Measuring the rump fat of the Hokkaido sika deer *Cervus nippon yesoensis*

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Survival, growth, and reproduction of cervids are all closely related to body condition. Body condition has been commonly assessed based on the extent of accumulation of fat subcutaneously, around the kidneys, and in the femur marrow following Riney (1955). These fat indices, however, are obtained lethally or from post-mortem animals. To assess the body condition of live animals, subcutaneous rump fat thickness (RFT) measured ultrasonically has been developed as a non-lethal index in moose *Alces alces* (Stephenson et al. 1993, 1998), caribou *Rangifer tarandus* (Chan-McLeod et al. 1995), elk *Cervus elaphus* (Cook et al. 2001a, b), and mule deer *Odocoileus hemionus* (Stephenson et al. 2002). In these studies, ultrasonic RFT showed seasonal fluctuations and predicted the total body fat levels of the animals well. In addition, Testa and Adams (1998) and Keech et al. (2000) applied this technique to field studies and reported that the maximum RFT of female moose was associated with their reproductivity. Therefore, ultrasonic RFT was considered to be a good index of body condition. For sika deer *Cervus nippon*, Maruyama (1985) examined relationships between RFT and other indices such as kidney fat and femur marrow fat indices, and suggested that RFT could be a suitable condition index in addition to kidney fat index. However, Maruyama (1985) did not detail a method to measure RFT. Subsequently, sika deer body condition has only been estimated using the kidney fat index (Kaji et al. 1988; Asada 1996; Yokoyama et al. 1996), kidney fat mass (Yokoyama et al. 2001), femur and mandible marrow fat, or a combination of these with kidney fat (Takatsuki 2000; Yokoyama et al. 2000) using post-mortem samples. To obtain a body condition index for live sika deer, we examined the site of maximum RFT, and the relationship between directly and ultrasonically measured RFT.

Materials and methods

We used 57 carcasses of sika deer shot for simultaneous studies or nuisance control in Shari Town (114°33’–115°22’E, 43°44’–44°21’N), eastern Hokkaido, Japan, in September and November 1999, April, June, and October 2000. These periods were selected to cover the nutritionally best and poorest seasons (Suzuki et al. 2001; Yokoyama et al. 2001). The carcasses were carried to the field station as soon as possible after shooting. We laid down each carcass with the left side up, and detected its coxal tuber and ischial tuber on the pelvic bone and spinous process of vertebrae by palpation. We defined the surface area over the left half of the pelvis as the rump region. We incised the skin and subcutaneous fat layer of the rump region transversely at intervals of 2–3 cm using a surgical blade. Then, we directly mea-
assured RFT at two points, the point of ocular maximum thickness (MAX) and the midpoint of the rump region (MID), with a stainless steel ruler to the nearest 0.5 mm. To express the location of MAX and MID, we also measured the longitudinal distance from the coxal tuber to the ischial tuber and the transverse distance from the spinous process to the coxal tuber with a stainless steel ruler to the nearest 1 mm. Then, we assigned a relative coordinate that regarded 100% of the longitudinal length as the x-axis and 100% of the transverse length as the y-axis (Fig. 1). As a consequence, the location of MID was expressed as the point at 50% of the length of each axis (Fig. 1).

Out of the 57 carcasses, 12 in September 1999 and seven in April 2000 were also used to determine the relationship between ultrasonically and directly measured RFT. Ultrasonic RFT was scanned and measured using a portable ultrasound scanner EUB-405 (13.1 kg, W30 × D40 × H28 cm, Hitachi Medical Corporation, Tokyo, Japan) and a 3.5 MHz convex probe EUP-C314 with a standard AC plug. Prior to scanning, hair on the rump region was shaved with razors to assure air-free contact of the probe with the skin. Because the 3.5 MHz probe was suitable for scanning relatively deep from the body surface (approximately 20–150 mm), we scanned ultrasonic RFT using a gel pad (1.5 cm in thickness, 9 cm in diameter, Focus Conforming Gel Pad, Pharmaceutical Innovations Inc., Newark, USA) on the skin to improve focal depth. Then, ultrasonic RFT was measured at two points, MAX detected on the ultrasound images and MID, with the electronic calipers to the nearest 0.1 mm. Thereafter we made incisions crossing the MAX and MID, and directly measured RFT at the same two points.

The gel pad (approximately ¥7,000 each) was relatively plastic, collapsed easily, and thus, could not be used repeatedly. To reduce operating expenses, therefore, we also tried measuring ultrasonic RFT using an edible gelatinous pad of starch, ‘konnyaku’ (devil’s tongue) (about 2 cm in thickness, white type), which is relatively elastic, cheap (¥70), and easily available at food shops. The relationship between ultrasonic RFT using the gel pad and using ‘konnyaku’ was tested for 14 live-captured sika deer using the Alpine Capture Systems cloth trap (Takahashi et al. 2002) and a dart gun in February 2000 on Nakanoshima Island (140°51'E, 42°36'N) in Lake Toya, Hokkaido. We carried a generator (EB3000, 100 V 50–60 Hz, 62 kg, W50 × D61 × H49 cm, HONDA, Tokyo, Japan) as a power source for the ultrasound devices to the capture site. The deer were immobilized with a lyophilized medetomidine and ketamine mixture (Onuma et al. 2004). Then, we scanned and measured ultrasonic RFT at MAX with both the gel pad and the ‘konnyaku’ using the same procedure as described for the carcasses above.

**Results and discussion**

*Variation in rump fat thickness*

For all 57 carcasses, direct RFT ranged from 0.0–44.0 mm at MAX and 0.0–35.0 mm at MID. No RFT was observed in five carcasses (all three calves and two of four adult males) in April. These data indicate that subcutaneous fat thickness varies among sites within the rump region before the rump fat disappears completely. For adult females (n = 28) sampled in each season, RFT at MAX reached the minimum in April (mean 3.9 ± SD 4.2 mm, n = 7) and the maximum in October (39.7 ± 4.5 mm, n = 3). These periods approximately coincided with seasons of the minimum and maximum total body mass (Suzuki et al. 2001) and kidney fat mass (Yokoyama et al. 2001) of sika deer in eastern Hokkaido. Kidney fat mass of sika deer can be an adequate index of a wide range of body conditions before the onset of severe nutritional stress (Yokoyama et al. 2001). Fat gain and loss of cervids occur concurrently among bone marrow, visceral, and subcutaneous depots, though subcutaneous fat completely disappears first in late winter or spring (Riney 1955; Chan-McLeod et al. 1995). Therefore, RFT is expected to cover a relatively better range of body conditions in sika deer as well as in other cervids.
Site of maximum thickness

Since RFT varied among sites, accurate location of measurement is important in order to obtain the maximum RFT. Excluding the five carcasses with no RFT in April, the location of MAX tended to concentrate into a certain range \((n = 52, \text{Fig. 2})\). The mean location of MAX was 68% (range 49–79%) of the longitudinal length and 48% (33–83%) of the transverse length. In previous studies, regardless of whether using ultrasound or not, the maximum RFT was scanned and measured along a line set optionally on the rump region (Riney 1955; Stephenson et al. 1993, 2002; Chan-McLeod et al. 1995; Cook et al. 2001a). Since the scanned range in our study almost covered the scanned lines in the previous studies, scanning the fat layer within the range could be an effective means of detecting and measuring the maximum RFT.

Validity of ultrasound

Ultrasonic RFT (UT) well predicted results obtained with direct RFT (DT) including both MAX and MID \((DT = 1.025UT + 0.064, r^2 = 0.997, n = 38, P < 0.001, \text{Fig. 3a})\). The absolute residual of the regression averaged 0.367 ± 0.303 mm and was not related to the direct thickness \((r = 0.032, n = 38, P = 0.849)\), suggesting that the degree of measurement error with ultrasound was not dependent on absolute fat thickness. Ultrasonic RFT at MAX using ‘konnyaku’ \((UT_k)\) for immobilized deer almost equaled that using the much more expensive gel pad \((UT = 0.984UT_k - 0.001, r^2 = 0.991, n = 14, P < 0.001, \text{Fig. 3b})\). The absolute residual averaged 0.411 ± 0.404 mm, suggesting that ‘konnyaku’ is a useful alternative gel material. In conclusion, ultrasound accurately predicts RFT of sika deer and is applicable to live animals.

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