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THE RELIABILITY OF SKINFOLD-CALIPERS FOR MEASURING BLUBBER THICKNESS OF STELLER SEA LION PUPS (*EUMETOPIAS JUBATUS*)

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Abstract

Twelve dead Steller sea lion pups (*Eumetopias jubatus*) aged 3–14 d were recovered from rookeries in Southeast Alaska. They had a wide range of body sizes and conditions (small to large and fat to no fat). The ability of calipers to estimate the thickness of their blubber layer was assessed with a set of skinfold calipers. Average error of measurement for skin and blubber thickness was an acceptable 5.4%, but the skin and blubber of the pups were highly compressible. Skinfold thickness increased with body mass but did not necessarily reflect the development of blubber, given that pups with no blubber also showed an increase in skinfold thickness with increases in body mass. Skinfold thickness of sea lion pups appears to predict body size better than it predicts blubber thickness, making it difficult if not impossible to develop a simple index of body condition or a calculation of percent body fat for Steller sea lion pups from skinfold caliper measurements.

Key words: Steller sea lion, *Eumetopias jubatus,* pups, blubber, skin, body condition, calipers.

The amount of subcutaneous fat (blubber) that a pinniped has should theoretically reflect its nutritional status, unless it is sick or heavily infested with

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parasites. Animals with thick layers of blubber relative to their length or mass have presumably fed better than animals of the same age with little or no blubber. Different non-invasive methods have been proposed and tried to assess the relative condition of an animal by indirectly measuring body fat. Some, for example, have tried to estimate relative indices of body condition by relating mass to length (Markussen *et al.* 1989, Trites 1992, Trites and Bigg 1992) or mass to length and girth (Pitcher 1986, Renouf *et al.* 1993). Others have tried to estimate the percentage of blubber from length, mass, and the density and thickness of blubber (Ryg *et al.* 1990). Still others have explored blubber measuring techniques such as ultrasound (Gales and Burton 1987, Renouf *et al.* 1993) and skinfold calipers (Castellini *et al.* 1993) or have tried to estimate total body fat content from Bioelectrical Impedance Analysis measurements (Gales *et al.* 1994, Arnould 1995). None of these methods has yet received wide acceptance.

Castellini *et al.* (1993) measured and compared the axillary skinfold thickness of Steller sea lion pups (*Eumetopias jubatus*) to total body mass. They found a significant correlation and concluded that the increase in skinfold thickness with mass of the pups was indicative of a fattening pup. This finding and the continued use of skinfold calipers by researchers studying sea lions led us to necropsy dead Steller sea lion pups to assess the reliability and accuracy of skinfold calipers to measure blubber thickness. Calipers are inexpensive and easy to take to the field. A number of caliper studies done on humans have shown high correlations between skinfold thickness and actual fat layer thickness (Lee and Ng 1965, Himes *et al.* 1979). Total body fat of people can be estimated from skinfold measurements taken from as few as four locations on the human body (Durnin and Womersely 1974). Our goal was to determine whether caliper pinches correlate with blubber thickness and whether a simple protocol could be developed to estimate the body condition and overall nutritional status from measures of skinfold thickness.

Materials and Methods

Sea Lions

Twelve dead Steller pups were recovered from rookeries at Forrester Island in Southeast Alaska in June and July, 1994 (Trites and Jonker, in press). We sought a range of sizes and states (heavy to light and fat to no fat). Seven of the pups had died of starvation and five from trauma. All were assumed to be between the ages of 3 and 14 d based on the synchronous timing of birth and the size and condition of the bodies. Standard length and weight were taken according to accepted procedures (American Society of Mammalogists, Committee on Marine Mammals, 1967).

Skinfolds on the intact pups were measured every 10 cm along the dorsal and ventral side of the body with a new Rosscraft Slimguide ABS caliper (Rosscraft, 14732 16-A Ave, Surrey, BC V4A 5M7). The skin and fat layer was then sliced at these same spots with a scalpel to measure the actual sculp thickness with a ruler (accuracy 0.5 mm). Axillary skinfold thickness was measured at the lateral and dorsal side to compare skinfold thickness and total body mass.

The sculp (skin and subcutaneous fat layer), excluding flippers, was dissected from the body core with a scalpel and placed on a table. It was stretched until length equaled the standard length of the animal. Skinfolds and actual sculp thickness were measured every 10 cm across the length and width of the sculp (Ryg *et al.* 1990). For five of the dead pups, blubber was removed before skin thickness was measured. Thickness of the blubber layer was calculated by subtracting the skin thickness from the sculp thickness (for those pups that had a discernable blubber layer).

Caliper Measurements

Skinfold thickness of both the sculp and the intact pups was measured with the Slimguide caliper (accuracy 0.5 mm) following the procedure of Lee and Ng (1965). Each skinfold was picked up by the forefinger and thumb. The caliper was placed over the base of the pinch and the measurement read from the dial the instant the needle ceased moving. The fold consisted of two layers of skin and subcutaneous tissue containing fat and other structures.

Each point was measured three times. The memory effect of crushing a skinfold was reduced to a minimum by measuring all points over the animal's body once, then measuring all points a second time, before starting the series over for a third and final time. The median of the three measurements is more robust than the mean and was retained as the best estimate for each spot.

Analyses

The technical error of measurement (*error*) was calculated for each spot (*i*) using

$$error_i = \sqrt{\frac{(A_i - B_i)^2 + (A_i - C_i)^2 + (B_i - C_i)^2}{2n}} \tag{1}$$

where A_i, B_i, and C_i, are the three skinfold measurements taken at location i, and $n = 3$ (the number of times each spot was measured). The percent technical error of measurement was derived from

$$\%error_i = \left(\frac{error_i}{median(A_i, B_i, C_i)}\right) \times 100 \tag{2}$$

leading to the estimate of mean percent error for all locations N as

$$\overline{\%error} = \frac{\sum_{i=1}^{N} \%error_i}{N}. \tag{3}$$

Raw correlations were determined between the skinfold thickness and actual sculp thickness for both intact and dissected sculps. Adjusted correlations were also calculated after adjusting the data to account for differences between (1) the mean thickness of the twelve animals, (2) the ventral and dorsal sides, and (3) the different spots measured on each animal. Degrees of freedom were adjusted to reflect the number of animals measured, rather than the total number of recorded measurements. All analyses were completed with S+ (Becker *et al.* 1988) using standard statistical techniques (Zar 1996).

Results

Dissection of the 12 pups revealed that seven did not have any discernable blubber. Skinfold thickness measured with calipers on the lateral (behind the flipper) and dorsal (on the neck and rump) sides of the body were highly correlated with mass ($P < 0.01$ for all three locations, Fig. 1). Caliper readings correlated with blubber thickness (Fig. 2, $r = 0.67$, $P < 0.01$) and skin thickness ($r = 0.39$, $P < 0.01$). However, pups with higher caliper measurements did not necessarily have more blubber than pups with low skinfold thickness (Fig. 1). For the most part, increases in skinfold thickness reflected heavier pups having thicker sculps than lighter pups.

Skinfold thickness (measured with a caliper) correlated with the sculp thickness (measured with a ruler) of the intact pups (Fig. 3, $r = 0.65$, $P < 0.01$) and skinned-out sculps ($r = 0.72$, $P < 0.01$). Adjusting the data sets for differences between the animals reduced the correlations to $r = 0.32$ for the intact pups and $r = 0.41$ for the skinned-out sculps ($P < 0.01$). In general, the caliper readings and the ruler measurements were essentially the same (Fig. 3), even though the calipers measured two layers of skin, blubber and visceral tissue.

Caliper measurement error ranged from 3.5% to 7.0% and averaged 5.4% for all animals combined ($\sigma = 0.32$, $n = 12$, Fig. 4). A total of 940 spots were measured on the twelve animals. Measurement error over all spots did not differ significantly between animals with blubber and those without blubber (Fig. 4).

Discussion

Studies of humans show that correlations between skinfold caliper readings and actual blubber thickness varied between $r = 0.60$ and $r = 0.90$ depending upon the experience of the technician, the side of the body measured, methods, sample size, and fatness of the subject (Himes *et al.* 1979, Lee and Ng 1965, Lohman 1981). Our correlation coefficients from the intact and skinned sculp were 0.65 and 0.72, respectively (Fig. 3), and 0.32 and 0.41 after adjusting the data for differences between pups. Skinfold-thickness measurements of the sculps spread out on a table were comparable to those from the intact animals.

The lower-than-desired correlations from the Steller pups could be related to a number of factors such as the choice of calipers, the accuracy of the

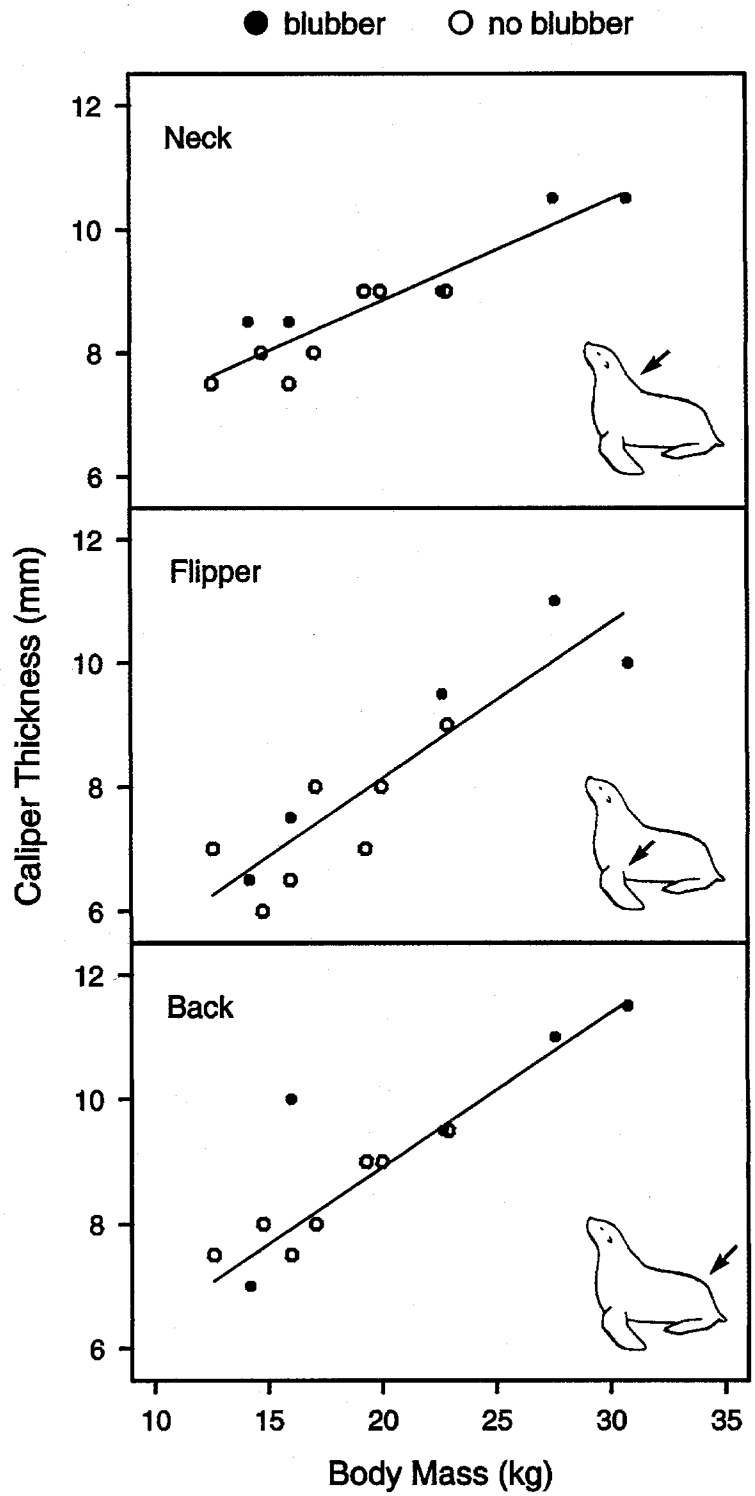

Figure 1. Skinfold thickness measured with calipers from 12 pups at three locations (neck: r^2 = 0.86, side: r^2 = 0.81 and back: r^2 = 0.96). All three regressions showed highly significant relationships between skinfold thickness and body mass ($P < 0.001$).

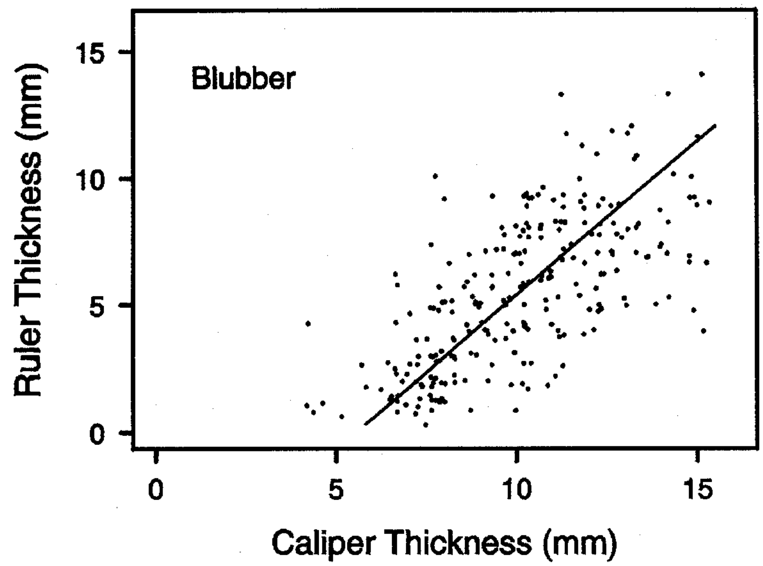

Figure 2. Relationship between skinfold thickness (measured with caliper) and blubber thickness (measured with ruler) of five pelts that contained blubber. Measurements made over extensive matrix (10 cm × 10 cm) of locations from sculps lying on table top. Plotted data jittered.

measurements (% error, Eqs. 1–3) and the compressibility of sea lion skin and blubber.

Schmidt and Carter (1990) compared five types of calipers and concluded the Slimguide caliper (which we used) was accurate and reliable. It was comparable to the Harpenden caliper for measuring from 4 to 45 mm and had a dial accuracy of ±0.5 mm, which is acceptable for calipers. Pressure varied for the different openings, but was within 1 g mm^{-1} (tolerance of ±2.0 g mm^{-1}), and compressibility was comparable to that for the Harpenden caliper.

Measurement errors are related to the way the skinfold is grabbed and pulled from the body, the place where the jaws of the caliper are placed, and the amount of time taken to read the caliper following application to the skinfold. Normally, studies done with humans under clinical circumstances should have an error less than 5% (Lohman 1981). Errors may range from 5%–10% under field situations.[2] We estimated our average error of measurement was 5.4% (range 3.5%–7.0%) which is acceptable compared to human studies.

The almost one-to-one correspondence between sculp thickness (one layer of skin and blubber) and skinfold thickness (two layers of skin and blubber) suggests that the calipers underestimate the actual thickness due to compression of the tissue. Studies of humans support this contention (Himes *et al.* 1979). Compressibility at different places on the human body varies between and within individuals (Himes *et al.* 1979, Bellisari *et al.* 1993), and becomes larger as the skinfold gets thicker (Schmidt and Carter 1990). Calipers read

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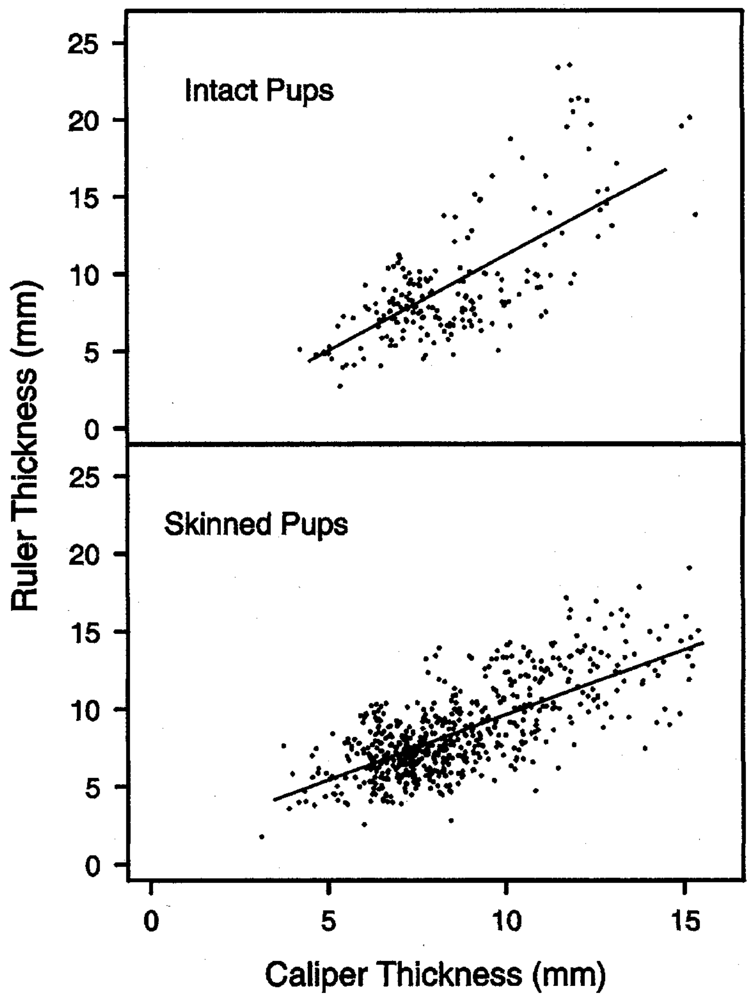

Figure 3. Relationship between skinfold thickness (measured with caliper) and sculp thickness (measured with ruler) of 12 pelts. Measurements made every 10 cm along dorsal and ventral sides of intact animals (top panel) and over extensive matrix (10 cm × 10 cm) of locations from sculps lying on table top (bottom panel). Plotted data jittered.

about 60% of the actual thickness of the subcutaneous fat layer of humans (Fletcher 1962).

Compressibility is affected by the composition, denseness, and amount of subcutaneous fat, as well as by the thickness of the skin and, for sea lions, the thickness of the hair layer. The density of the blubber layer of marine mammals and humans are both about 0.90 g cm^{-3} (Lohman 1981, Øritsland *et al.* 1985). Density is influenced by the amount of lipid in the fatty tissue and by the amount of body water. Variation in the water of subcutaneous adipose tissue is about 2% in humans.

The triceps, mid-thigh, and the supra-iliac side are the preferred places to measure skinfold on humans because they have consistent compressibility, are easy to reach, and give the highest correlations with body fat (Bellisari *et al.* 1993). In sea lions the subcutaneous fat layer seems to be thickest on the ventral side (Trites and Jonker, in press), but it is difficult to access and

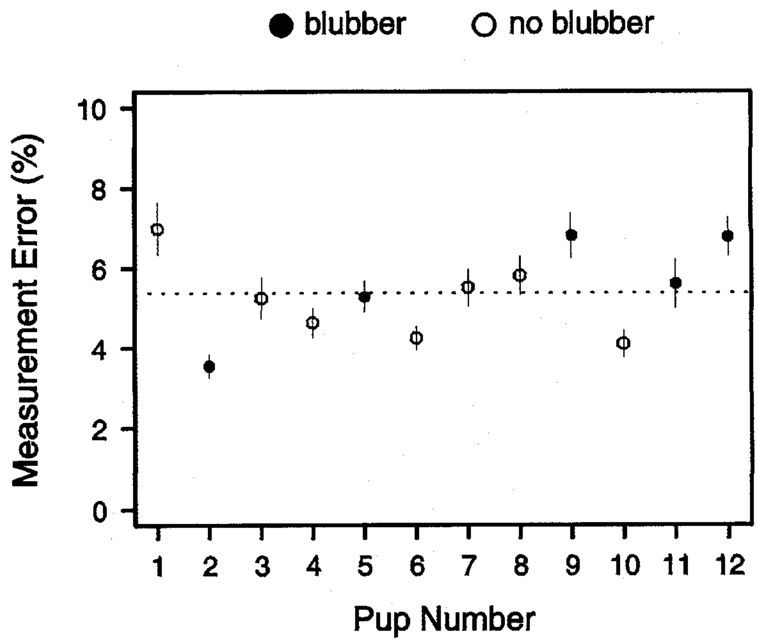

Figure 4. Mean technical error of caliper measurements (calculated using Eq. 3) for 12 dissected sculps. Pups ordered from lightest to heaviest. Vertical bars are standard errors and dashed line is overall mean error (5.4%).

measure this spot on living animals. This means that blubber measurements should be taken from the back and the lateral side (as in Fig. 1), as long as the spots can be precisely and repeatably determined. Thickness of the subcutaneous fat layer of the sea lions is not uniform (Trites and Jonker, in press), but we have no insight into whether sea lions deposit and mobilize fat over the body surface in a uniform manner. This merits further investigation. Similarly, our conclusions about the reliability of calipers to assess body condition are based on data covering a period of intense growth and development (and also catastrophic catabolic effects) and should be investigated with adult sea lions.

We found that skinfold thickness of the dead pups correlated with body mass (Fig. 1) as did Castellini *et al.* (1993) for live Steller pups. However the two data sets differed in terms of variance in the skinfold measurements and the slope of the relationships. Variance in skinfold pinches taken by Castellini *et al.* (1993) increased geometrically with pup size compared to the homogeneous measures we show in Figure 1. These increases were likely related to the difficulty of handling large pups and human error (*i.e.,* inadvertently pinching the muscle and other visceral tissues of the struggling animal). Data from the dead pups is of uniform high quality and should provide a reliable assessment of the distribution of subcutaneous fat and the accuracy of skinfold calipers.

Axillary and rump regions showed the highest variability in skinfold thickness over a range of body sizes (Fig. 1). However, the rise in skinfold thickness with body mass does not necessarily reflect the development of fat as concluded by Castellini *et al.* (1993), given that we found pups with no blubber also showed an increase in skinfold thickness with increases in body mass. During early ontogeny, skinfold thickness appears to correlate more with body size than with body condition. It therefore seems unlikely that a simple index of body condition or a calculation of percent body fat for Steller sea lion pups can be derived from skinfold caliper pinches. Instead, a more reliable index of body condition may be the ratio of observed to expected body mass derived from standardized mass-length relationships (unpublished data).

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