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Are there any differences in bone metabolism of lactating sheep and goats kept on high altitude and lowland pastures

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Abstract
The purpose of this study was to investigate the impact of increased movement on different landscapes of lactating ewes and goats on bone metabolism.
A group of five adult lactating ewes and goats was kept on pasture at 2000 to 2600 m a.s.l. and 400 m a.s.l., respectively. Two ewes and goats were equipped with a GPS receiver in order to calculate daily tracks on the alpine landscape. The milk yield was measured, blood samples were taken and the metatarsus was measured three times with peripheral computed tomography (pQCT).
The ewes walked on average longer distances and covered larger altitude differences. They remained mainly on grass-covered landscapes, whereas the goats stayed in bush-dominated areas. The sheep from both groups revealed an increase in cortical thickness, bone mineral density (BMD) and bone mineral content (BMC). The goats from the lowland group revealed a decrease in BMD, whereas in the goats from the alpine group a decrease in cortical thickness and an increase in BMC was detectable. The goats produced significantly more milk than the sheep. In sheep, there was no lactation induced bone loss detectable compared to the goats which could be partially reduced by increased movement straights.

Keywords: small ruminants, bone metabolism, exercise, lactation, high altitude

Introduction
During lactation, maternal mineral and bone metabolism is altered due to milk production. To meet the high calcium requirements, a reversible demineralisation of bone takes place. Bone loss due to lactation is described in animals (Zeni *et al.*, 1999; Gonen *et al.*, 2005; Liesegang *et al.*, 2006) and in humans (Hayslip *et al.*, 1989; Polatti *et al.*, 1999; Laskey *et al.*, 2010). In humans and in rats the BMD at the end of lactation was significant lower compared to non lactating control groups. A study from Lovelady *et al.* (2009) suggests that exercise may slow bone loss during lactation due to the well known fact that exercise induces an increase in bone size, cortical thickness, cortical bone area, bone mineral content (BMC) and/or bone mineral density (BMD) (Raub *et al.*, 1989; Hiney *et al.*, 2004; Firth *et al.*, 2010). BMD and BMC can be determined by peripheral quantitative computed tomography (pQCT). The content of this study was to investigate the impact of increased movement on different landscapes of lactating ewes and goats on bone metabolism.

Material and methods
A group of five adult lactating ewes and five adult lactating goats was kept on pasture at the ETH research station Alp Weissenstein, Albula, Grissons at 2000 to 2600 m a.s.l (sheep alpine group = SA; goats alpine group = GA). The lowland group, also five adult lactating ewes and goats, was kept on pasture at the ETH research station Chamau, Central Switzerland, 400 m a.s.l. (sheep lowland group = SL; goats lowland group = GL). At the beginning of the experiment, SA were in lactation 98.4± 1.96 d, SL 94.4 ± 5.41 d, GA 72.4 ± 6.75 d and GL 93.4 ± 2.66 d. They were milked twice daily and the milk yield was measured. During daytime, they had access to the pasture for 10 hours. At night, they stayed either in the barn or at the pasture, depending on weather conditions, but always treated the same way on high altitude and in the lowlands. Two ewes and two goats from the alpine-group were equipped with a GPS receiver in order to calculate daily tracks and the movement pattern of the animals. At the beginning of the experiment blood samples were taken from all animals. In addition, the animals were weighed and the left metatarsus of each animal was measured with pQCT. Blood samples were taken and the weight was controlled after two weeks of adaptation period and then again six and eight weeks after the start of the experiment and at the end of the experiment at week 12.

pQCT was performed at the end of the experiment at week 12 and 6 weeks afterwards at week 18. At week 18 also blood samples where taken and the animals were weighed. The experiment is divided in the experimental period (week 1 to week 12) and the post experimental period (week 12 to week 18). In the experimental period, the animals were kept either at the alpine or the lowland pasture. In week 12, they were brought back to the home barn and both groups where kept under the same conditions until week 18, when the final sampling was performed.

Results and discussion

The SA walked on average longer distances and covered larger altitude differences than GA. From the beginning of the experiment, the SA and the GA significantly increased the distances until week 6 and week 5, respectively (Figure 1). In the second half of the experimental period the SA covered significant shorter distances, the distances covered by the GA did not change significantly in the second half of the experimental period. The SA remained mainly on grass-covered landscapes, whereas the GA stayed in areas where bushes dominated.

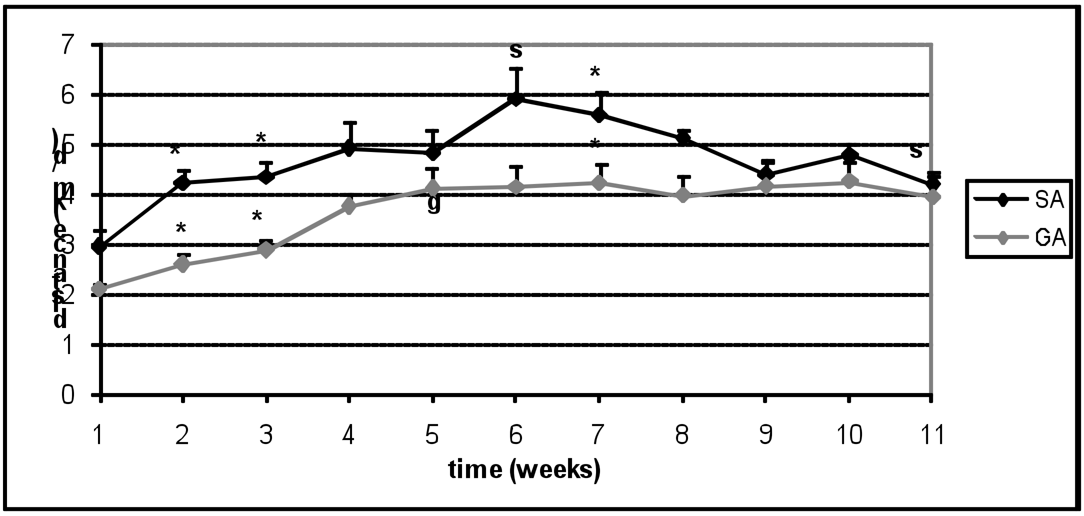

Figure 1: distance travelled by the SA and GA. s = significant difference between timepoints in SA; z = significant difference between timepoints in GA; * = significant group difference (SA versus GA).

The daily movement of the SL and GL can only be guessed. Due to the fact that the pasture of the SL and GL groups was smaller than the pasture of the alpine groups and the landscape includes no hills, these groups had lower movement straights.

The goats compared to the ewes showed a significant higher milk production of 2.15 l/day compared to 0.73 l/day, respectively during the experimental period.

Table 1: results pQCT. Crt_thk = cortical thickness (mm); BMD_D = bone mineral density diaphysis (mg/cm^3); BMC_D = bone mineral content diaphysis (mg/cm); BMD_E = bone mineral density epiphysis (mg/cm^3); BMC_E = bone mineral content epiphysis (mg/cm); w = week; ns = non significant difference between timepoints; * = significant group difference within species

	SA				**SL**				**GA**				**GL**			
	w0	**w12**	**w18**	**sign.**	**w0**	**w12**	**w18**	**sign.**	**w0**	**w12**	**w18**	**sign.**	**w0**	**w12**	**w18**	**sign.**
crt_thk	3.32	3.48	3.58	w0-18	3.11	3.35	3.49	w0-12 w0-18	2.90	2.63	2.58	w0-18	2.96	2.92	2.72	ns
BMD_D	940 *	924	990	w0-18	865 *	886	938	w0-18	826	750	722	ns	811	817	737	ns
BMC_D	198	225	219	w0-12 w0-18	200	230	224	w0-12 w0-18	175	171 *	171	ns	185	187 *	186	ns
BMD_E	560	551	561	ns	532	566	612	w0-18	532	512	516	ns	625	534	465	w0-18
BMC_E	190	217	289	ns	203	220	309	w0-18 w12-18	164	169	238	w0-18 w12-18	160	181	176	ns

The effect on bone in sheep was according to the above mentioned studies on the effect of exercise on bone. No effect of lactation was detectable, probably because the milk production in sheep was low. Goats showed different results in bone metabolism compared to sheep. The calcium concentration in sheep milk (1.93mg/g) is higher than in the goat milk (1.34mg/g) (Park *et al*., 2007), still the goats lost more calcium through the milk, because they produced significantly more milk than the sheep. In addition, within the group, the GA had higher milk yield compared to GL, probably due to the fact that they were on average in lactation for a shorter time than GL. The loss of BMD in the epiphysis in the GL is corresponding to the studies from Zeni *et al.* (1999) and Laskey *et al.* (2010), where a bone loss is described due to lactation located mainly in areas with high trabecular bone. In the GA group, no loss in BMD or BMC in diaphysis or epiphysis was detectable. In contrast, the BMC of the epiphysis was increased significantly. This fact is probably due to increased movement straights on the alpine pasture. On the other hand, the cortical thickness decreased significantly. The reason for this decrease in cortical thickness might be the high milk production, although this would be in contrast to the above mentioned studies, where lactation induced bone loss was observed mainly in trabecular bone. Interestingly, findings of Liesegang *et al*. (2006, 2007) supported the results of the present study since decreased cortical thickness during lactation in goats was also shown in their studies. In the goats, a significant difference between GA and GL in the BMC in diaphysis was observed at week 12. The BMC was significantly smaller in GA compared to GL. The reason for this might be the higher milk production of GA compared to GL. In conclusion, there was no lactation induced bone loss detectable in sheep. In goats, lactation induced bone loss could be partially reduced by increased movement straights.

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