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Do implanted transmitters affect maximum running speed of two small marsupials?

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Radiotelemetry is used to quantify behavioral, ecological, and physiological variables of animals. Because of technological limitations, relative transmitter size generally increases with decreasing body mass of the study animal, and the recommended transmitter mass of <5% of body mass often prohibits work on small mammals. We compared burst running speed, important for predator avoidance, in 2 small marsupials, *Sminthopsis crassicaudata* (fat-tailed dunnart) and *Planigale gilesi* (Giles' planigale), without and with implanted transmitters. In both species maximum running speed was not affected by the transmitters, whose mass ranged from 6.4% to 14.1% of body mass. Further, relative transmitter mass was not correlated with maximum running speed. Consequently, transmitters well above 5% of body mass need not affect locomotor performance of small terrestrial mammals. DOI: 10.1644/10-MAMM-A-052.1.

Key words: internal transmitters, maximum running speed, *Planigale gilesi*, *Sminthopsis crassicaudata*

The study of behavior, ecology, and physiology of animals is fundamental in understanding mammalian biology. Many field and laboratory studies use biotelemetry, because it allows researchers to examine freely moving conscious animals remotely, whether this is simply to track animals to determine home range or to measure various physiological functions (Leon et al. 2004; Van Vuren 1989). A major advantage associated with use of radiotransmitters is elimination of stress linked with handling and restraint during measurements. However, the extra mass that must be transported can have negative effects (Gursky 1998; Leon et al. 2004). Field studies often use implanted transmitters that require an invasive surgical procedure before animals can be tracked and physiological variables can be measured, and many of these studies assume that radiotransmitters have negligible effects on the study animals and thus, that the data collected are not biased.

Transmitters have several potential negative effects depending on the method of attachment. Transmitters can be attached either externally as collars or via harnesses or glue, or they can be implanted internally. Although external transmitters appear to be the obvious alternative because they can be attached quickly without surgery, they do add mass and can create problems that can modify behavior (Guynn et al. 1987). External transmitters can affect maneuverability, especially when individuals are navigating through small gaps and cracks, as would be the case for the species examined here. Collar removal by the animal is another common problem, unless the collar is attached very tightly, which can result in severe skin lesion (e.g., in mink [*Neovison vison*], ground squirrels [*Spermophilus franklinii*], and sugar gliders [*Petaurus breviceps*]—Eagle et al. 1984; Körtner and Geiser 2000). Moreover, although collar transmitters generally have a greater transmission range than implants, they are not as accurate with regard to body temperature measurements, important for studies of thermal energetics (Körtner and Geiser 2000). With internal transmitters, long-term effects associated with external transmitters are largely avoided, with only extra mass being added.

Transmitter mass is important when studying small animals. Obviously, the smaller the animal, the smaller the transmitter should be, but any slight reduction in transmitter mass can be costly in terms of transmitter life and range (Caccamise and Hedin 1985; Gursky 1998). Generally, it is recommended that the transmitter mass should not exceed the study animal's tolerable mass limit, which is defined as the maximum amount of mass an animal can carry (in the form of a radiotransmitter) with no apparent effect on its behavior, survival, and general well-being (Gursky 1998). Although for most species this tolerable mass limit remains unknown, it often is suggested to be <5% of the animal's body mass (Caccamise and Hedin 1985; Gursky 1998).

The effect of radiotransmitters is especially important when conducting field studies, because locomotion can be negatively affected. Locomotion is fundamental to predator avoidance, territoriality, mating interactions, and foraging and thus overall fitness (Gilchrist 1996; Le Galliard et al. 2003; Navas 1996). In small species maximum running speed is especially important whereas endurance is less critical because long-distance running is relevant only for large mammals that potentially outrun predators (Lovegrove 2001).

Because data verifying that transmitters do not affect the locomotor performance of small terrestrial mammals are not available, we tested 2 hypotheses: that in agreement with the ''5% rule,'' internal transmitters > 5% of the animals' body mass affect maximum running speed; and that transmitter mass is correlated with maximum running speed in 2 small marsupials. The species used were *Sminthopsis crassicaudata* (fat-tailed dunnart) and *Planigale gilesi* (Giles' planigale). These arid-zone species live for 2–3 years and were chosen because they forage on the ground often not far from their refugia of soil cracks, burrows, or rocks (Geiser and Baudinette 1988; Morton and Dickman 2008; Read 2008; Warnecke et al. 2008), and because commercially available transmitters are relatively large and can affect agility and speed required to capture prey or escape predation.

Materials and Methods

Animals.—We used 12 captive-bred *S. crassicaudata* ($\bar{X}$ = 17.4 g ± 1.3 *SD*) and 5 *P. gilesi* (12.6 ± 0.7 g) captured from Kinchega National Park (32°30′S, 142°20′E, New South Wales, Australia). Animals were housed individually in cages (20 × 35 × 50 cm) at the University of New England (New South Wales, Australia) and were exposed to natural photoperiod and 21°C ± 3°C. Cages, cleaned every 2 weeks, contained running wheels and wood shavings and boxes with shredded paper for nesting. A mix of soaked cat food pellets and canned cat food and water were provided ad libitum. Supplements of minerals and multivitamins powder (Petvite, Poulenc Animal Nutrition Pty. Ltd., West Footscray, Victoria, Australia) and mealworms were provided once a week.

Running speed.—An illuminated 5-m-long × 20-cm-wide running track lined with carpet (to maximize traction) was used. Markings for analysis of speed were made every 2 cm along the track. A small box was placed at the far end of the track to provide refuge for the animals. All animal runs were videotaped to determine running speeds using a Samsung Digital Cam (VP-MX20R, 25 frames per second; Samsung Electronics, Seoul, South Korea). Animals were encouraged to run along the track using various visual cues and noises by tapping the track, rattling keys, and the sudden appearance of a person in view. Before measurements animals were trained by repeatedly running them along the track. Running speed was recorded over a 2-m section of the track as the maximum speed for each animal out of >6 runs ($\bar{X}$ = 21 runs ± 8 *SD*). Maximum speeds of 6 *S. crassicaudata* and 5 *P. gilesi* were measured before and after transmitter implantation. Body mass was measured to the nearest 0.1 g before each measurement using an electronic scale (MAXI, pro-fit 63-9534; InterTan, Newcastle, Australia). All individuals were allowed at least 3–4 weeks between the initial runs and runs after surgery. Animals were run 3–30 days before surgery and 13–36 days after surgery; several individuals were run up to 2 months later and showed no difference in maximum running speed. An additional 6 *S. crassicaudata* were used as controls and were run over the same time period but without transmitter implantation. Paired *t*-tests were used to compare running speeds of individuals before and after transmitter implantation, or the initial speed and final speed for controls. Shapiro–Wilk tests for normal distribution showed samples were normally distributed for experimental *S. crassicaudata* (P = 0.56), control *S. crassicaudata* (P = 0.42), and *P. gilesi* (P = 0.19). Post hoc power analyses also were carried out (Zar 2010). Potential effects of transmitter mass and running speed were examined by linear regression and the resulting residuals showed linearity.

Surgical procedures.—Transmitters were implanted intraperitoneally under general oxygen–isoflurane anesthesia. Transmitters (XM model, Minimitter 1.23–1.35 g; Minimitter, Bend, Oregon; and Sirtrack 1.90–2.13 g; Sirtrack, Havelock North, New Zealand) were inserted through a small (1-cm) abdominal incision. Muscle and skin layers were sutured separately using vicryl absorbable suture (ETHICON; Johnson & Johnson, Somerville, New Jersey), and local anesthetic (Ban Itch; Apex Laboratories, Somersby, New South Wales, Australia) and Leuko spray bandage plastic skin (BSN Medical, Clayton, Victoria, Australia) were applied. Postsurgery, animals were kept individually at 24°C and monitored closely for several days, and a pain killer was added to the food for 3 days. Experimentation followed guidelines of the American Society of Mammalogists (Gannon et al. 2007), except for the recommended transmitter mass of <5–10% of body mass, which, although not specified, likely is a recommendation for fieldwork, not laboratory work. The Animal Ethics Committee at the University of New England approved the study.

Results

Maximum running speed of *S. crassicaudata* was 2.37 ± 0.35 m/s ($\bar{X}$ ± *SD*) before and 2.57 ± 0.32 m/s after transmitter implantation (Fig. 1). The maximum running speed of *P. gilesi* was 2.12 ± 0.12 m/s without transmitters and 2.00 ± 0.07 m/s with transmitters (Fig. 1). Transmitters had no significant effect on maximum running speed in either *S. crassicaudata* (t_5 = 1.05, P = 0.34) or *P. gilesi* (t_4 = 1.76, P = 0.15). Similarly, maximum running speed of the control *S. crassicaudata* was indistinguishable (t_5 = 0.85, P = 0.43) when initial speed (2.85 ± 0.32 m/s) was compared with that after a month (2.78 ± 0.45 m/s), in both cases without transmitters (Fig. 1). Post hoc power analyses provided power values of 0.99 for experimental *S. crassicaudata*, 0.93 for control *S. crassicaudata*, and 0.72 for *P. gilesi*.

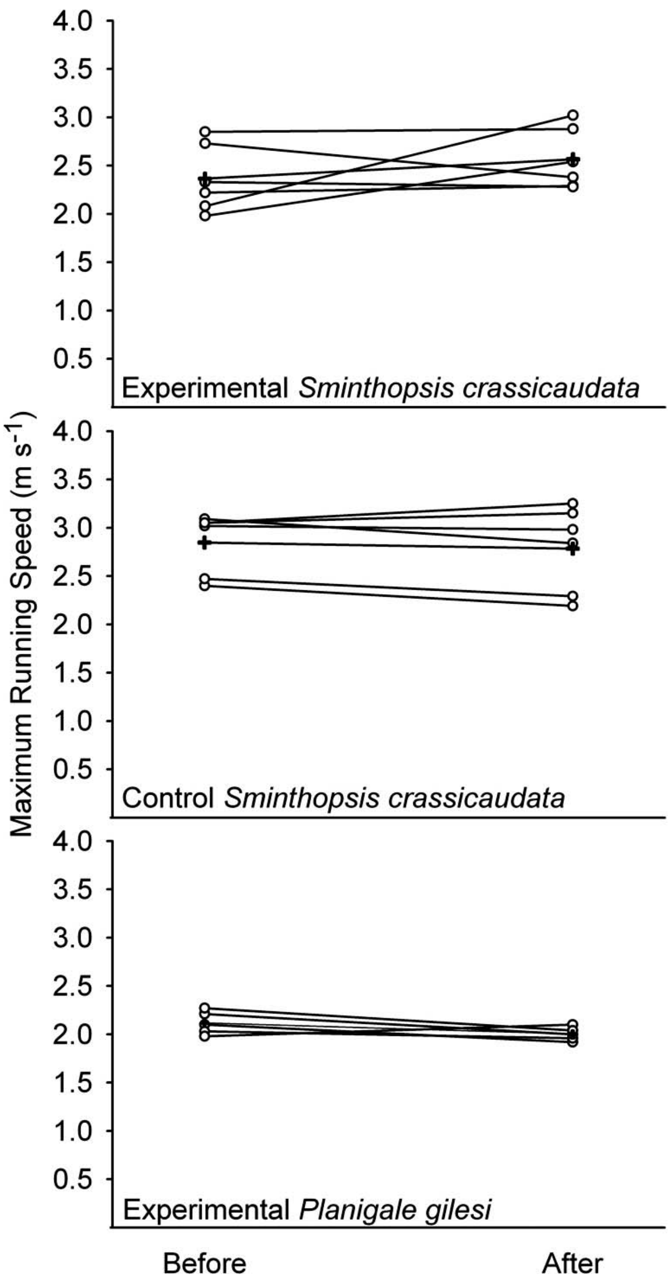

Fig. 1.—Maximum running speed of experimental *Sminthopsis crassicaudata*, control *S. crassicaudata*, and experimental *Planigale gilesi* before and after transmitter implantation. Crosses indicate the mean values.

Implanted transmitter mass (percent of body mass) ranged from 6.4% to 12.2% (*S. crassicaudata*) and 11.3% to 14.1% (*P. gilesi*; Table 1), but transmitter mass and maximum running speed were not related, as shown by the linear regression for *S. crassicaudata* ($F_{1,4} = 0.11$, $r^2 = 0.03$, $P = 0.76$) and *P. gilesi* ($F_{1,3} = 0.04$, $r^2 = 0.01$, $P = 0.86$).

Discussion

Despite miniaturization of transmitters, their use on small species remains controversial because relatively large transmitters are required. Unfortunately, instead of investigating potential mass-related problems, biologists often apply arbitrary guidelines for transmitter size, potentially limiting research on small mammals. We examined whether internal transmitters affect running speed in small mammals as a measure of their performance. This is important for small animals, which, according to the ''5% rule,'' would require especially small transmitters with limited battery life and transmitter range. Hence, determining whether transmitters exceeding 5% of body mass affect running speed is highly relevant and fundamental to many studies, such as, for example, those investigating torpor, because most heterothermic mammals are small (Geiser and Ruf 1995). Examination of our data on 2 small marsupials does not support the hypotheses that internal transmitters > 5% of the animals' body mass affect maximum running speed or that transmitter mass and maximum running speed are correlated.

The animals in our study were able to tolerate the mass and accommodate transmitters in their peritoneal cavity without apparent problems over many months. Female dunnarts implanted with transmitters have given birth, and males have sired several litters (A. D. Rojas, G. Körtner, and F. Geiser, pers. obs.). The much larger North American beaver (*Castor canadensis*; mass ~18 kg) also tolerated transmitters well, apart from occasional adhesion between the implant capsule and peritoneal structures (Guynn et al. 1987). The recovery rate of mice and rats, but not their normal function, was affected by transmitter size (Leon et al. 2004).

The transmitters used in our study were substantially larger than the commonly accepted and recommended 5% of body mass, yet performance in both species examined as maximum running speed was not affected by either transmitter implantation or transmitter mass. The maximum running speeds of *S. crassicaudata* measured here with and without transmitters were almost identical to those reported for *S. crassicaudata* without transmitters previously (Garland et al. 1988). Running speeds of individuals with heavy and light transmitters were indistinguishable even though in some cases (for *P. gilesi*) the transmitters weighed up to 14% of body mass.

For both species investigated here some individuals were faster and others were slower after implantation of transmitters, and this was also the case for the controls for the 2 measurements. This shows that some variation in running speed after implantation of transmitters was due to individual differences in performance on the day of measurement rather than impairment by the transmitter. Our results are consistent with those from a study on ground squirrels (*Spermophilus beldingi*) in which the increase in body mass during autumnal fattening had no significant effect on maximum running speed over the mass range of 200–300 g despite a 50% increase in mass. However, over the entire mass range of 200–450 g, running speed and body mass were negatively correlated (Trombulak 1989).

Arguably, flying animals are more affected by added mass. However, in microbats relative neonate body mass increases with decreasing body mass and even in the largest species measured is >10% of the maternal mass (Hayssen and Kunz

Table 1.—Body mass before and after transmitter implantation, and added transmitter mass. Values are mean ± *SD*, with minimum and maximum in parentheses.

	Body mass (g)		Transmitter	
	Before	After	Mass (g)	% of body mass
Sminthopsis crassicaudata				
Experimental	18.2 ± 0.9 (16.6, 18.9)	19.9 ± 1.7 (16.4, 20.7)	1.8 ± 0.4 (1.25, 2.13)	9.8 ± 2.4 (6.4, 12.2)
Control	16.9 ± 1.2 (15.7, 19.0)	16.3 ± 1.4 (14.2, 18.2)		
Planigale gilesi				
Experimental	12.6 ± 0.8 (11.5, 13.5)	11.9 ± 1.3 (9.3, 12.0)	1.3 ± 0.0 (1.23, 1.35)	12.4 ± 1.2 (11.3, 14.1)

1996). Similarly in birds relative egg mass increases exponentially with decreasing body mass (Rahn et al. 1975). Small birds (<100 g) have egg masses of ~10–20% of body mass, and only when body mass of birds exceeds 1 kg is egg mass ~5% (Rahn et al. 1975). Therefore, it is not surprising that larger birds are more affected than smaller birds by transmitters based on 5% of body mass (Caccamise and Hedin 1985). With regard to transmitter mass in bats, a significant drop in maneuverability with added loads was observed (Aldridge and Brigham 1988). However, the authors clearly demonstrated that bats of various body masses require different sizes of transmitters and that 5% of body mass for added transmitter mass is not appropriate for all species.

In conclusion, at least some small terrestrial mammals are able to cope well with larger added masses than the suggested 5% of body mass, and examination of our data also suggests no long-term negative effects associated with implanted transmitters. Because with current technology the ''5% rule'' severely limits work, especially on small species in the wild, and because transmitters can provide a wealth of new understanding about the biology of species, we recommend that the rule be relaxed to consider the size and foraging mode of the animal. When selecting appropriate transmitter masses it must be considered that relative capacity to carry masses scales with body mass (Schmidt-Nielsen 1977). In small, terrestrial, placental mammals, for example, neonate litter masses can be up to 36% in an animal with a body mass of 10 g, and this decreases only to 24% of maternal mass in an animal with a body mass of 100 g (Blueweiss et al. 1978). Whereas these percent values clearly exceed what should be used for transmitter masses, they demonstrate the large capacity of small mammals to carry extra weight. Therefore, our recommendation for transmitter masses in small terrestrial mammals is <10% of body mass because this still is less than one-half of neonate litter mass in placentals. This mass will ensure that transmitters have large enough ranges and long enough battery lives for meaningful data collection and therefore ethical experimentation without impeding animal performance.

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