important effect on the moment a female first becomes capable of breeding (Frisch, 1988), and some authors have examined the physiological mechanisms responsible for transmitting information on BW, body composition and nutritional status to the reproductive system (Foster et al., 1985).

In lambs, the close association between general body growth and sexual development is well established, and puberty may be delayed or advanced by varying the nutrition they receive (Allen and Lamming, 1961). Quirke and Gosling (1979) reported that food restriction during growth, and the resulting differences in live BW at puberty, have significant effects on ovulation rate in pubertal oestrous cycles. Zarazaga et al. (2009), who studied the onset of puberty in Payoya goats (endangered native Spanish breed) with respect to level of nutrition and season of birth, reported the latter to be the most important factor. The literature contains no information on the role of body condition score (BCS) on the onset of puberty in goats.

The Blanca Andaluza goat is an endangered native Spanish breed endangered (Real Decreto 2129/2008). Raised for its meat, it is distributed throughout Andalusia, but always in mountainous areas with difficult terrain, poor soil and a dry, warm climate. Interest in the preservation of native breeds raised in extensive or semi-extensive grazing systems has increased amongst Spanish farmers, yet no data on the Blanca Andaluza breed's reproductive characteristics, nor on what might influence the onset of puberty, are available.

The aim of the present study was to determine the onset of reproductive activity, including ovarian activity and oestrus, in Autumn-born Blanca Andaluza female kids, and to determine the influence of BCS on the onset of puberty independently of the effect of BW.

Material and Methods

2.1 Animals

This study was conducted at the experimental farm of the University of Huelva (latitude 37º 15'N) and was performed in accordance with Spain's animal protection policy described in *Real Decreto 53/2013*, which conforms to

European Union Directive 2010/63 regarding the protection of animals used in scientific experiments.

The experimental animals were 36 entire, Blanca Andaluza female kids born in Autumn (7th November±0.8 days). The experiment started on the 7th July when the animals were 241.3±0.8 days old, and finished on the 1st December, when they were 388.3±0.8 days old. During the experimental period (147 days), the animals were kept permanently in communal yards, each with an uncovered area, without supplementary light.

To distinguish the effect of BCS (Hervieu et al., 1991) from that of BW, the kids were distributed into three experimental groups: low BW and low BCS (LL, N=10), low BW and high BCS (LH, N=10), and high BW and high BCS (HH, N=16) (Table 1; note the significant differences between the values described for the three groups).

Animals of each experimental group were kept together. Feeding was adjusted weekly in relation to BW to ensure a weight gain of 50 g per day, in accordance with INRA standards (Morand-Fehr and Sauvant, 1988). All animals were fed concentrate, a commercial mixture of maize (26.3%), beans (20%), oats (14.1%), cotton-seed (13.7%), peas (13.4%), lupin (7.3%), barley (0.2%), wheat (0.2%), sunflower seeds (0.2%), a mineral–vitamin complement (4.6%), and barley straw. The nutritional values of the concentrate was 0.93 milk fodder units (UFL) and 76 g of digestible protein per kilogram of dry matter and the barley straw 0.37 UFL and 25 g of digestible protein per kilogram of dry matter. Concentrate was offered once a day and distributed individually; barley straw was administered *ad libitum*. All animals had free access to water and mineral blocks containing trace elements and vitamins.

2.2 Management

BW and BCS were recorded weekly, the latter always by the same handler. Oestrous activity was checked daily, employing young vasectomized males fitted with a marking harness. The ovulation rate was examined by transrectal ultrasonography conducted 10±2 days after the detection of oestrus (Simoes et al., 2005). All such explorations were performed using an Aloka SSD-500 apparatus connected to a 7.5 MHz linear probe. Scanning was performed as previously described (Schrick et al., 1993). After placing a water-soluble contact gel into the rectum, the transducer was introduced perpendicularly to the abdomen wall. When the urinary bladder was surpassed and the uterine horns located, the probe was rotated laterally 90º clockwise and then 180º counter-clockwise to observe both ovaries and their structures. The number of corpora lutea was recorded for each ovary by an expert operator.

The presence of corpora lutea was also examined weekly by determining the plasma progesterone concentration in blood samples collected by jugular venipuncture in tubes containing heparin. Plasma was obtained after centrifugation at 3000 x g for 30 min, and stored at -20 ºC until use.

2.3 Hormone assays

Plasma progesterone was determined in duplicate samples using a commercial enzyme linked immunoassay (ELISA) kit (Ridgeway Science Ltd., Gloucester, UK) following the manufacturer's instructions (Madgwick et al., 2005). The mean intra-assay and inter-assay coefficients of variation were 6.6% and 9.9% respectively. The sensitivity of the assay was 0.1 ng/mL.

2.4 Measurements

The female kids were deemed to have ovulated if the progesterone concentration was >0.5 ng/mL. The date of the last plasma progesterone value below baseline that was followed by the first extended cyclical pattern was taken as the onset of ovulatory activity. Ovulatory activity was deemed confirmed when two or more consecutive plasma samples returned progesterone concentrations above baseline (0.5 ng/mL) (Chemineau et al., 1984; Zarazaga et al., 2009) with subsequent cyclicity. The date of onset of puberty was defined as that at which a kid’s first oestrus was detected by the males, followed by characteristic ovarian cyclicity. The ovulation rate associated with this first cycle was also recorded for each animal.

The percentage of adult live weight at the first ovarian activity and at the onset of puberty was calculated for each animal in relation to an adult live weight of 60 kg (Aparicio, 1947; Fuentes García et al., 2000).

Patterns of sexual activity observed during the onset of reproductive activity were classified as associated with: (i) the oestrous cycle - when oestrous behaviour was accompanied by an increase in serum progesterone to above 0.5 ng/mL; (ii) silent ovulation - when an increase in serum progesterone to above 0.5 ng/mL in at least two consecutive samples was seen but was not preceded by oestrous behaviour; or (iii) anovulatory oestrus - when oestrous behaviour was accompanied by no increase in serum progesterone; (iv) length of oestrus cycle classified as normal (16-27 days), short (<16 days) or long (>27 days) duration.

2.5 Statistical analysis

The change in BW and BCS in each group was examined by repeated measures ANOVA. The daily gain (g/d), total weight gain, the date of the onset of ovulatory activity, the onset of puberty and the percentage of adult live weight at each moment were analysed by factorial ANOVA with the experimental treatments as fixed effects. When differences were observed, the Tukey test was performed. The differences between groups with respect to percentage incidence of ovarian activity, percentage of detected oestrus or percentage of cycles classified according with the duration were compared using the χ^2-test. The mean ovulation rate for the animals of each group at the first detected oestrus was compared using the Mann-Whitney U test. All analyses were performed using the SPSS package (Statistical Package for the Social Sciences, 2008).

Results

Body weight and body condition score

The mean BCS (entire experimental period) for the LL group (2.48±0.05) was lower ($P<0.01$) than that of the LH and HH groups (2.79±0.05 and 2.94±0.04 respectively; $P>0.05$). The differences in BW and BCS between groups at the beginning of the experiment were maintained until the end (Fig. 1). Thus, the feed provided allowed the animals to grow, albeit at a rate slightly lower than expected, with no differences in growth rate between groups ($P>0.05$) (Table 1).

Effect of body condition score on the onset of ovarian and oestrous activity

The HH and LH kids experienced the onset of ovarian activity and puberty at an earlier age than the LL animals ($P<0.01$) (Table 1). The differences in BW and BCS between the groups at the onset of the experiment were maintained at these times (Table 1).

The first ovarian activity was characterised by a higher incidence of silent ovulations of short or normal duration in the LL group (50%) than in the HH group (12.5%) ($P<0.05$). No effect of experimental group was observed on ovulation rate (Table 1).

Discussion

The recorded date of onset of breeding activity shows that Autumn-born Blanca Andaluza female kids enter puberty in the following breeding period. This agrees with that reported by our group for Payoya goat kids born in Autumn (Zarazaga et al., 2009); the latter animals reached puberty in the following Autumn, at the same time as those born in Winter (they were therefore slightly older and heavier). Similarly, Papachristoforu et al. (2000), working with Damascus goats, Freitas et al. (2004) with Anglo-Nubian and Saanen goats under tropical conditions, Deveson et al. (1992) with Saanen goats in Europe, Greyling and Van Niekerk (1990) with Boer goat kids, and Delgadillo et al. (2007) with Creole goat kids, observed puberty to begin during the first breeding season after birth. Together, these results suggest a strong effect of season on the onset puberty in goats, with the photoperiod apparently playing a key role (Chemineau et al., 1988).

Gordon (1975) indicated that puberty in farm animals requires a critical body weight be reached. For goats, Smith (1980) reported this to be 60-75% of the mature body weight. However, North Moroccan Indigenous goat kids reach puberty at an estimated body weight of 17.6 kg, i.e., 46% of their adult weight, similar to that recorded for Saanen (Freitas et al., 2004) and Payoya goats (Zarazaga et al., 2009). Similarly in the present experiment given that the adult body weight of a Blanca Andaluza goat is around 60kg, the present LL and LH kids entered puberty at 39.6±0.8% of their adult weight. This suggests that, for this breed, the critical BW for initiating puberty is lower than the 50% of the mature body weight. The HH kids reached this critical weight before the beginning of the experiment, but they did not enter puberty because of the photoperiod - the main factor controlling its onset.

The mean date of onset of puberty (September 20th±5.1 days) was earlier than that reported by Zarazaga et al. (2009) for Payoya goat kids born in the same season (October 21st±5.5 days). This might be explained by breed differences. In this earlier work, the animals entered puberty when their BW was 28.3 kg and their BCS 2.71. While the females of the present LL group entered puberty at a date similar to that recorded for the above Payoya kids, they did so with a lower BW that it has been demonstrated that could be a limiting factor and lower BCS.

The results show BCS plays a critical role in the onset of puberty in Blanca Andaluza goat kids, independent of BW. The LH kids entered puberty at the same time as the HH kids, and all of these before the LL kids. These results agree with previous findings for Payoya goats reported by Zarazaga et al. (2009). In the latter work, BW did not modify the time of onset of puberty, but kids of higher BCS began reproductive activity earlier. In that study, groups of animals of different BCS were established independent of nutrition level. In the present work, the effects of BW and BCS were independent, and not confounded as may have been the case in the above study (i.e., Zarazaga et al., 2009). Thus, the differences seen between the LH/HH kids and LL kids might be explained by leptin secretion. An increase in plasma leptin during the onset of puberty probably acts as a signal to move towards sexual maturity (Vitali et al., 2005; Foster and Jackson, 2006); this signal appeared to come earlier in the kids of higher BCS.

No effect of BCS or BW on ovulation rate was observed at puberty. This contrasts with previous results obtained by our group when working with Payoya kids born in the same season (Zarazaga et al., 2009). In that experiment, no effect of nutrition or BCS was observed on ovulation rate, but a clear effect of BW on this variable was observed. The reason could be that these heavier animals were more fully developed, allowing them to attain an ovulation rate similar to that of adult goats. However, in the present experiment, despite the HH kids having a heavier body weight than the LL animals, no difference in ovulation rate was seen. Breed differences may account for this. Nonetheless, the present animals attained puberty at an earlier age than in this prior work; as a consequence, their endocrine axes may have been insufficiently developed for a high ovulation rate to be achieved.

Conclusion

The present results show that Blanca Andaluza female kids reach puberty in their first natural breeding period after their birth, and that BCS is a determining factor in the onset of puberty, independent of BW.

Conflict of interest statement

None of the authors of this paper has any financial or personal relationship with any person or organisation that might inappropriately influence or bias its content.

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Figure 1: Weekly mean (±SEM) body condition scores (BCS) for the Autumn-born Blanca Andaluza goat kids with initial low BCS and low body weight (BW) (●), low BCS and high BW (□), and high BCS and high BW (■).

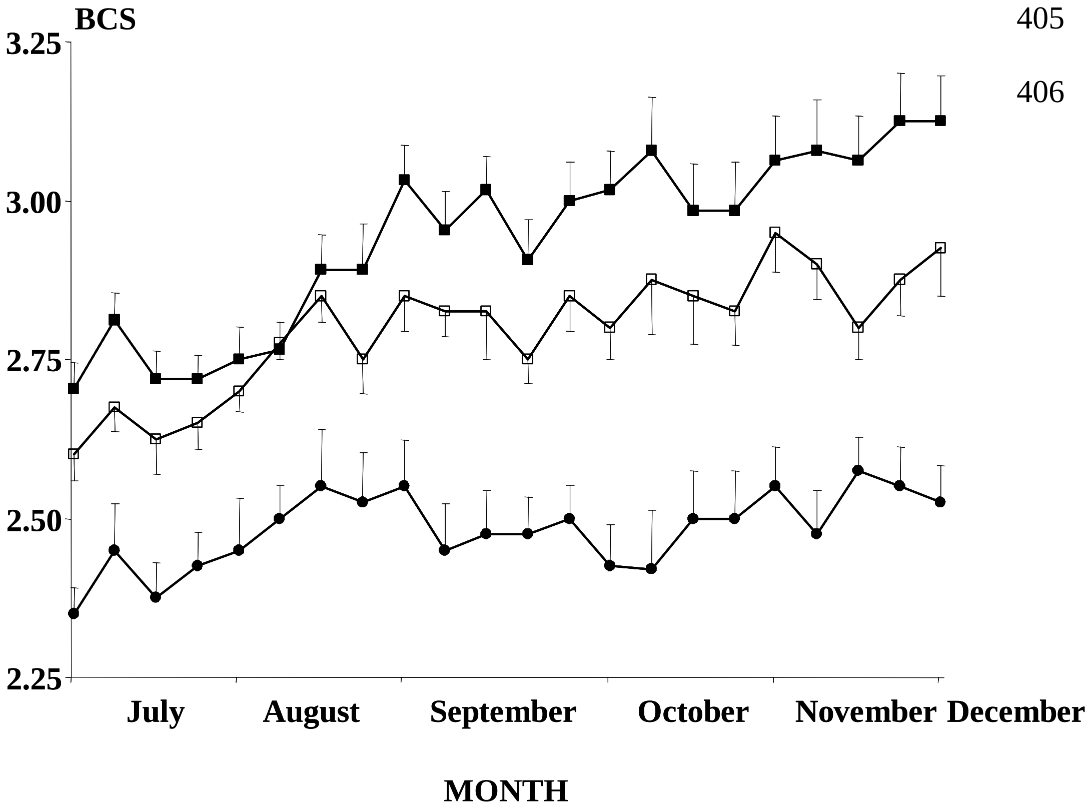

Table 1: Mean of different variables recorded for the Autumn-born Blanca Andaluza goat kids with initial low BCS and low body weight (LL group), low BCS and high BW (LH group), and high BCS and high BW (HH group).

	LL (N=10)	LH (N=10)	HH (N=16)	SEM[a]	P[b]
Initial BW (kg)	21.7b	22.1b	26.4a	0.6	***
Initial BCS	2.35b	2.60a	2.70a	0.03	***
Final BW (kg)	25.7b	28.0b	32.2a	0.8	***
Final BCS	2.53b	2.93a	3.12a	0.06	***
Daily body gain rate (g/d)	27.2	38.4	38.9	6.9	n.s.
Date of ovulation	21st October B	13th September A	31st August A	4.8	***
% adult weight at ovulation	37.8b	40.3b	47.1a	1.1	***
BW at date of ovulation	22.7B	24.1B	28.3A	0.7	***
BCS at date of ovulation	2.48B	2.90A	2.98A	0.05	***
Date of 1st oestrus	25th October B	19th September A	31st August A	5.1	***
% adult weight at oestrus	38.4b	40.8b	46.0a	1.0	**
BW at 1st oestrous	23.1b	24.5b	27.6a	0.6	**
BCS at 1st oestrous	2.45b	2.85a	2.94a	0.05	***
Ovulation rate of 1st oestrus	1.00	1.00	1.06	0.03	ns

[a]Standard error of mean.

[b]: *$P<0.05$; ** $P<0.01$; *** $P<0.001$; ns: not significant, $P>0.05$.

Values with different letters in the same row are significantly different (a, b: $P<0.05$; A, B: $P<0.01$).