Growth and relationship of live weight to body measurements in semi-domesticated reindeer (*Rangifer tarandus tarandus* L.)

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Abstract: Estimation of live weight from measurements of body dimensions is useful in many management activities with domestic animals. In present study live weight was measured from 2932 female and 1037 male semi-domesticated reindeer *(Rangifer tarandus tarandus* L.) during different seasons in 1969-85. The age of reindeer varied between 1 day and 14 yrs. Back length (along back from second spinous process to base of tail) and chest girth (just behind front legs) were taken also from 1490 female and 510 male reindeer. The growth of reindeer from birth to adulthood was cumulative consisting of a rapid weight accretion during summers followed by a weight loss or stasis during winters. The mathematical analyses of the growth based on exponential solutions gave average values for growth of female and male reindeer. Body weight of females increased until the age of 4.5 yrs and that of males until the age of 5.5 yrs. During winter and spring body weight of hinds decreased 10 to 15 kg and that of stags 30 to 50 kg in different age groups. Significant linear regressions were found between live weight and back length ($r=0.809$ and 0.892), live weight and chest girth ($r=0.860$ and 0.872) and live weight and combined body measure (back length + chest girth) ($r=0.877$ and 0.941) and live weight and body volume ($r=0.905$ and 0.954, respectively) in female and male reindeer. Exponential regressions gave, however, the best estimations of live weight with combined body measure.

Key words: reindeer husbandry, management

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Introduction

Rates of reproduction are usually related to body size, and growth and development are also functions of adult body size (see Blueweiss et al. 1978). According to Clutton-Brock et al. (1982) red deer *(Cervus elaphus)* and reindeer *(Rangifer tarandus)* are species that form the largest breeding parties and also show the greatest degree of size dimorphism: in reindeer, average male weights in autumn are 1.6 times female weight. Sexual weight dimorphism is not, however, consistent since at the same female weight Norwegian reindeer may reach a dimorphism of 2.2 - 2.8, while Canadian tundra caribou reach only 1.2 - 1.6 (see Geist 1988).

Relationship among body weight, size and morphological traits have been described for numerous large animals, but most data are based on dead animals. Body measurements and rations are useful taxonomic criteria and are used in *Rangifer* systematics (Banfield 1961, Nieminen & Helle 1980). Interrelationships between live weight and live measurements have been investigated in several studies with domestic animals (see Ruohomäki 1975). The most common measurements taken have been heart girth, width of chest, depth of chest, height at withers, height of back and natural length. Estimation of live weight from body measurements has been useful in many management activities with domestic animals. According to Ringberg et al. (1981) length measurements were considered, however, to be impractical for the prediction of carcass weight in reindeer.

The growth of the reindeer from birth to adulthood is cumulative consisting of an rapid weight accretion during summers followed by a weight loss or stasis during winters. The growth rate of the reindeer is, thus, a complex of events. Mathematical analyses on the dynamics of the growth based on logarithmic or exponential solutions have been carried out on the reindeer by Krebs & Cowan (1962) and on the caribou by McEwan (1968). The growth rate of the reindeer is handled mathematically also with the aid of polynomial functions fitted to the average values obtained from several populations (see Timisjärvi et al. 1982).

This paper describes growth and average growth curves and relationships of live weight to body measurements in semi-domesticated reindeer in northern Finland. Regressions between live weight and body measurements are examined to determine the best predictive equation for weight in situations where weighing of reindeer is not practical.

Material and methods

Live weight was measured from 2932 female and 1037 male reindeer in Kaamanen Reindeer Research Station and in different reindeer hearding cooperatives in Finland during different seasons in 1969-85. Reindeer were freely grazing. The age of reindeer varied from 1 day to 14 yrs. The calves ranging in age from 1 day to 20 days were weighed with a steelyard to the nearest 0.1 kg. The older calves and adults were weighed using a spring balance to the nearest 0.5 kg. Body measurements were taken on the same day of live weight determination. All the measurements were performed mainly by the same person. Back length (from second spinous process to base of tail) and chest girth (just behind front legs) were taken from 1490 female and 510 male reindeer (Fig. 1). Body measurements were measured to the nearest millimetre with a steel metric rule. The combined body measures (back length + chest girth) and body volumes were calculated $\left(V = \frac{\text{back length x chest girth}^2}{4\pi}\right)$

The exponential equations were used for estimation the growth in reindeer. Exponential and linear regressions between body measurements and body weight were calculated.

Results

The mean birth weight was 5.0 kg for female and 5.3 kg for male calves. The birth weight doubled within 4 weeks, and then again within 6 weeks. At the age of 5 to 6 months the mean body weight of female calves showed a range from 40 to 45 kg. The mean body weight of male calves ranged from 45 to 50 kg. The growth ceased during winter. The growth proceeded during the next spring and summer. The hinds reached the adult body weight at the age of 3 to 4 yrs and the stags at the age of 5 to 7 yrs. During winter and spring the body weight of hinds decreased on an average 10 to 15 kg in different age-groups.

The decrease of body weight in stags was higher (30 to 50 kg). The actual measurements

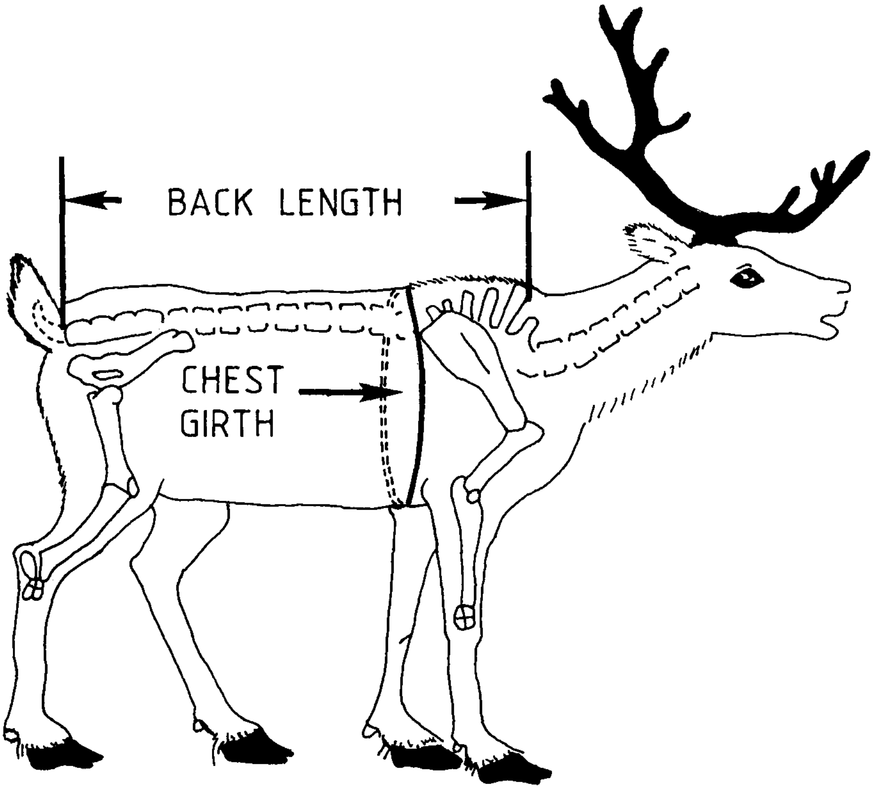

Fig. 1. Body measurements used in the study.

of body weight for female and male reindeer are presented in Figs 2 and 3. Figs 4 to 6 represent mathematical growth curves in female reindeer during different seasons and Figs 7 to 9 in male reindeer, respectively.

The combined body measure (back length + chest girth) showed a range from 131 to 215 cm in young reindeer females (age <3 yrs) and from 141 to 218 cm in young reindeer males. The values for adult hinds (age >3 yrs) and stags were from 170 to 220 cm and from 180 to 238 cm, respectively. There were significant linear regressions between back length and body weight ($r=0.809$, $n=1490$, $P<0.001$ and $r=0.892$, $n=510$, $P<0.001$), between chest girth and body weight ($r=0.860$, $n=1490$, $P<0.001$ and $r=0.872$, $n=510$, $P<0.001$) and between combined body measure and body weight in female and male reindeer. Significant linear regression were also found between body weight and body volume in female and male reindeer ($r=0.905$, $n=1490$, $P<0.001$ and $r=0.954$, $n=510$, $P<0.001$, respectively) (Figs 10 and 11).

Exponential regressions between body weight and combined body measure in female and male reindeer are presented in Figs 12 and 13. Comparisons of linear and exponential regressions are given in Table 1. Exponential regressions gave better correlations than linear regressions in this study. Estimations of live weight from combined body measure for female and male reindeer are given in Table 2.

Discussion

Growth is a complex set of metabolic events, which are environmentally and genetically controlled. Rates of prenatal, preweaning and postweaning growth of reindeer are influenced, for example by temperature, snow depth, humidity, air movement and radiation. These in turn affect the amount of food and water intake, en-

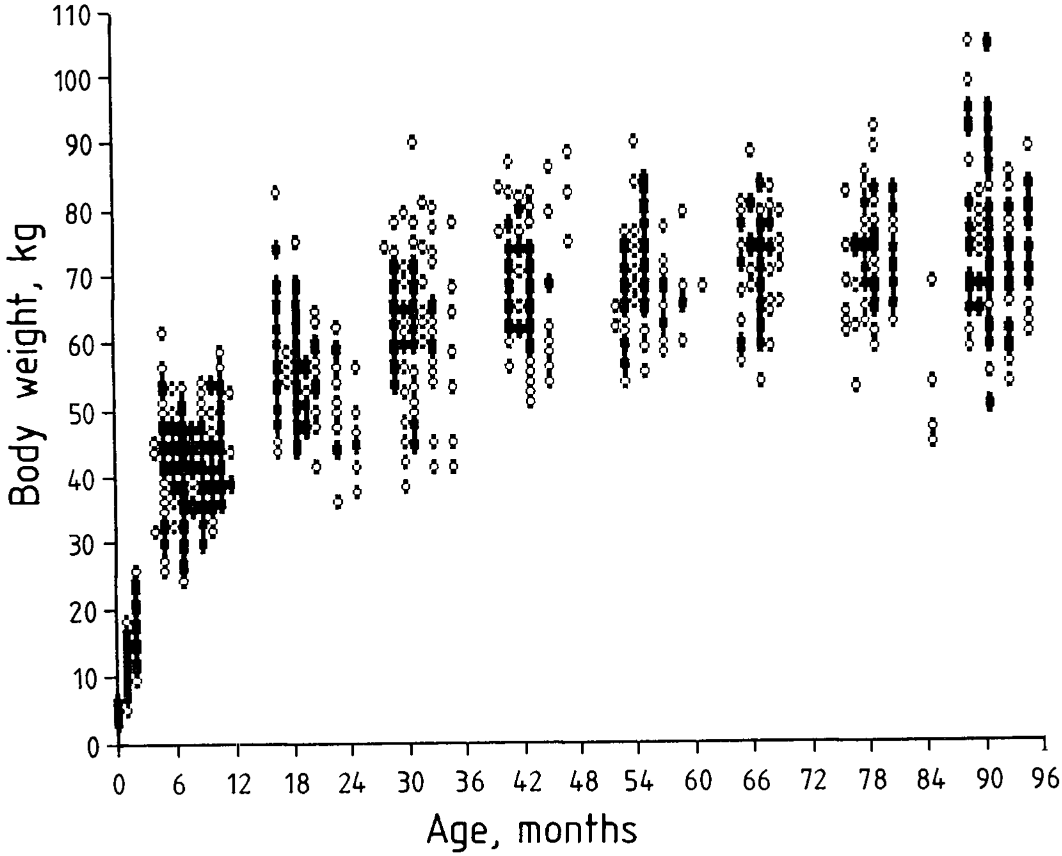

Fig. 2. Body weights of female reindeer (n=2932) in different age groups during different seasons 1969-85.

ergy available in ingested forage, the heat production and net energy available for productivity and body composition. According to Anderson (1981) there are in theory three phases of postnatal growth: 1) from birth to near the end of weaning, when growth is accelerating, 2) from weaning to sexual maturity, when growth is slowing rapidly, and 3) during sexual maturity, when growth may be slightly negative.

Brown (1961) published the first growth-in-body-weight curve of black-tailed deer *(Odocoileus hemionus columbianus)*, based on sequential weighings of one female and male deer from 12 to 54 months of age. These curves reflected seasonal changes in weight and continuing growth until maturity. Wood et al. (1962) noted later the complexity of growth among deer subspecies and employed four curves to describe the course of growth : 1) prepubertal growth, 2) actual weight changes through an animal cycle, 3) maximum annual weight reached, and 4) minimum annual weight reached. According to Timisjärvi et al. (1982) the growth in the reindeer was also phasic and complex with the greatest growth rate in the neonatal period. The growth was stopped by winter and proceeded the next spring but now at a lower rate. The polynomial growth curves used gave average values for growth and growth rate. In present study the mathematical analyses of the growth based on exponential solutions gave average values for growth of female and male reindeer.

Sexual dimorphism is well known among ruminants. According to Fock (1966) the breadth measurements and particularly length-breadth indicies were important for distinguishing the sexes. Because also reindeer are sexu-

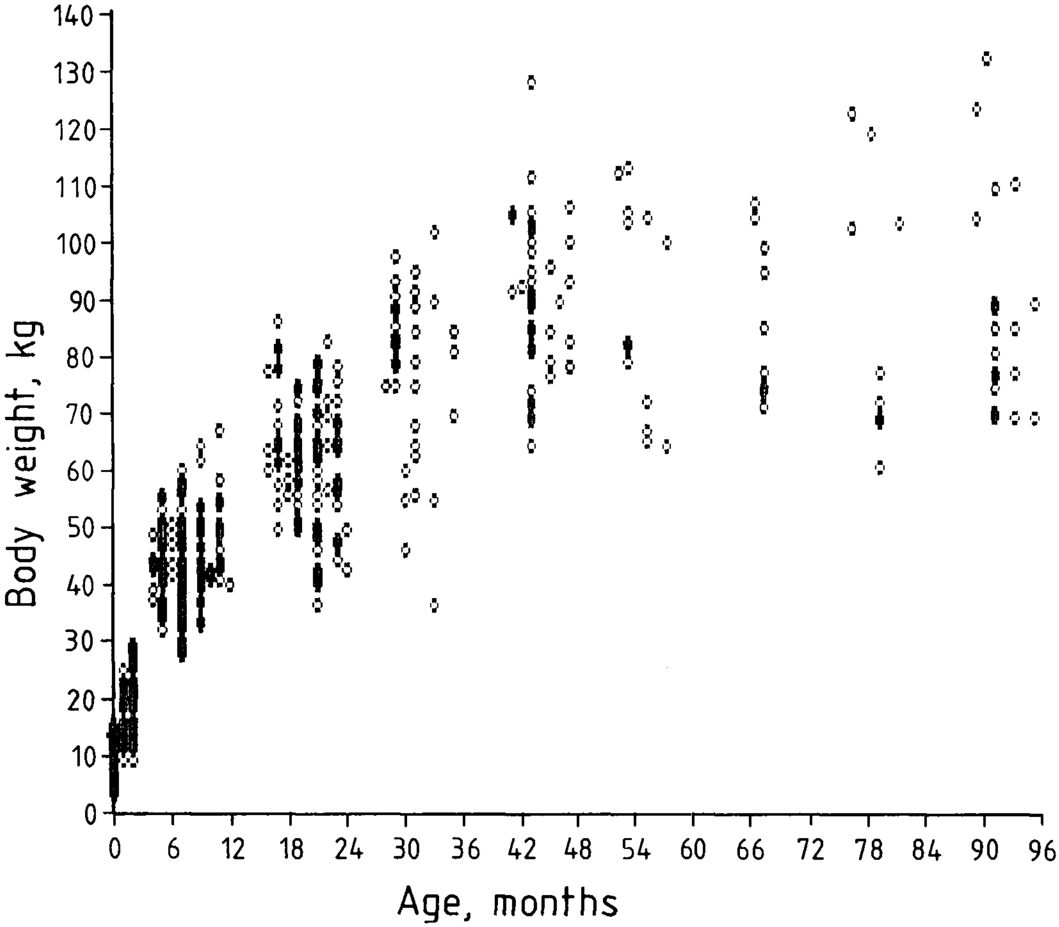

Fig. 3. Body weights of male reindeer (n=1037) in different age groups during different seasons 1969-85.

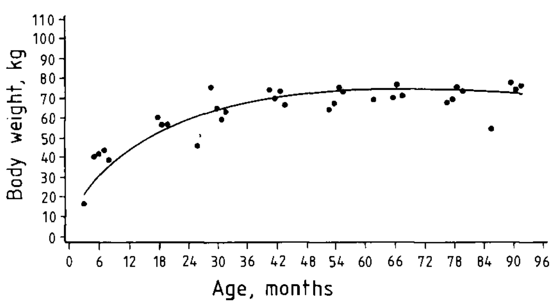

Fig. 4. The body weight of the female reindeer (n=1522) as plotted against the age of the reindeer. The weight curve is a weighed exponential equation ($y=11.35\ x^{0.584}e^{-0.009X}$, $R_2=95.43$) based on actual mean values measured during summers and autumns in 1969-85.

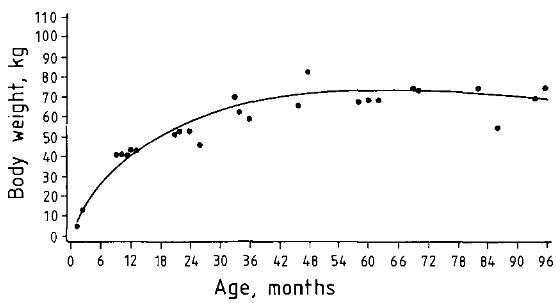

Fig. 5. The body weight of the female reindeer (n=1424) as plotted against the age of the reindeer. The weight curve is a weighed exponential equation ($y=8.41\ x^{0.688}e^{-0.011X}$, $R_2=97.78$) based on actual mean values measured during winters and springs in 1969-85.

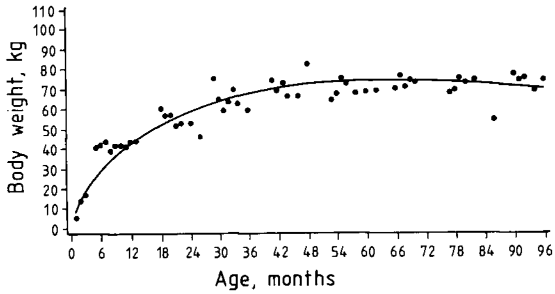

Fig. 6. The body weight of the female reindeer (n=2932) as plotted against the age of the reindeer. The weight curve is a weighed exponential equation ($y=9.65\ x^{0.644}e^{-0.009X}$, $R_2=97.03$) based on actual mean values measured during different seasons in 1969-85.

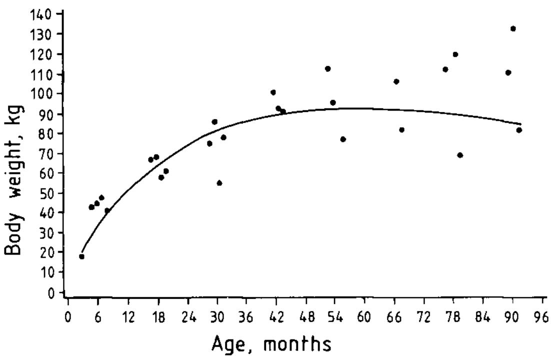

Fig. 7. The body weight of the male reindeer (n=832) as plotted against the age of the reindeer. The wieghed curve is a weight exponential equation ($y=9.25\ x^{0.748}e^{-0.013X}$, $R_2=$:94.54) based on actual mean values measured during summers and autumns in 1969-85.

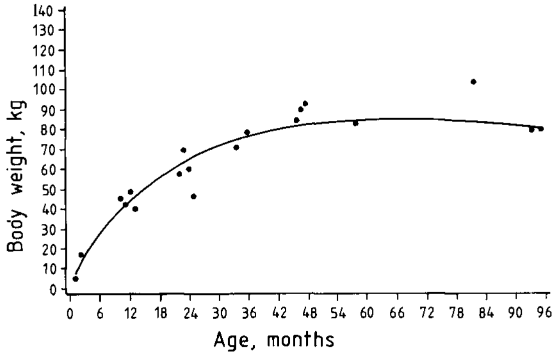

Fig. 8. The body weight of the male reindeer (n=921) as plotted against the age of the reindeer. The weight curve is a weighed exponential equation ($y=8.29\ x^{0.731}\ e^{-0.011X}$, $R_2=96.50$) based on actual mean values measured during winters and springs in 1969-85.

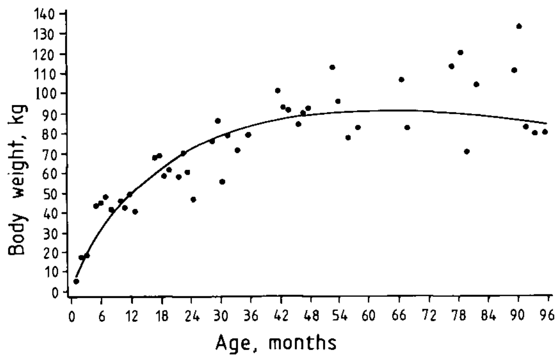

Fig. 9. The body weight of the male reindeer (n=1037) as plotted against the age of the reindeer. The weight curve is a weight exponential equation ($y=8.95\ X^{0.739}e^{-0.012X}$, $R_2=95.44$) based on actual mean values measured during different seasons in 1969-85.

ally dimorphic and sexes differ in their body proportions, females and males were analyzed separately in present study. In both sexes postpubertal weight fluctuated seasonally during each year of life. Weight was gained in summer and early autumn and lost during late autumn and winter. Bandy *et al.* (1970) found that mule deer male declined in weight during winter twice as fast as did females but generally reached the point of inflection about twenty days later and at higher body weight. Present results show that during winter and spring body weight of adult semi-domesticated reindeer females decreased about 10 to 15 kg and that of males about 30 to 50 kg in different age groups. The winter body weight loss of 41 - 55% in Svalbard reindeer *(R. t. platyrhynchus* Vrolik) is caused by a nearly complete loss of fat, 28-40 % loss of lean tissue and 16 - 50% weight decrease of the digestive tract (Reimers & Ringberg 1983).

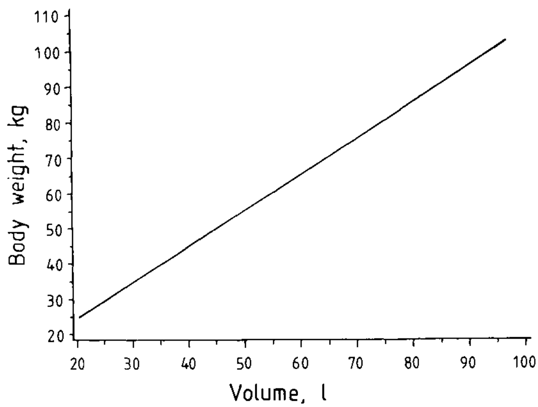

Fig. 10. The linear regression between body weight and body volume in female reindeer ($y=4.09 + 1.02x$, $R_2=81.89$, $n=1490$).

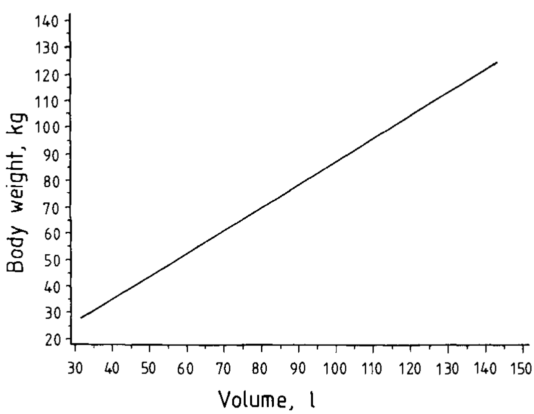

Fig. 11. The linear regression between body weight and body volume in male reindeer ($y=0.33 + 0.87x$, $R_2 91.04$, $n=510$)

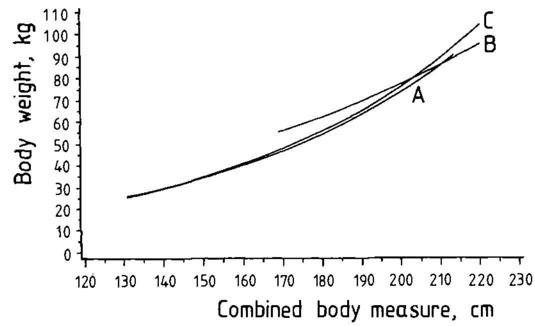

Fig. 12. The exponential regressions between body weight and combined body measure (back length + chest girth) in young (age < 3 yrs), adult (age > 3 yrs.) (B) and all (n=1490) female reindeer (C) in study. Equations are: (A) $y=3.45\ e^{0.015X}$, (B) $y=9.27\ e^{0.011X}$, (C) $y=3.27\ e^{0.016X}$.

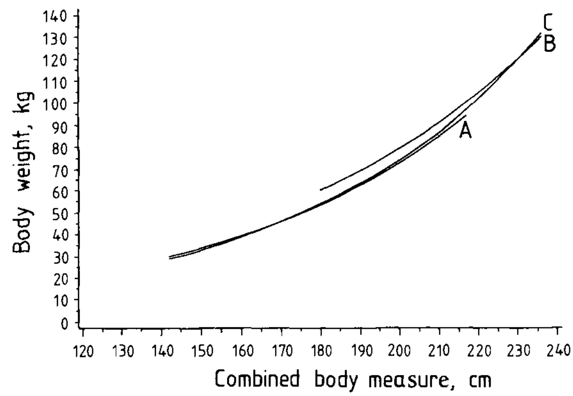

Fig. 13. The exponential regressions between body weight and combined body measure (back length + chest girth) in young (age <3 yrs) (A), adult (age > 3 yrs) (B) and all (n=510) male reindeer (C) in study. Equations are: (A) $y=3.44\ e^{0.015X}$, (B) $y=5.11\ e^{0.014X}$, (C) $y=3.06\ e^{0.016X}$.

According to Seip and Bunnell (1984) chest girth provided the best predictive equation for body weight in Stone's sheep *(Ovis dalli stonei)*, but hind foot length and horn length were also useful estimators. From live measurements in young beef cattle the best estimators were width of chest, chest girth and natural length (Ruohomäki 1975). Significant linear regressions were found in the present study between live weight and back length, live weight and chest girth. The best linear regressions were found between live weight and combined body measure and live weight and body volume. Exponential regressions gave, however, the best estimations of live weight with combined body measure.

The basic requirement for the measurements is that they are biologically reasonable and according to Weber (1957) the following sources of error are possible: 1) differencies between animals, 2) differencies between persons who perform the measuring, 3) differencies between animals and persons and 4) errors in the measurements by one person. It is observed

Table 1. Comparison of linear and exponential regression between body weight and combined body measure (back length + chest girth) in female and male reindeer.

Sex and age	n	Linear regression	r	Exponential regression	r
Females					
<3 years	856	y= -81.9+0.758x	0.914	$y=3.45e^{0.015x}$	0.958
>3 years	623	y= -75.8+0.763x	0.697	$y=9.27e^{0.011x}$	0.983
Total	1490	y= -78.6+0.761x	0.877	$y=3.27e^{0.016x}$	0.931
Males					
<3 years	433	y= -87.6+0.794x	0.924	$y=3.44e^{0.015x}$	0.959
>3 years	69	y=-161.1+1.208x	0.932	$y=5.11e^{0.014x}$	0.969
Total	510	y=-111.9+0.940x	0.941	$y=3.06e^{0.016x}$	0.939

that usually no errors occur provided when the head and feet of the animal remain in one position. The greatest difficulties and inaccuracies under the practical circumstances are caused by the movements of the animal. In the present study the measurements were performed mainly by the same person. Thus it can be supposed that there appears a minimum of measurement errors in this material.

In conclusion, the growth in semi-domesticated reindeer is phasic and complex with the greatest growth rate in the neonatal period. The growth is stopped by winter and proceeds the next spring. Body weight of females increases usually until the age of 4.5 yrs and that of males until the age of 5.5 yrs. The mathematical analyses of the growth based on exponential solutions gave average values for growth of female and male reindeer. In present study exponential regressions gave the best estimations of live weight with combined body measure.

Table 2. Estimated body weights from combined body measures (back length + chest girth) based on exponential regressions in female ($y=3.27e^{0.016x}$) and male ($y=3.06\ e^{0.016X}$) reindeer.

Combined body measure (cm)	Body weight (kg) Females	Males
180	55.6	54.5
181	56.5	55.4
182	57.4	56.3
183	58.3	57.2
184	59.2	58.1
185	60.1	59.1
186	61.1	60.0
187	62.1	61.0
188	63.0	62.0
189	64.0	63.0
190	65.1	64.0
191	66.1	65.0
192	67.1	66.1
193	68.2	67.2
194	69.3	68.2
195	70.4	69.3
196	71.5	70.5
197	72.6	71.6
198	72.8	72.7
199	75.0	73.9
200	76.2	75.1
201	77.4	76.3
202	78.6	77.6
203	79.8	78.8
204	81.1	80.1
205	82.4	81.4
206	83.7	82.7
207	85.0	84.0
208	86.4	85.4
209	87.7	86.8
210	89.1	88.2

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