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The effect of winter nutrition on growth of young Scottish Red deer (*Cervus elaphus*)

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(With 1 figure in the text)

Compared with European Red deer, Scottish Red deer stags are remarkably small. Previous research has shown that this may be primarily due to nutritional, rather than genetic reasons. The present study tested the hypothesis that poor nutrition, especially during the first winter of life, prevented the stags from reaching their genetic potential size. The study was carried out at Glensaugh Research Station on 20 newly weaned Red deer assigned to either of two groups, one fed a high plane of nutrition during the winter, the other a low plane. The trial began in December 1977 and in May 1978 both groups were released into a 200 acre paddock. In September 1978 some of each group were slaughtered. Despite considerable compensation by the low plane winter nutrition group there were significant differences in live weight, antler length and carcass weight at slaughter. It is considered that Scottish Red deer stags reach the maximum size that the environment can maintain despite this being far below their genetic potential.

Contents

Introduction

Red deer (*Cervus elaphus*) vary considerably in weight throughout their range and Scottish deer are among the smallest. The average mature live weight of a stag from Rhum, is 120 kg (Lowe, 1977), Glenfeshie 120 kg (Mitchell, Staines & Welch, 1977), Glendye 143 kg, Glen Prosen 100 kg and Invermark 133 kg (Staines, 1970). However, stags from Grizedale in northwest England which are of the same native genetic stock as Scottish stags (Lowe & Gardiner, 1974) average 210 kg live weight and may be up to 230 kg (Mitchell & Grant, 1981). Elsewhere in England stags may be even larger but artificial selection has altered the populations genetically (Lowe & Gardiner, 1974) and thus they are not comparable. Stags

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from eastern Europe are the largest of all—up to 350 kg, but slight genetic differences exist between them and Scottish deer.

However, if Scottish deer are fed well from birth, live weights similar to those from England and Europe can be achieved. At the Rowett Institute a 3-year-old stag weighed 196 kg and two 2-year-old stags weighed 160 kg and 185 kg (Blaxter, Kay, Sharman, Cunningham & Hamilton, 1974). Red deer from Scotland which are farmed intensively in New Zealand weighed 160 kg and 135 kg from feedlot and pasture, respectively (Drew, 1976) at 2 years of age. Thus it appears that plane of nutrition is the single most important factor determining body size in Red deer stags.

Scottish Red deer live on the north-western edge of the range of the species (Whitehead, 1972) on exposed hill-land with a very short (May–September) growing season and are often denied their preferred forest habitat (Mitchell, Staines *et al.*, 1977). This unfavourable situation may explain the small size of Scottish Red deer. During the winter and spring stags undergo a period of under-nutrition which is followed by a summer of adequate nutrition during which compensatory growth is possible. This effect would be expected to be most marked in young, growing animals during their first year as skeletal growth does not stop during this time (Blaxter *et al.*, 1974; Mitchell, McCowan & Nicholson, 1976). If growth is unduly retarded by poor nutrition during the long winter and spring and if, during the short summer, the animals fail to compensate fully for this winter check before skeletal development ceases, at about 18 months of age, then the deer will be limited skeletally to a body size well below their genetic potential. The aim of this study was to test the hypothesis that poor nutrition in the winter and subsequent failure to catch-up might be responsible for small Scottish Red deer. This study was a field experimental parallel to a penned experiment at the Rowett Institute (Suttie, 1981).

Materials and methods

Twenty-one male calves born at Glensaugh Experimental Deer farm, Kincardineshire during June and July 1977 and reared by their dams, were allocated randomly to 2 groups on the 1st of December 1977, when about 23 weeks of age. The groups were housed indoors in separate pens and bedded on straw.

The first group (10 calves) was fed 1·1 kg/head daily of a mixture of 90% loose barley and 10% pelleted fish meal protein and vitamins and the second group was fed 0·23 kg/head of the same diet daily. Second cut meadow hay and water was offered to appetite. From April 1978 (43 weeks of age) the first group was fed 1·6 kg/head daily and the second group 0·45 kg/head daily of the barley diet due to an increase in appetite of the first group at the time. Throughout this paper the first group will be referred to as the first winter high (FWH) group and the second group the first winter low (FWL) group. One stag from the FWH group escaped leaving group sizes of 9 and 11 for the FWH and FWL groups, respectively. In mid-May 1978 (46 weeks of age) at the start of the plant growth season at Glensaugh both groups were released into the same 200 acre paddock. The vegetation consisted mainly of *Calluna/Eriophorum* with smaller areas of *Calluna* dominant and *Vaccinum/Calluna* but there were areas of *Agrostis/Festuca* grassland around the wetter places. While indoors, stags were weighed and the hind foot length (a measure of skeletal development) and antler length were measured at three week intervals. After release into the paddock these measurements were taken at irregular intervals.

In Autumn when the stags were about 67-weeks-old they were gathered and on the 12 September 1978, 12 of them, 7 from the FWH group and 5 from the FWL group were slaughtered. The slaughter procedure was as follows. All stags were first weighed and hind feet and antlers measured. They were then shot with a captive bolt pistol and bled out into a tray. The carcass was weighed in the skin but

TABLE I

Growth rates in kg/week or cm/week (mean ± standard error of the mean) for the first winter high group (FWH) and first winter low group (FWL) between weeks 23–46 and 46–67

Growth rates	Age	
	Weeks 23–46	Weeks 46–67
Live weight gain (kg/week)		
FWH	0·99 ± 0·04 (9)	0·01 ± 0·09 (7)
FWL	0·23 ± 0·06 (11)	0·54 ± 0·05 (8)
t-test	10·7**	5·05**
Hind foot length (cm/week)		
FWH	0·20 ± 0·01 (9)	0·10 ± 0·01 (8)
FWL	0·11 ± 0·01 (11)	0·13 ± 0·01 (8)
t-test	6·64**	2·31*

The number in each group is given in parenthesis.
* Indicates $P<0{\cdot}05$ and ** indicates $P<0{\cdot}001$.

with the alimentary tract, liver, heart, lungs, kidneys, reproductive tract, head and lower legs removed. The alimentary tract, kidneys and surrounding fat, both testes, the lower jaw, the left foreleg and the antlers were bagged and labelled and taken to the laboratory for further analysis.

In the laboratory the alimentary tract was weighed full and empty, the kidney fat index (Riney, 1955) was determined, the testes were weighed and a section fixed in Bouins solution, sectioned and stained with haemotoxylin and eosin, the lower jaw was measured from the outer ridge of the incisiform canine socket to the posterior angle of the jaw (Mitchell & Brown, 1974), the antlers were weighed and the specific gravity determined by dividing the oven dry weight of the antlers (100°C for 48 h) by the weight in air minus the weight in water and the metacarpal marrow fat was estimated using the technique of Atkinson, Fowler, Garton & Lough (1972). This technique involves shaking a weighed piece of tissue in known volumes of methanol and chloroform at a pH <7. A fixed volume of solvent containing extracted fat is drawn off and dried down. The fat is then weighed and fat content of tissue calculated.

Significance was determined by using the unpaired 2-tailed Student's *t*-test.

Results

Table I shows the growth rates during different stages of the study. During the winter, weeks 23–46 the FWH group grew significantly faster and during the catch up phase the FWL group grew significantly faster. The FWH grew faster before released from pens ($t=10{\cdot}1$, $P<0{\cdot}01$) than after, and the FWL grew faster after they left the pens ($t=4{\cdot}18$, $P<0{\cdot}001$) than before. The differences in live weight are compared in Table II; there was no significant difference in live weight at the start of the study but despite compensatory growth there were significant differences after 65–69 weeks.

Hind food length grew significantly faster in the FWH group compared with the FWL group before release from pens and vice versa afterwards. However, although the FWH grew more slowly after they left the pens ($t=6{\cdot}92$, $P<0{\cdot}001$) the FWL group did not grow significantly faster ($t=1{\cdot}62$, not significant) after release into the paddock. There was a significant

TABLE II

Live weight (kg) and hind foot length (cm) (mean ± standard error of the mean) for the first winter high group (FWH) and the first winter low group (FWL) at weeks of age 23, 46, 67

	Age (weeks)		
Growth	23	46	67
Live weight (kg)			
FWH	37·0 ± 1·6 (9)	59·7 ± 1·8 (9)	60·9 ± 1·6 (7)
FWL	37·8 ± 1·9 (11)	43·1 ± 1·7 (11)	54·9 ± 2·0 (8)
t-test	0·20 n.s.	6·69**	2·30*
Hind foot length (cm)			
FHW	29·5 ± 0·2 (9)	34·3 ± 0·2 (9)	36·4 ± 0·3 (8)
FWL	30·0 ± 0·3 (11)	32·5 ± 0·4 (11)	35·4 ± 0·5 (8)
t-test	1·18 n.s.	3·92**	1·70 n.s.

The number in each group is given in parenthesis.
n.s. Indicates $P > 0{\cdot}05$, * indicates $P < 0{\cdot}05$ and ** indicates $P < 0{\cdot}001$.

difference at week 46 but this was lost by week 67. However, the FWH group remained larger than the FWL.

Figure 1 shows the antler growth curves for both groups of stags. The antlers of the FWH group were significantly longer at both 46 and 67 weeks of age than the FWL group.

Details of antler weight, specific gravity and carcass characters are presented in Table III. The antlers of the FWH group were significantly heavier but there was no significant difference in specific gravity. Carcass weight, empty body weight, combined testes weight and gut weight/live weight ratio were significantly different.

On the day of the slaughter 3/7 of the FWH group had hard antlers, 1/7 was shedding the velvet and 3/7 were still in velvet. None of the FWL group were in hard antler, 1/5 was shedding the velvet and 4/5 were in velvet.

The sections of testis were examined at ×400 magnification. All sections showed all stages of spermatogenesis and all but one had sperm in the epididymis; the exception, a member of the FWH group, had a very much smaller combined testis weight (12·6 g) than the mean for the group.

Discussion

The pattern of live weight gain is similar to Mule deer *Odocoileus hemionus* (Wood, Cowan & Nordan, 1962), Reindeer *Rangifer tarandus* (McEwan, 1968) and in previous reports of Red deer (Blaxter *et al.*, 1974; Suttie, 1981). A phase of reduced weight gain was shown by the FWH group between weeks 23 and 34 but rapid growth commenced after that. Due to their low plane of nutrition this growth check was extended for the FWL group and despite the rapid growth shown after release on to pasture in May, they could not fully compensate for the winter growth deficit. The FWH group lost weight after release and they took the whole summer to make up this loss of some 10 kg. However, some of the apparent

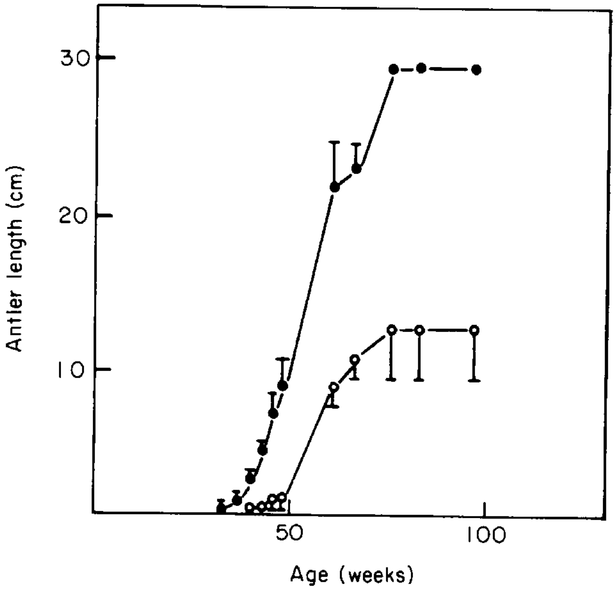

FIG. 1. The changes in antler length of each group. Bars indicate standard error of the mean. At 46 weeks of age the mean ± standard error of the antler length of the FWH group was 6·7 ± 1·0, $n=9$ and of the FWL group was 1·1 ± 0·3, $n=11$; $t=5{\cdot}28$, $P<0{\cdot}01$. At 67 weeks of age antler length of the FWH group was 22·3 ± 2·0, $n=8$, and of the FWL group was 10·1 ± 1·0, $n = 9$; $t = 5{\cdot}45$, $P<0{\cdot}001$. ●——●, FHW; ○——○, FWL.

TABLE III

Mean ± standard error of the mean antler weight (g) antler specific gravity (gDM/ml) and carcass characters for the two groups of stags

	Antler weight (g)	Antler specific gravity (gDM/ml)	Carcass weight (kg)	Empty body weight[1] (kg)	Kill out[2] (%)	Empty gut (kg)
FWH	48·9 ± 7·6 (8)	0·80 ± 0·10 (8)	36·2 ± 1·1 (7)	51·8 ± 1·7 (6)	58·9 ± 0·8 (6)	3·49 ± 0·11 (7)
FWL	18·3 ± 2·9 (10)	0·59 ± 0·08 (10)	32·0 ± 0·8 (5)	46·0 ± 1·6 (5)	57·8 ± 1·6 (5)	3·45 ± 0·17 (5)
t-test	3·69***	1·62 n.s.	2·98**	2·50*	0·62 n.s.	0.02 n.s.
	Gut content (kg)	**Metacarpal fat (%)**	**Kidney fat index (%)**	**Combined testes (g)**	**Jaw length (cms)**	**Gut weight[3] live weight (%)**
FHW	10·0 ± 1·0 (7)	62·4 ± 1·0 (6)	13·5 ± 2·0 (7)	35·6 ± 4·5 (7)	22·1 ± 0·27 (5)	20·5 ± 0·8 (6)
FWL	9·6 ± 0·9 (5)	66·3 ± 5·1 (5)	10·5 ± 1·7 (5)	21·7 ± 1·5 (5)	21·8 ± 0·43 (4)	23·4 ± 0·9 (5)
t-test	0·28 n.s.	0.62 n.s.	1·15 n.s.	2·90**	0·59 n.s.	2·42*

The number in each group is given in parenthesis.
n.s. Indicates $P>0{\cdot}05$, * indicates $P<0{\cdot}05$, ** indicates $P<0{\cdot}02$ and *** indicates $P<0{\cdot}01$.
[1]Empty body weight = live weight − weight of gut contents.
[2]Kill out % = Weight of dressed carcass/live weight × 100.
[3]The ratio of gut weight to live weight = total weight of gut + contents/live weight × 100.

catch-up may be attributed to the change in weight of gut contents as they went from a diet barley to one of hill pasture.

The hind foot continued to grow throughout the winter in both groups as described by Blaxter *et al.* (1974) and Mitchell, McCowan *et al.* (1976). Nonetheless poor winter nutrition restricted skeletal growth rate and a smaller animal resulted. In view of this it is surprising that the differences in hind foot length are not significant; this may be due to small sample size or possible high measurement error if the stag is hard to handle. It is likely that jaw length offers a better measure of skeletal development particularly after 18 months of age as it continues to grow for longer than the hind foot (Suttie & Mitchell, in prep.).

It is superficially surprising that a significant difference in antler weight is not reflected by a significant difference in antler specific gravity, but this is not without parallel. Hyvarinen, Kay & Hamilton (1977) found a significant difference in mean antler weight between two and three to four year old stags but no significant difference in specific gravity. The FWL stags probably sacrificed antler development for skeletal development.

The significant differences in carcass weight and empty body weight between the groups indicate that the differences in live weight are not due simply to the weight of gut contents. Indeed there were no significant differences between empty gut weight nor weight of the gut contents. The significant differences in gut weight/live weight ratio at slaughter suggests that the FWL consumed relatively more forage per kilogram live weight.

The lack of significant differences between the two groups in killing-out percentages, kidney fat index and metacarpal marrow fat together with the suggestion that the FWH group were skeletally larger suggests that the FWH group were larger but not fatter than the FWL group.

The FWH group probably reached sexual maturity faster than the FWL group, antlers were grown earlier as the body weight required for each stage was reached earlier (Suttie & Kay, in press). At the time of slaughter more had hard antlers or were in the process of cleaning their antlers of velvet than the FWL group. The testes of the FWH group were larger at slaughter than the FWL group but almost all showed all stages of spermatogenesis.

Having shown experimentally that poor winter nutrition during the first winter results in a significantly smaller deer at 15 months, how does this affect a stag on the hill? The strong correlation between dominance achieved as a result of larger body size and reproductive success (Gibson & Guiness, 1980) underlines the necessity for stags to grow as large as they can. The fact that the potential for growth is highest during the first years of life means that stags must grow as large as they can as fast as they can. However, the environment places severe restrictions on this growth and it is likely that stags grow to the maximum size their environment can maintain. This is confirmed in the present study by the fact that the FWH group failed to grow when released on the hill in May, indicating severe feed restriction; they had presumably reached a weight-for-age that the environment could not maintain. If this improves even when they are adult they still may show an ability to compensate as Robinette, Baer, Pillmore & Knittle (1973) showed for Mule deer. Animals may only achieve their genetic potential size if the environment is ideal throughout their lives; on the Scottish hill the environment is far from ideal for stags but they adapt to it well and attain the maximum size possible.

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