Chapter 5:

The Effects of Treadmill Exercise on Physiological Responses of Male and Female Goats

5.1 Introduction

Preliminary experiments in the field (Bali-Indonesia) on the DAP of Bali-cattle and swamp buffalo (Chapter 4) showed that males were less heat tolerant than females. In Bali-cattle for example, RR, RT and ST were higher in males than females (66 vs 61/min., 39.4 vs 39.2°C and 37.6 vs 37.1°C respectively); comparable values for buffaloes were 54 vs 46/min., 39.2 vs 38.9°C and 37.0 vs 36 5°C respectively. In an earlier comparison of cattle walking outdoors in Australia, MURRAY and YEATES (1967) also reported that males reacted more than females, with both RR and RT highest in males (152 vs 146/min. and 40.7 vs 40.1°C respectively). In each of the above studies, however, the heat stressors (e.g. environmental temperature, relative humidity, air velocity, infra-red and ultra-violet radiation, time of day and duration of exercise) all varied simultaneously, and because of this confounding the individual effects could not be seperated.

In order to study those patterns more accurately and measure parametres that could not be measured in the field, a series of detailed experiments were undertaken in the climate laboratory with controlled temperature and exercise on a treadmill. The results of previous studies were also confounded by differences in such factors as body weight, body condition and plane of nutrition. Specific experiments were thus included in this Chapter to individually examine these possible effects.

Since there were no Bali-cattle and swamp buffalo available for use in the animal climate laboratory at the Animal Science Department, UNE, Armidale, goats were chosen as an experimental animal model. Goats belong to the family of ruminant animals, and are spread worldwide especially in Developing Countries such as Indonesia. Both milk (Saanen) and meat (Toggenburg and Anglo Nubian) type goats were available.

In this chapter experiments are reported which examine the responses of male and female goats which: differed in both body weight and feed intake (the normal field

situation; Experiment 5), were simila· in body weight and fed either at maintenance (Experiment 6) or below or above mair tenance (Experiment 7), and were exercised at 20, 30 and 40°C (Experiment 8).

5.2 Experiment 5: Physiological Re:ponses to Exercise in Male and Female Saanen Goats at Differen: Body Weights and Feed Intakes

5.2.1 Materials and Methods

Two male (LW 99 and 100 kg) and two female (LW 49 and 50 kg) Saanen goats, similar aged of 3.4 ± 0.2 years, were exercised for 2 h/d at 20 ± 1° (control) and 30 ± 1°C (treatment). They were fed a basal diet (D.M. of 1.5% of LW) except during exercise on the treadmill at 3.8 km/h, when neither feed nor water were on offer.

At 20°C, exercise was for 3 days and a 7 (times of measurement during exercise at 20 minutes intervals) x 3 (days) x 2 (sexes) x 2 (replicates) factorial design was adopted. At 30°C exercise was continued for 12 consecutive days with 1 day resting in between, so a 12x7x2x2 factorial resulted. Within days and sexes, animals were exercised in random order. RT, RR and ST were monitored as described previously.

5.2.2 Results

Experiment at 20°C:

Respiration rate (RR):

In the absence of significant interactions, there were no significant differences between the sexes in RR (30.8 ± 0.7/minute). For RR there were significant effects of time during exercise ($P < 0.01$), but the absolute increases were small (16/minute). Differences between days for RR were also significant; values declined from 33 to 26/minute between days 2 and 3 ($P < 0.05$).

Rectal temperature (RT):

There were no significant differences between the sexes in RT (39.9 ± 0.1°C) and no significant interactions. For RT there were significant effects of time during exercise ($P < 0.01$), but the absolute increases were small (0.5°C). Differences between days for RT were non significant.

Table 14. Mean RR, RT, ST of male and female Saanen goats during treadmill exercise at 3km/h and 20°C environmental temperature

Sex:	male	female	SEM	Level of significance
RR:	31.5a	30.1a	0.1	ns
RT:	39.9a	39.8a	0.002	-
RST:	37.1a	37.1a	0.003	ns
LST:	36.9a	36.8a	0.004	ns
EST:	36.9a	36.7b	0.01	*

Day :	D1	D2	D3	SEM	Level of significance
RR:	32.7a	33.1b	26.6c	0.1	*
RT:	39.9a	39.9a	39.8b	0.004	ns
RST:	37.0a	37.2b	37.2b	0.01	*
LST:	36.9a	36.9a	36.8a	0.01	ns
EST:	36.9a	36.8a	36.7a	0.01	ns

Times: (min)	0	20	40	60	80	100	120	SEM	Level of significance
RR:	20.4a	26.0b	28.0b	33.8c	34.3c	36.6c	36.6c	0.3	**
RT:	39.5a	39.7b	39.8c	39.9d	40.0e	40.0e	40.0e	0.010	*
RST:	36.8a	37.0b	37.1c	37.2d	37.3e	37.3e	37.3e	0.01	*
LST:	36.7a	36.7a	36.8ab	36.9bc	37.0cd	37.0cd	37.1d	0.01	*
EST:	35.9a	36.3b	36.8c	37.0cd	37.1cd	37.1cd	37.2d	0.03	*

Values within lines with dissimilar superscripts differ significantly (ns=non significant; -P < 0.1; *P < 0.05; **P < 0.01

Skin temperature (ST):

There were no significant interactions for ST, but the differences between the sexes at each of the 3 sites (rump: 37.1 ± 0.0°C; loin: 36.9 ± 0.1°C; ear: 36.8 ± 0.1°C) were significant ($P < 0.05$). ST at all 3 sites increased with time ($P < 0.05$), but in each case the

absolute increase was small (< 1.3°C) and final values ranged from 37.1 to 37.3°C (Table 14).

Experiment at 30°C:

Respiration rate (RR):

For RR there was a significant sex x day interaction ($P < 0.01$; Fig. 12), with values for males increasing progressively from day 1 to 12, while in females RR declined from day 3 after an initial increase. The effects of sex x time on RR were also highly significant (Fig. 12), males recorded significantly higher values than females, the differences averaging 28, 71, 106, 125, 134 and 137/min after 20, 40, 60, 80, 100 and 120 min of exercise respectively. By the end of 2h of exercise, males were regularly exhibiting open-mouthed panting, tonguing and excessive salivation.

Rectal temperature (RT):

In the absence of significant interactions, the main effect for RT indicates significant differences between the sex; males having lower values (39.8 vs. 40.0°C; $P < 0.01$; Table 15) than females. The effects of time were both highly significant, and of greater magnitude than at 20°C (ie. increases of 1.3°C RT). By the end of 2h of exercise, males were regularly exhibiting open-mouthed panting, tonguing and excessive salivation. Between days, RT differed significantly ($P < 0.01$); values decreased from 39.8 to 39.4°C between days 9 to 12 (Table 15).

Skin temperature (ST):

The day x sex interaction for loin ST was significant ($P < 0.05$; Fig. 12), females had significantly higher values than males on days 2, 3, 4, 6, 7, 9, 10 and 11. Between days, ST in females increased significantly from day 1 to 4 (from 37.3 to 38.1°C) and then declined to a plateau level until day 12 of about 37.5°C. In males the highest loin ST was recorded on day 6 (37.8°C) and values then decreased to a plateau level of about 37.3°C between days 7 and 12.

No significant interactions were found in either RST or EST and while there were significant differences between the sexes at both the rump and ear sites (female > male), but the absolute differences were only 0.1°C (Table 14). Both RST and EST increased progressively with time, by 1.2 and 1.5°C in 2 hours respectively ($P < 0.001$; Table 15).

Table 15. Mean RT, RST and EST of male and female Saanen goats during treadmill exercise at 3 km/h and 30°C environmental temperature

Sex:	male	female	SEM	Level of significance
RT:	39.8a	40.0b	0.002	**
RST:	37.6a	37.7b	0.002	*
EST:	37.5a	37.6b	0.004	*

Day :	D1	D2	D3	D4	D5	D6	SEM	Level of significance
	D7	D8	D9	D10	D11	D12		
RT:	39.9de	40.2g	40.4h	40.1fg	40.0ef	40.2g	0.01	**
	40.0ef	39.6b	39.8cd	39.7bc	39.6b	39.4a		
RST:	37.5bc	37.9d	38.1e	38.0de	37.6c	37.9d	0.01	**
	37.6c	37.3a	37.5bc	37.4ab	37.4ab	37.6c		
EST:	37.2a	37.5abc	37.8def	38.0f	37.6bcd	37.9ef	0.02	**
	37.7cde	37.3a	37.2a	37.4ab	37.3a	37.6bcd		

Times: (min)	0	20	40	60	80	100	120	SEM	Level of significance
RT:	39.1a	39.5b	39.9c	40.0c	40.2d	40.3de	40.4e	0.01	***
RST:	36.9a	37.3b	37.6c	37.8d	37.9de	38.0ef	38.1f	0.01	***
EST:	36.5a	37.2b	37.5cd	37.7df	37.9fg	37.9fg	38.0g	0.01	***

Values within lines with dissimilar superscripts differ significantly (*P < 0.05; **P < 0.01 and ***P < 0.001)

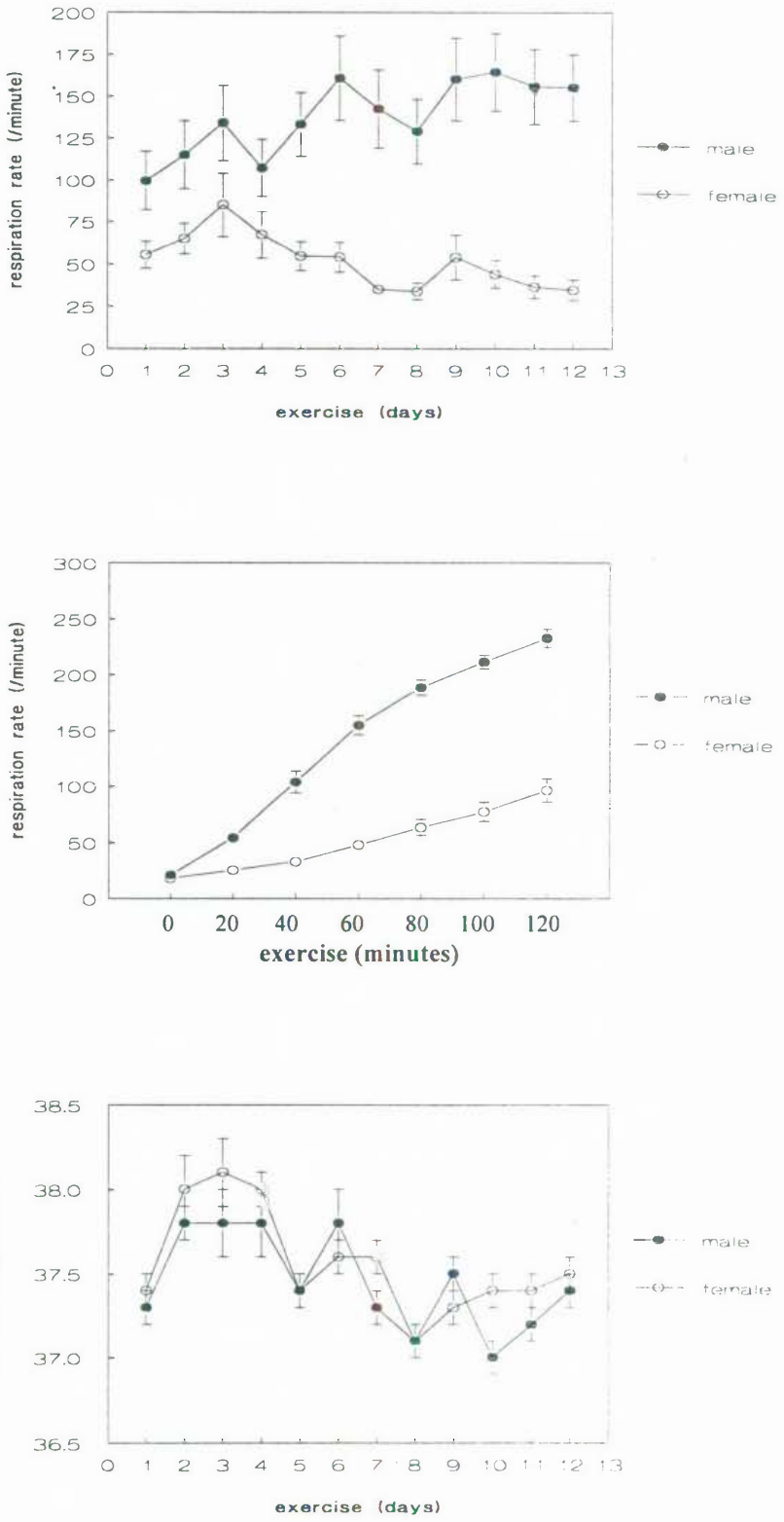

Fig. 12 Mean RR and LST of Saanen goats during treadmill exercise at 3 km/h and 30°C environmetal temperature

5.3 Experiment 6: Physiological Responses in Male and Female Saanen Goats at Similar Body Weights and Fed at Maintenance

5.3.1 Materials and Methods

Two different pairs of male and female Saanen goats (males aged 2.5 years and females 3.5 years), all weighing 30 kg, were employed. The animals were fed 600 g pelleted ration/d, an amount which trials showed would maintain LW. Animals were exercised for 2 hours every day for 3 days and measurements were taken at 20 minute intervals. A 7x3x2x2 (7 times of measurement, 3 days with 1 day resting in between, 2 sexes and 2 animals of each sex) factorial design was used.

5.3.2 Results

Respiration rate (RR):

For RR there was a significant sex x time interaction ($P < 0.001$; Fig. 13), with values for males increasing markedly from time 1 (before exercise) to time 7 (after 120 minutes), while in females RR increased only slightly. Overall mean values of RR were 248 and 67/min in male and female respectively after 120 minutes. Between days RR did not differ significantly ($P > 0.05$).

Rectal temperature (RT):

In the absence of significant interactions, RT differed significantly between days ($P < 0.05$; Table 16), and declined gradually from 40.4°C on day 1 to 40.0°C on day 3. At different times of exposure, RT increased significantly ($P < 0.001$) to reach an overall mean of 40.9°C after 120 mins, and did not differ significantly ($P > 0.05$) between the sexes.

Skin temperature (ST):

The time x sex interaction on ST was also significant ($P < 0.01$; Fig.14), values for males were higher than females, however the differences were small in magnitude (a

maximum of 0.3°C at 120 minutes) and it was concluded that this interaction did not compromise interpretation of the main effects. For RST there were significant effects associated with the time x sex ($P < 0.05$) interaction (Fig.15), with values for males once again higher than for females with magnitudes of 0.4°C after 2 hr of exercise. Between days EST did not differ significantly ($P > 0.05$; Table 16), however, RST and LST did differ signicantly ($P < 0.05$). With days, RST increased (37.5, 37.8 and 37.9°C respectively on days 1 to 3). The highest LST (37.7 °C) was recorded on day 2, and values then decreased on day 3 to 37.4°C. At different times of exposure, EST increased significantly ($P < 0.001$) to reach an overall mean of 37.7°C after 120 mins. Between the sexes EST did not to vary significantly ($P > 0.05$).

Table 16: Mean RT and EST of male and female Saanen goats during 3km/h treadmill exercise at 30°C environmental temperature and 600 g feed intake

Sex:	male	female	SEM	Level of significance
RT:	40.2a	40.1a	0.03	ns
EST:	36.6a	36.3a	0.2	ns

Day :	D1	D2	D3	SEM	Level of significance
RT:	40.4a	40.1b	40.0b	0.03	*
EST:	36.7a	36.4a	36.2a	0.1	ns

Times: (min)	0	20	40	60	80	100	120	SEM	Level of significance
RT:	38.9a	39.5b	40.0c	40.4d	40.6e	40.8f	40.9f	0.03	***
EST:	33.5a	35.9b	36.4bc	36.8bc	37.3bc	37.5c	37.7c	0.2	***

Values within lines with dissimilar superscripts differ significantly (ns non significant; *P < 0.05; and ***P < 0.001)

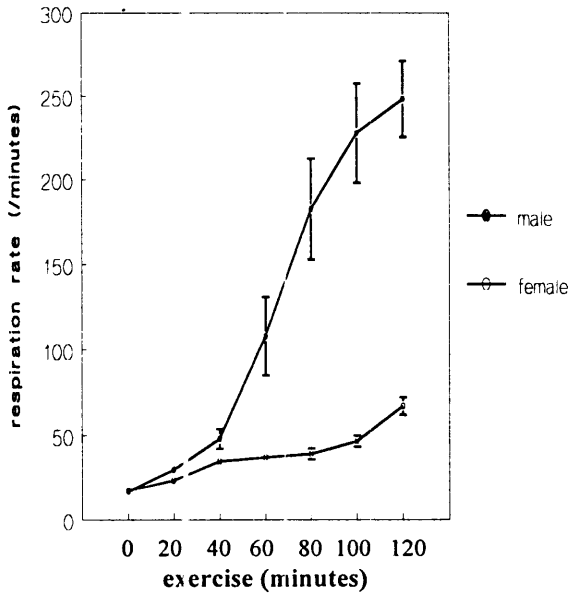

Fig. 13 Mean RR of male and female Saanen goats during 2h of treadmill exercise at 3 km/h and 600 g/d feed intake

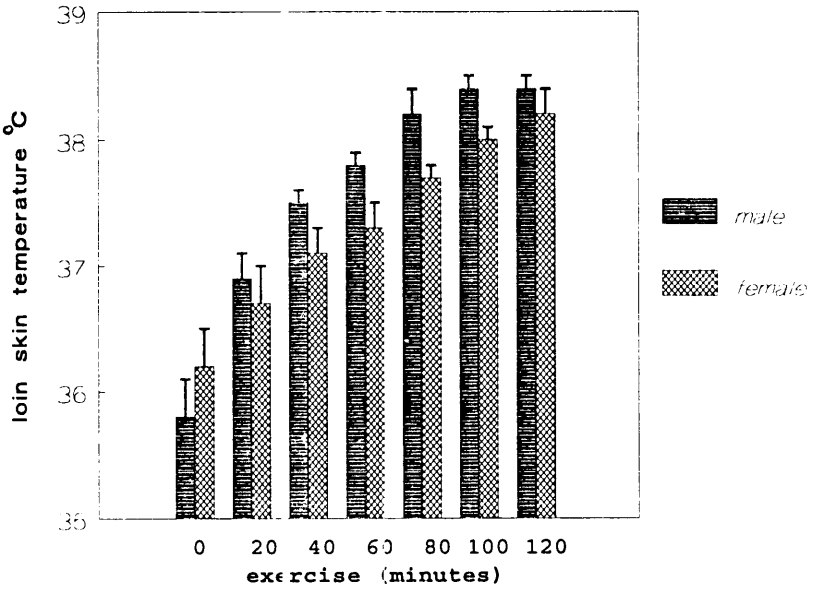

Fig. 14 Mean LST of male and female Saanen goats during 2h of treadmill exercise at 3 km/h and 600 g/d feed intake

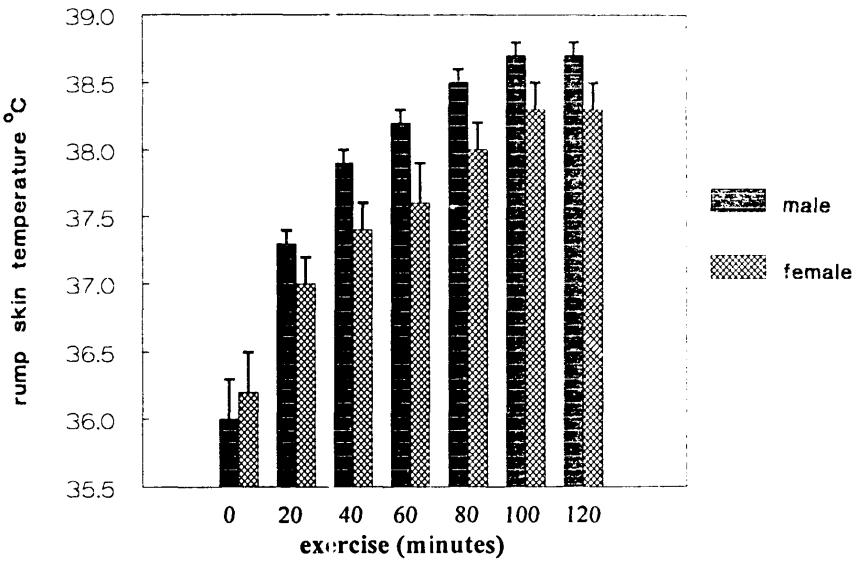

Fig. 15 Mean RST of male and female Saanen goats during 2h of treadmill exercise at 3 km/h and 600 g/d feed intake

5.4 Experiment 7: Physiological Responses to Exercise in Male and Female Saanen Goats at Similar Body Weights but Different Feed Intakes (400 and 1200 g/d)

5.4.1 Materials and Methods

Four animals from experiment 6 (2 males and 2 females) were randomly selected for use. Body weight was maintained at 30 kg by controlled feeding of the individual animals in the pre-experimental period. Exercise was carried-out for 1 hour and 15 minutes on each of 3 days (reduced from the 120 minutes in Experiment 6 in order to limit the RR responses). A split-plot design was employed with 2 levels of feeding (400 and 1200 g/d), 3 days of treatment, two replicates, and two animals of each sex type.

5.4.2 Results

Respiration rate (RR):

For RR there was a significant time x sex ($P < 0.05$; Fig. 16) interaction. Progressive increases were recorded in both males and females, but the males reacted more, and after 1 hr the respective RR were 163.5 and 115.5/min. RR also differed significantly between feed intake levels, with values being much lower at 400 g/d intake than at 1200 g/d (mean values of 38 vs 110/min respectively; $P < 0.001$). There were significant differences between days in RR ($P < 0.05$), but the differences were small (70, 74 and 77/min on days 1, 2 and 3 respectively).

Rectal temperature (RT):

There was a significant feeding level x sex interaction ($P < 0.05$) in RT; once again values for the male were higher in comparison to the female, and in both feeding regimes. At the 1200 g/d feeding level the RT in males and females were 40.0 and 39.7°C respectively (Fig. 17). With days, RT did not to differ significantly ($P > 0.05$). However, with time there were significant effects ($P < 0.001$); values increased progressively from 38.8 to 40.2°C during the 1h of exercise. With time, RT increased progressively and significantly ($P < 0.001$), with a mean magnitude of 1.4°C after 1h exercise.

Skin temperature (ST):

For both RST and LST there were significant ($P < 0.05$) interactions between feeding level x sexes (Figs. 18 and 19). In both cases values were higher for females than males at the 400g/d feeding level (both N.S.), but at 1200g/d feeding the reverse was true ($P < 0.05$).

The time x sex interaction for EST was also significant ($P < 0.05$; Fig. 20). Values for females were uniformly higher than for males, but the difference was greatest before exercise (time 0). For EST there were significant differences between feed intake levels, with values being much lower at 400 g/d intake than at 1200 g/d (34.4 vs 35.9°C respectively). Within days EST did not differ significantly ($P > 0.05$). There were,

however, significant differences between days in RST and LST ($P < 0.05$), but in each case the differences were small (eg RST were 37.0, 36.9 and 37.2°C and LST were 36.9, 36.9 and 37.2°C on days 1, 2 and 3 respectively). With time, both RST and LST increased progressively and significantly ($P < 0.001$). Before and after 1h of exercise the values in RST were 36.1 and 37.7°C, while in LST they were 36.2 and 37.6°C.

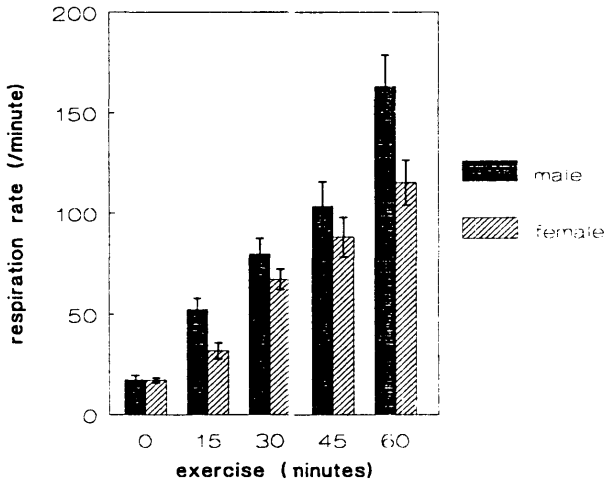

Fig. 16 Mean RR of male and female Saanen goats during exercise (mean of the 3 days) on a treadmill at 3 km/h

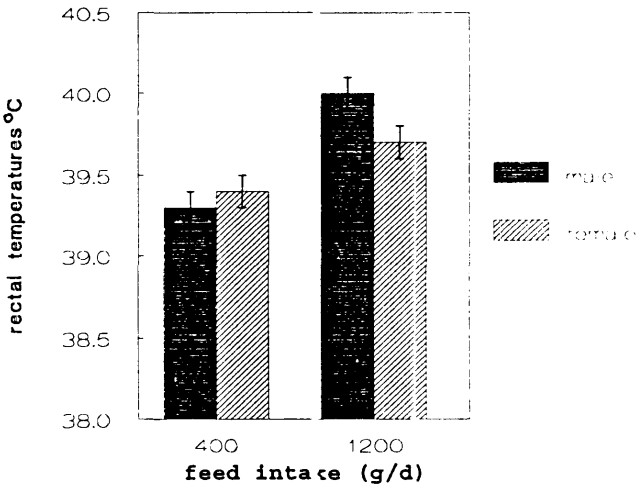

Fig. 17 Mean RT of male and female Saanen goats during treadmill exercise at 3 km/h speed and at either 400 or 1200 g/d feed intake

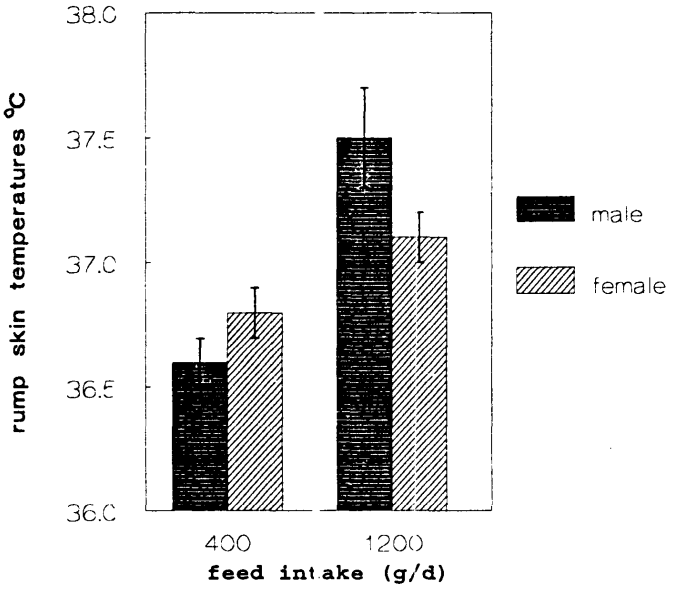

Fig. 18 Mean RST of male and female Saanen goats during treadmill exercise at 3 km/h and at either 400 or 1200 g/d feed intake

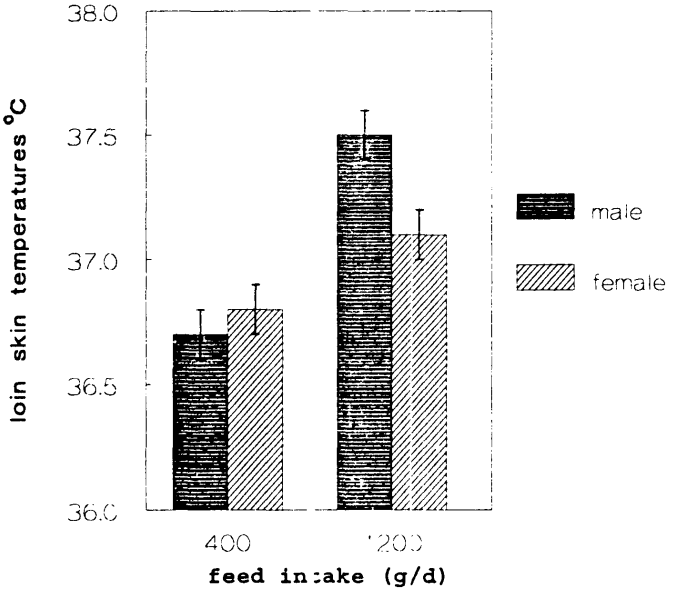

Fig. 19 Mean LST of male and female Saanen goats during treadmill exercise at 3 km/h and at either 400 or 1200 g/d feed intake

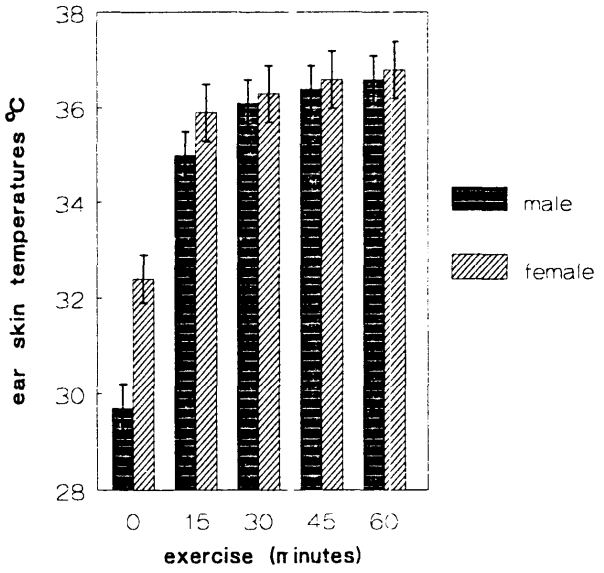

Fig. 20 Mean EST of male and female Saanen goats during 3 days of treadmill exercise at 3 km/h and at either 400 or 1200 g/d feed intake

5.5 Experiment 8: Physiological Responses During Exercise in Male and Female Saanen Goats at Temperatures of 20, 30 and 40°C

5.5.1 Materials and Methods

Two male (66.6 ± 3.4 kg live weight) and 2 female (47.8 ± 0.5 kg live weight) Saanen goats were employed, and each was fed a basal diet at the rate of 1.5% of body weight. A 2x2x3x3x4 factorial design (2 animals of each sex; 2 sexes; 3 different environmental temperatures: 20, 30 and 40°C; 3 days with 1 day resting in between and 4 measurements at intervals of 10 minutes during exercise) was used.

5.5.2 Results

Respiration rate (RR):

For RR there was a significant sex x time interaction ($P < 0.001$; Fig. 21). Values increased progressively with time, and were higher for males than females. By the end of

30 mins of exercise the respective values for males and females were 164.2 vs 103.3/min. Between temperature levels, RR differed significantly, increasing gradually with rising temperature (39.6, 62.0 and 90.4/min; $P < 0.001$). Between days, RR did not differ significantly ($P > 0.05$).

Rectal temperature (RT):

For RT there was a significant sex x time interaction ($P < 0.01$; Fig. 22). Values increased progressively with time, and were higher for males than females. By the end of 30 mins of exercise the respective values for males and females were 40.1 vs 39.7°C. Between temperature levels, RT differed significantly and gradually decreased with increasing temperature levels (from 39.4 to 39.2 C ; $P < 0.05$). Between days, RT did differ significantly, but the differences were small and mean values averaged 39.4, 39.4 and 39.2°C on days 1, 2 and 3 respectively ($P < 0.05$).

Respiratory moisture loss (RML):

For RML there was a significant sex x time interaction ($P < 0.001$; Fig. 23). Values increased progressively with time, and were both higher and increased faster in males than females. By the end of 30 mins of exercise the respective values for males and females were 606.5 vs 375.3 mg/min. Between temperature levels, RML differed significantly ($P < 0.001$), increased gradually with rising temperature with values 263.9, 310.5 and 346.6 mg/min at 20, 30 and 40°C respectively. Between days, RML did not differ significantly ($P > 0.05$).

Packed Cell Volume (PCV):

Between times, sexes and temperature levels, PCV differed significantly ($P < 0.01$, $P < 0.05$ and $P < 0.01$ respectively), however, on different days it did not differ significantly ($P > 0.05$). During 30 minutes of exercise the PCV decreased from 35.9 to 31.8%. Values for males were higher than for females (34.7 vs 32.9%), and they

decreased gradually from 35.2, to 33.3 and 32.9% as temperature increased from from 20 to 30 to 40°C (Table 17).

Table 17: Mean PCV (%) in male and female Saanen goats during treadmill exercise at 20, 30 and 40°C environmental temperature

	PCV (%)			SEM	Level of significance
Time (0-30 mins)	35.9a	31.8b		0.06	**
Sex (males and females)	34.7a	32.9b		0.06	*
Day (1-2)	33.7a	33.8a		0.06	ns
Temperature level (20, 30 and 40°C)	35.2a	33.3b	32.9c	0.09	**

Values within lines with dissimilar superscripts differ significantly (ns=non significant; *P < 0.5; **P < 0.01)

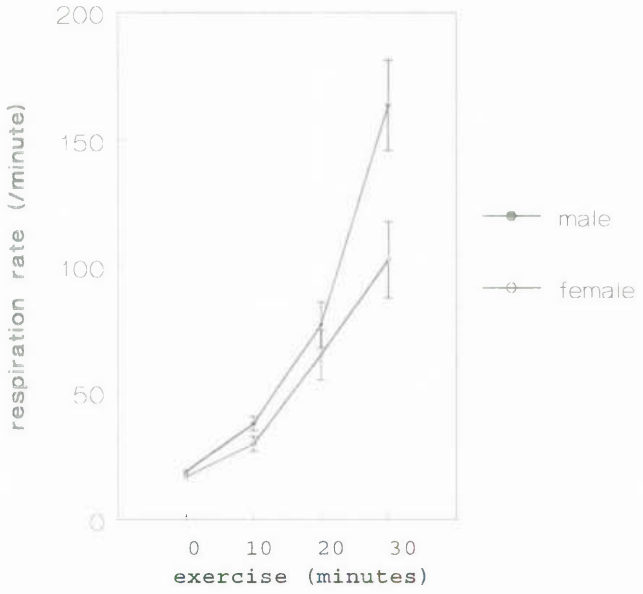

Fig. 21 Mean RR (/minute) of male and female Saanen goats during treadmill exercise at 3 km/h (Means of values at 20, 30 and 40°C)

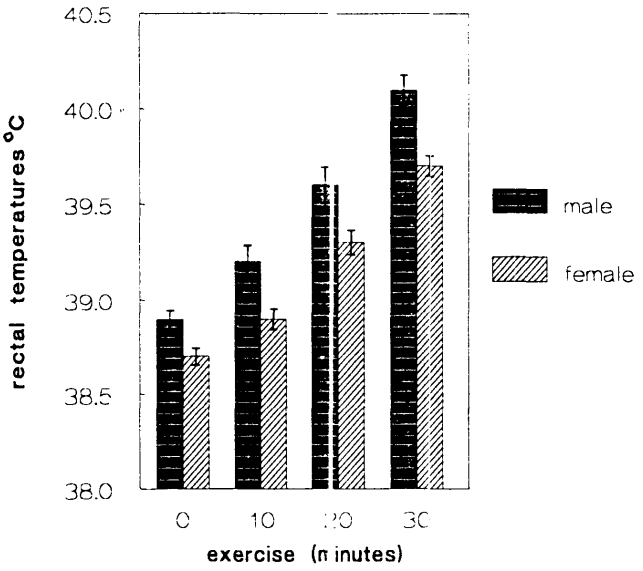

Fig. 22 Mean RT (°C) of male and female Saanen goats during treadmill exercise at 3 km/h (Means of values at 20, 30 and 40°C)

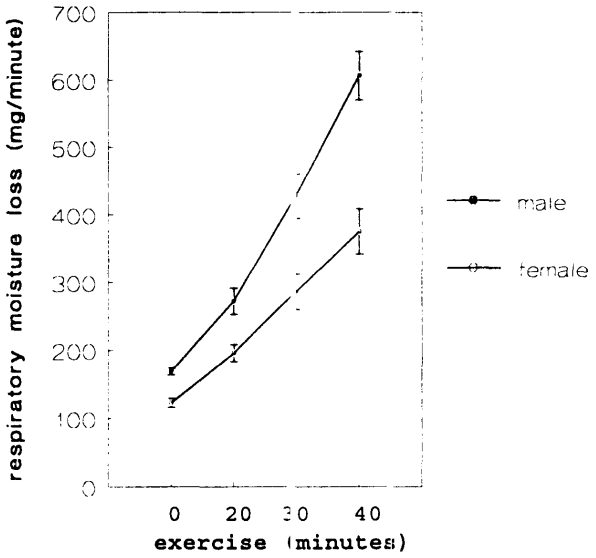

Fig. 23: Mean RML (mg/minute) of male and female Saanen goats during treadmill exercise at 3 km/h (Means of values at 20, 30 and 40°C)

5.6 Discussion

From the overall results of Experiments 5 - 8 it can be concluded that RR in males was higher than in females in every test imposed. As such, these results in goats are in full accord with the results of the preliminary observations on male and female Bali-cattle and swamp buffalo in the field in Bali (Experiments 1 and 2). The current results are also in general agreement with those of MURRAY and YEATES (1967) from walking trials with male and female cattle. These greater thermoregulatory reactions of males could be due, at least in part, to a bigger mass of muscle which would be expected to consume more oxygen and produce more heat during exercise than other tissues (VERNON, 1970). However, the observed differences in heat tolerance during exercise may also be considered as a genuine sex characteristics that could be due to genetic influences operating through factors such as heat production and the efficiency of evaporative cooling, as well as through such aspects as differences in body weight, body condition and food intake. In Experiment 5, even though the animals were of similar age, the results were confounded by differences in body weight (males almost double the body weight of females), and feed intake. These deficiencies were specifically rectified in Experiments 6 and 7, which provide clear evidence that when male and female goats had similar body weights, the superior heat tolerance of females (as compared to males) was maintained. Live weight, per se, can thus be seen not to be a major factor in the differences between males and females in their responses to exercise.

Result at different levels of feed intake (Experiment 7) clearly revealed that animals on higher intakes experienced more stress (higher RR, RT and ST) than those less well fed, and as such are consistent with previous reports. ROBINSON and LEE (1947) observed that well-fed ewes experienced greater increases in RT and RR in both hot-wet and hot-dry atmospheres (but without exercise) than those on a maintenance diet. Such differences in response between feeding levels could be due to relatively more energy being consumed (and heat produced) on high plane than on low-plane diets. For example, GRAHAM *et al.* (1959) found that sheep fed at low (600 g), medium (1200 g) and high (1800 g) levels produced heat at rates of 6, 8 and 10 KJ/d

respectively, and JUDSON *et al.* (1976) reported that the entry rate of blood glucose was 0.44 ± 0.03 mmol/min in sheep at rest, while during exercise it increased to 0.84 ± 0.004mmol/min. Similar patterns have been reported by PURWANTO *et al.* (1993) in dairy cattle and HARMAN and PETHICK (1994) in sheep.

From the current results it can also be clearly concluded that the higher the ET, the more stressed the goats became (Experiment 8). These findings are in close agreement with SIQUEIRA *et al.* (1993), who reported that sheep kept in the sun had higher RT and RR than those in the shade. Such differences are associated with different radiant heat loads (PARER, 1963), which BLACK (1956) indicates may be as high as 5-8 MJ/m²/h for direct sunlight at ground level in summer.

The overall conclusions to be reached from the work reported in this chapter are that:

1. Males were more stressed by exercise than females.
2. This disadvantage for the male was not primarily a consequence of their greater live weight.
3. Animals (both sexes) fed at high levels (2x maintenance) suffered more stress during exercise than those fed less (either at maintenance or 2/3 of maintenance).
4. Intolerant animals of either sex (ie. those with higher RR and RT) had higher RML than tolerant ones.

Further detailed experiments, reported in the following section (Chapter 6), are required to determine whether the differences referred to in 4. above also occur on a between-breed basis.