

## Hoof and foot loads for reindeer (*Rangifer tarandus*)

Mauri Nieminen

Finnish Game and Fisheries Research Institute, Reindeer Research, Koskikatu 33A, SF-961 00 Rovaniemi, Finland

**Abstract:** Hoof and foot measurements and body weights were taken from 60 living semi-domesticated reindeer (*Rangifer tarandus tarandus* L.) (8 female and 13 male calves, 10 young females (age 2 yrs), 9 young males (age 2-3 yrs) and 20 adult hinds) at the Kaamanen Reindeer Research Station during the winter 1988. The outline of the hooves and the feet (hoof + dew claws) from front and hind legs were drawn when pressed down on a hard substrate in a natural position. Measurements were taken also from foot prints of 26 wild forest reindeer (*R. t. fennicus* Lönn.) (7 calves, 11 hinds and 8 stags) made on hard snow surfaces in Kuhmo and Salamajärvi national park during 1985-88. Reindeer had bigger hooves and feet on front than on hind legs, and male calves had bigger hooves and feet than female calves. Hoof and foot areas of wild forest reindeer (means 74.6 and 200.3 cm<sup>2</sup> for calves, 79.4 and 230.4 cm<sup>2</sup> for hinds and 83.6 and 258.6 cm<sup>2</sup> for stags) were bigger than those of semi-domesticated reindeer (means, front legs, 60.9 and 165.3 cm<sup>2</sup> for calves and 78.9 and 214.1 cm<sup>2</sup> for hinds, respectively). There were significant correlations between live weight and hoof areas ( $r=0.839$  and  $0.792$ ), between live weight and foot areas in front and hind legs ( $r=0.714$  and  $0.664$ ) and between live weight and foot area when supported by 4 legs ( $r=0.726$ ) in semi-domesticated reindeer. Load on ground and foot load in semi-domesticated reindeer when supported by 4 legs were 235 and 85 g/cm<sup>2</sup> in calves and 268 and 102 g/cm<sup>2</sup> in hinds.

**Key words:** snow

**Rangifer**, Special Issue No. 3, 1990: 249-254

### Introduction

Reindeer and caribou (*Rangifer tarandus*) spend over 40 per cent of each year in snow. They are true *chinophiles* (Formozov 1946, Pruitt 1959), which means that they are highly adapted to snow. They have blunt toes, crescent-shaped hooves with a sharp edge for grip on hard snow and ice and functional lateral digits, or dew claws. A heavy growth of bristle-like hairs surrounds the hoof, and the joints of the middle

toes can be bent sharply to assume an almost horizontal position. In fact, the reindeer hoof can be considered in a state of transition toward a plantigrade foot (see Nasimovich 1955). Those adaptations greatly increase the surface area of the hoof and help the reindeer to float on soft snow.

External morphology and behavior reflect adaptation to snow. The measurements of the foot area is a prerequisite in the determination

of load on ground and, hence, an important measure of the adaptability of mammals to snow of various depths, densities and hardnesses. The load on ground can be divided up into hoof load and foot load (Thing 1977). The hoof load is the measurement most frequently used in the literature (Nasimovich 1955, Kelsall 1969), but the foot load seems to be a more realistic measurement since the whole hoof-pastern-dew claw area offers support in snow (Telfer & Kelsall 1979).

The ability to move in snow not only depends on the snow characteristics, but also on the load on ground and length of legs of the animals. No comparative studies are available on the load on ground between the various reindeer populations. This paper describes hoof and foot measurements for semi-domesticated and wild forest reindeer and calculated hoof and foot loads for semi-domesticated reindeer in Finland.

## Material and methods

Hoof and foot measurements and body weights were taken from 60 freely grazing and supplementary fed semi-domesticated reindeer (8 female and 13 male calves, 10 young females (age 2 yrs), 9 young males (age 2-3 yrs) and 20 adult hinds) at the Kaamanen Reindeer Research Station during winter 1988. Hoof and foot characters of living reindeer were measured to the nearest millimetre with a steel metric rule. Broken hooves were omitted. The outline of the hoofs and the feet (hoof + dew claws) from the left front and hind legs were drawn when pressed down on a hard substrate and in a natural position. Hoof and foot areas were calculated according to Kelsall & Telfer (1971) (Fig. 1). To be sure that the hoof and foot areas were as correct as possible, control measurements were taken on distinct reindeer foot prints on hard snow surfaces to determine space between the hooves and the distance between hind edge of hooves and dew claws (Thing 1977). Measurements were taken also on distinct foot prints of 26 identified wild forest reindeer (*Rangifer t. fennicus* Lönn.) (7 calves, 11 hinds and 8 stags)

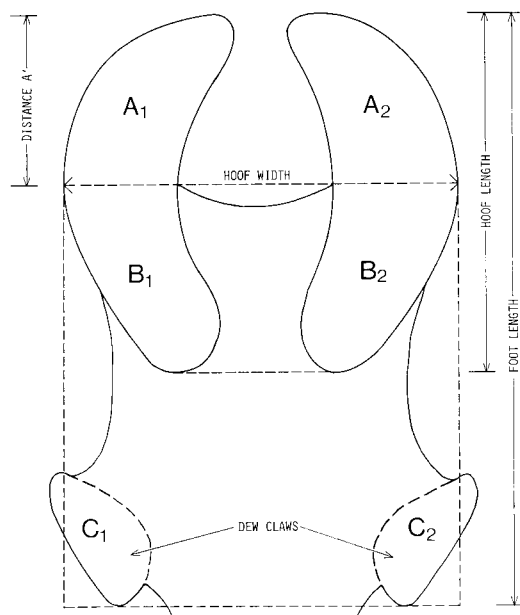


Fig. 1. Diagram of a reindeer foot seen from below showing hoof and foot lengths and hoof outline. Hoof area =  $A_1 + A_2 + B_1 + B_2$  cm<sup>2</sup> and foot area is obtained by adding to  $A_1 + A_2$  area the area of the rectangle (foot length — distance A x hoof width) (see Kelsall & Telfer 1971).

on hard snow surfaces in Kuhmo and Salamajärvi national park during 1985-1988.

Hoof and foot loads were calculated for each reindeer by dividing live weights by the combined area for all 4 hooves or feet. The load on ground was calculated also for moments when the reindeer was supported by 4, 3, 2 or 1 foot (Fig. 2).

## Results and discussion

Results are given in Tables 1 and 2. Reindeer had bigger hooves and feet on front than on hind legs, and male calves and young males had bigger hooves and feet than female calves and young females. According to McCullough (1965) no significant differences existed between sexes in measurements of hooves in black-tailed deer fawns (*Odocoileus hemionus*), but differences in yearlings and adults were significant. Hoof and foot areas of wild forest reindeer (means 74.6 and 200.3 cm<sup>2</sup> for calves, 79.4 and 230.4 cm<sup>2</sup> for hinds and 83.6 and 258.6 cm<sup>2</sup> for stags) in present study were big-

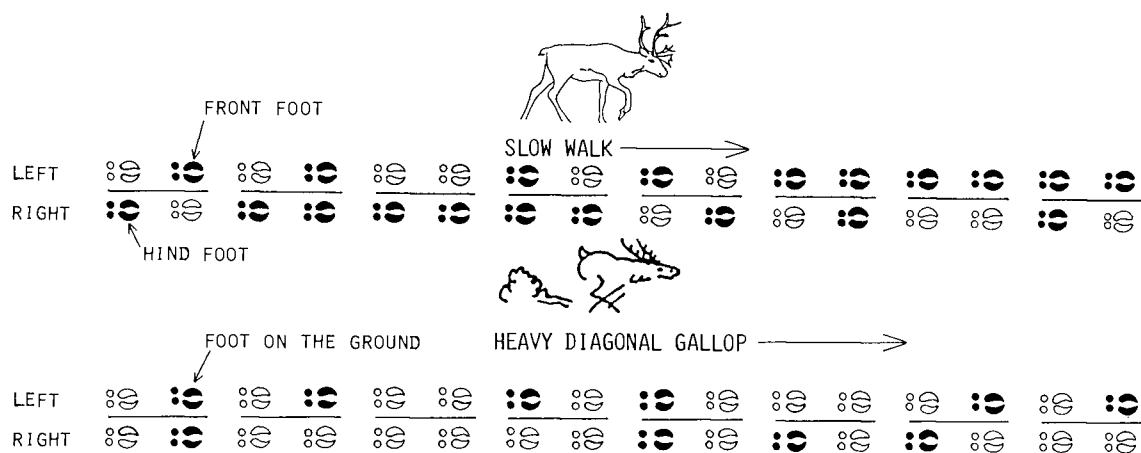


Fig. 2. Graphic representations of the symmetrical normal walk and heavy diagonal gallops of reindeer and their support graphs.

ger than those of semi-domesticated reindeer (means, front legs, 60.9 and 165.3 cm<sup>2</sup> for calves and 78.9 and 214.1 cm<sup>2</sup> for hinds, respectively). The length of the dew claws in wild forest reindeer was also bigger than that of semi-domesticated reindeer (Table 1, Fig. 3).

There were significant correlations between live weight and hoof areas ( $r = 0.839$  and  $0.792$ ,  $n = 60$ ,  $P < 0.001$ ) between live weight and foot areas of front and hind legs ( $r = 0.714$  and  $0.644$ ,  $n = 60$ ,  $P < 0.001$ ) between live weight and foot area when supported by 4 legs ( $r = 0.726$ ,  $n = 60$ ,  $P < 0.001$ ) in semi-domesticated reindeer (Fig. 4). The hoof load and the foot load in semi-domesticated reindeer, when supported by 4 legs, was 235 and 85 g/cm<sup>2</sup> in calves and 268 and 102 g/cm<sup>2</sup> in adult females (Table 1).

In the present study, hoof and foot measurements of wild forest reindeer were taken from distinct foot prints on hard snow surfaces. Thus it can be supposed that there appear to be some measurement errors in this material. However, it has long been known that both in wild and semi-domestic stocks in Finland and Sweden the differences are clearest between the mountain and forest reindeer forms (Lönnerberg 1909, Klemola 1928, Itkonen 1948). The wild forest reindeer is 10-15 cm taller than the mountain reindeer and semi-domesticated reindeer. It has significantly longer legs, both relative-

















ly and absolutely, than the wild Norwegian mountain reindeer and semi-domesticated reindeer (Nieminen 1980, Nieminen & Helle 1980). According to Banfield (1961), the hoof size in wild Fennoscandian mountain reindeer males is 60 x 60 mm and in wild forest reindeer males 110 x 95 mm, which may indicate considerably lower load on ground in the wild forest reindeer. It is concluded, that the long legs and low load on ground of the wild forest reindeer are important adaptations to taiga conditions, where the snow cover is usually very deep and soft (see Nieminen & Helle 1980).

The lowest hoof loads and foot loads were calculated in present study for calves and young reindeer (Table 1). The hoof load and the foot load are important when one wants to know how hard the snow cover has to be in order to support a reindeer. If it is too soft, the reindeer will sink through and therefore have to use more energy when walking than if it was walking on top of the snow cover. Usually the load on ground is calculated by dividing total body weight with total hoof or foot area, and it will then only refer to an animal standing still on all 4 feet and not to an active and moving animal. However, information on load on ground has practical value only when given for 1, 2, 3, or 4 feet as according to the different ways of locomotion used by the animal in question. As can be seen in Fig. 2, the reindeer

Table 1. Hoof and foot measurements, live weights and hoof and foot loads ( $\bar{x} \pm S.E.$ ) in semidomesticated reindeer. Measurements of wild forest reindeer were taken from foot prints on hard snow surfaces.

Species	Sex	N	Leg	Hoof length (cm)	Hoof area (cm <sup>2</sup> )	Dew claw length (cm)	Dew claw area (cm <sup>2</sup> )	Hoof width (cm)	Foot length (cm)	Foot area (cm <sup>2</sup> )	Live weight (kg)	Hoof load (g/cm <sup>2</sup> )	Foot load (g/cm <sup>2</sup> )	
Semi- domesticated reindeer	Calf	F	Front	8.6 ± 0.1	58.2 ± 1.2	6.0 ± 0.1	18.9 ± 0.4	11.0 ± 0.1	16.3 ± 0.1	158.4 ± 1.2	50.3 ± 1.4	234.2 ± 2.2	85.2 ± 1.2	
			Hind	8.4 ± 0.1	49.7 ± 0.6	4.7 ± 0.1	12.6 ± 0.4	9.5 ± 0.1	16.3 ± 0.1	136.9 ± 1.3				
	Calf	M	Front	8.7 ± 0.3	62.6 ± 2.5	5.8 ± 0.3	19.1 ± 0.8	11.2 ± 0.2	16.9 ± 0.3	167.5 ± 5.4	54.5 ± 5.4	235.1 ± 4.1	84.4 ± 2.2	
			Hind	8.5 ± 0.3	53.2 ± 1.8	4.7 ± 0.2	12.4 ± 0.5	10.3 ± 0.1	17.1 ± 0.3	154.8 ± 3.4				
	Calf	F+M	21	Front	8.7 ± 0.2	60.9 ± 2.1	5.9 ± 0.2	19.0 ± 0.7	11.2 ± 0.1	16.8 ± 0.2	165.3 ± 4.0	52.9 ± 2.1	234.8 ± 3.5	84.7 ± 1.9
				Hind	8.5 ± 0.2	51.3 ± 1.4	4.7 ± 0.2	12.4 ± 0.6	9.9 ± 0.2	16.6 ± 0.2	144.2 ± 3.0			
Young	F	10	Front	9.0 ± 0.1	63.0 ± 0.8	6.2 ± 0.2	18.7 ± 0.7	11.7 ± 0.1	17.3 ± 0.2	166.3 ± 6.1	60.2 ± 1.6	264.3 ± 8.1	94.2 ± 4.7	
			Hind	9.0 ± 0.1	51.3 ± 1.3	4.6 ± 0.1	11.5 ± 0.8	11.0 ± 0.2	17.3 ± 0.3	156.9 ± 4.2				
Young	M	9	Front	9.2 ± 0.2	70.5 ± 3.0	6.6 ± 0.2	23.8 ± 1.4	12.2 ± 0.3	17.7 ± 0.4	186.3 ± 7.0	69.6 ± 2.6	268.0 ± 10.2	98.8 ± 3.9	
			Hind	9.1 ± 0.2	60.1 ± 2.4	5.1 ± 0.2	16.1 ± 1.0	10.9 ± 0.2	18.1 ± 0.3	167.8 ± 5.2				
Adult	F	20	Front	9.4 ± 0.3	78.9 ± 2.7	6.6 ± 0.1	20.0 ± 1.0	12.6 ± 0.1	17.9 ± 0.2	214.1 ± 4.1	76.2 ± 1.2	267.8 ± 5.4	101.9 ± 1.8	
			Hind	9.3 ± 0.1	63.4 ± 1.4	4.9 ± 0.1	14.6 ± 0.6	11.2 ± 0.2	17.6 ± 0.2	173.4 ± 3.9				
Wild forest reindeer														
Calf	F+M	7		10.7 ± 0.4	74.6 ± 4.8	8.3 ± 0.6	21.4 ± 0.5	11.8 ± 0.6	18.4 ± 0.7	200.3 ± 9.9				
			F	11	11.4 ± 0.5	79.4 ± 3.8	8.7 ± 0.4	26.2 ± 1.4	12.9 ± 0.4	19.2 ± 0.5	230.4 ± 7.8			
Adult	M	8		13.2 ± 0.3	83.6 ± 5.7	9.5 ± 0.8	28.0 ± 0.8	13.3 ± 0.6	23.6 ± 0.7	258.6 ± 8.3				

Table 2. Foot load values ( $\text{g}/\text{cm}^2, \bar{x} \pm \text{S.E.}$ ) of semi-domesticated reindeer supported by 1, 2, 3 or 4 feet.

	Calves (N=21)	Young females (N=10)	Young males (N=9)	Adult females (N=20)
Front foot Left 				
Right 	$84.7 \pm 1.9$	$94.2 \pm 4.7$	$98.8 \pm 3.9$	$101.9 \pm 1.8$
Hind foot				
 	$111.0 \pm 2.4$	$124.7 \pm 6.5$	$129.6 \pm 5.2$	$132.6 \pm 2.3$
 	$161.1 \pm 3.5$	$184.9 \pm 11.6$	$188.3 \pm 7.8$	$191.0 \pm 3.6$
 	$115.0 \pm 2.7$	$126.6 \pm 5.5$	$134.1 \pm 5.3$	$140.5 \pm 2.9$
 	$169.4 \pm 3.8$	$188.6 \pm 8.8$	$197.6 \pm 7.8$	$203.9 \pm 3.7$
 	$322.5 \pm 7.0$	$370.8 \pm 23.1$	$376.6 \pm 15.8$	$378.9 \pm 6.7$
 	$358.3 \pm 10.0$	$386.6 \pm 14.8$	$417.5 \pm 17.5$	$442.9 \pm 9.9$
 	$179.2 \pm 5.0$	$193.3 \pm 7.4$	$208.8 \pm 8.8$	$221.5 \pm 4.9$
Foot on the ground				

will be supported by only 2 or 3 feet at any time when it is walking. When the reindeer is moving in a heavy diagonal gallop it is supported by 1 or 2 feet only at any movement (Fig 2). Reindeer hoof load is only about 125 to 180  $\text{g}/\text{cm}^2$  when standing (Nasimovich 1955, Thing 1977), 500  $\text{g}/\text{cm}^2$  when walking, and 1 000  $\text{g}/\text{cm}^2$  when trotting (see Thing 1977), compared with 390 to 659  $\text{g}/\text{cm}^2$  for standing moose (Telfer & Kelsall 1979). In the present study the foot load of semi-domesticated reindeer was only about 85 to 102  $\text{g}/\text{cm}^2$  when standing and maximally 358 to 443  $\text{g}/\text{cm}^2$  when the reindeer was moving in a heavy diagonal gallop and supported by 1 foot (see Table 2). The effects of speed on the foot loads were not taken into consideration.

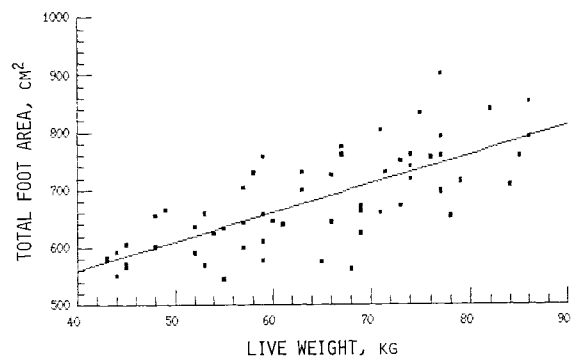


Fig. 4. Regression between live weight and total foot area supported by 4 legs in semi-domesticated reindeer ( $r=0.726$ ,  $n=60$ ).



Fig. 3. Wild forest reindeer (*R. t. fennicus*, Lönnb.) have bigger hooves and feet and is also 10 - 15 cm taller than wild mountain and semi-domesticated reindeer. Photo L. Rautiainen.

## Conclusions

Semi-domesticated reindeer, and especially wild forest reindeer are well adapted to travel through deep and soft snow. Hoof and foot areas and length of dew claws are bigger in wild forest reindeer than in semi-domesticated reindeer. Reindeer hind legs have bigger hooves and feet, and males have usually bigger hooves and feet than females. There are significant correlations between live weight and hoof and foot areas in reindeer. The results indicate that information on load on ground has a practical value only when given for 1, 2, 3 or 4 feet as according to the different ways of locomotion.

## References

- Formosov, A.N. 1946: Snow cover as an intergral factor of the environment and its importance in the ecology of mammals and birds. - *Fauna and Flora of the USSR. New Series. Zoology* 5 (xx). Occ. Publ. No. 1. Boreal Inst., Univ. Alberta, Edmonton. pp. 141.
- Itkonen, T. 1948: *Suomen lappalaiset vuoteen 1945. II. Porvoo* - Helsinki, pp 629.
- Kelsall, J.P. 1969: Structural adaptation of moose and deer for snow. - *J. Mammal.* 50:302-310.
- Kesall, J.P. & Telfer, E.S. 1971: Studies of the physical adaption of big game for snow. - In: *Proc. of the snow and ice in relation to wildlife and recreation Symp.*, Iowa State Univ., Ames., pp. 134-146.
- Klemola, V. 1929: Poronhoidosta ja sen levinneisyydestä Euraasiassa. - *Terra* 11:137-163.
- Lönnberg, E. 1909: Taxonomic notes about Palearctic reindeer. - *Arkiv Zool.* 6(4):1-18.
- McCullough, D.R. 1965: Sex characteristics of black-tailed deer hooves. - *J. Wildl. Manage.* 29(1):211-212.
- Nasimovich, A.A. 1985: *The role of the regime of snow cover in the life of ungulates in the U.S.S.R.* Moskva, pp.402.
- Nieminen, M. 1980: The evolution and taxonomy of the genus *Rangifer* in northern Europe. - In: *Proc. 2nd Int. Reindeer/Caribou Symp.* Røros, Norway, pp. 379-391.
- Nieminen, M. & Helle, T. 1980: Variation in body measurements of wild and semi-domestic reindeer (*Rangifer tarandus*) in Fennoscandia. - *Ann. Zool. Fennici* 17:275-283.
- Pruitt, W.O., Jr. 1959: Snow as a factor in the winter ecology of barren-ground caribou. *Arctic* - 12(3):158-180.
- Telfer, E.S. & Kelsall J.P. 1979: Studies of morphological parameters affecting ungulate locomotion in snow. - *Can. J. Zool.* 57(11): 2153-2159.
- Thing, H. 1977: Behavior, mechanics and energetics associated with winter cratering by caribou in northern Alaska. - *Biol. Paper of the Univ. of Alaska No. 18*:1-43.