Size constraints of telemeters in rats

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Moran, M. M., R. R. Roy, C. E. Wade, B. J. Corbin, and R. E. Grindeland. Size constraints of telemeters in rats. J. Appl. Physiol. 85(4): 1564–1571, 1998.—This study was designed to determine the maximum-size subcutaneous telemeter that would enable long-term and multichannel data collection in a 170-g rat for 90 days. In phase 1, rats with implants weighing 5 (2.5 cm³), 15 (7.5 cm³), 25 (12.5 cm³), 35 (17.5 cm³), or 45 (22.5 cm³) g were compared with sham-operated (SOC) and nonoperated (NOC) control animals. Severe skin lesions, seromas, and lower growth rates were observed in rats having implants ≥35 g. Thus, in phase 2, rats implanted with 23.5 g (17.5 cm³; 11-g active telemeter and 12.5-g implant) were compared with rats implanted with 11 g (6 cm³; telemeter only) and with the SOC and NOC groups. No differences were found among implanted groups in mean arterial pressure (MAP), heart rate (HR), subcutaneous temperature, or spontaneous activity under standard housing conditions. All groups were more active and had a higher MAP during the dark than the light phase of the daily cycle. During 2 h of cold exposure (3°C), both telemetered groups exhibited similar changes in HR, MAP, temperature, and activity levels. Adrenal glands were larger in the 23.5-g group (51 ± 1.6 mg) than in the SOC (46 ± 1.0 mg) and the NOC groups (41 ± 2.0 mg). No other significant differences were found in organ, muscle, or bone weights. Thesedata verify the feasibility of using 23.5-g (17.5 cm³) subcutaneous telemeters for chronic recordings in young adult rats.

telemetry; seromas; microgravity

PROGRESS IN HUMAN SPACE exploration will require an understanding of the physiological effects of prolonged exposure to microgravity. Short-term human studies conducted on board the Space Shuttle have provided limited information in this area because physiological adaptation to an altered environment can require up to 3 wk (3, 10, 25). Long-term studies in humans conducted on board Mir are difficult to interpret because of the variability within the small population samples. For these reasons, studies in animal surrogates are critical in space life-science research.

Animal studies conducted in space for up to 22 days or fewer have allowed data collection from larger population samples. Although these studies have provided adaptation data, longer studies will provide data on the physiological responses due to long-term microgravity exposure. In addition, most animal data have been obtained postmortem and after flight, which makes discerning the effects of launch, microgravity, and reentry impossible and thus provides little information on when changes occurred.

Biotelemetry is a method of data collection that can avoid the aforementioned problems. Data can be collected throughout a mission, thus enabling the crew to perform other tasks. Limiting the crew time required to collect data should provide more reliable data because crew fatigue may affect the reliability of the data (15). In addition, previous ground-based studies (2, 4, 5, 28) comparing telemetry data with data obtained from either hardwired, tail cuff, or colonic probes have found lower heart rate (HR), mean arterial pressure (MAP), and core temperatures in the telemetered animals.

Biotelemetry should allow for the collection of multiple channels of data; however, commercial telemeters (CT) do not meet the demands of long-duration spaceflights. Commercial devices are limited in the number of channels, battery life, and/or recording frequencies for biological signals (18). Multichannel CT are not equipped with an internal receiver, which requires waving a magnet over each animal to turn the device on and off. An internal receiver would allow a computer to control the on-off switch, providing a more efficient method for controlling the devices and conserving battery life. Presently available multichannel CT that provide both biopotential and blood pressure data are implanted intraperitoneally, limiting the size of the telemeter. Subcutaneous implantation would allow for a larger telemeter, providing room for a more powerful battery, a receiver, and additional electronics. It is possible, however, that the size (mass and volume) of these devices may interfere with the normal physiology of the animal.

The purpose of the present study was to determine the maximum-size telemeter that could be implanted subcutaneously in 170-g rats for a period of 90 days without impairing the animals' normal physiology. The study was conducted in two phases. In phase 1, the physiological response of the rats to different-size implants (nonactive telemeters without leads and/or catheters) was examined. In phase 2, rats were implanted with the complete telemeter at the largest biocompatible size (identified in phase 1), to include two electrophysiological...
diagram (ECG) leads and one blood pressure catheter. In addition, phase 2 animals were exposed to 2 h of 3°C to determine whether the implanted telemeter size would affect the animals’ ability to tolerate stress.

**METHODS**

Before initiation of this study, approval was received from the Animal Care and Use Committee at the National Aeronautics and Space Administration (NASA)-Ames Research Center. The study conforms to the NASA-Ames Research Center Animal Users Guide and the National Research Council guidelines for animal experimentation (17).

Experimental Animals and Design

The study was conducted by using 116 male albino rats (Simonsen Laboratories, Gilroy, CA) and was divided into two phases, phases 1 and 2. In phase 1, 70 animals were randomly selected and implanted with one of five different implant sizes or placed into one of two nonimplanted control groups (Table 1). In phase 2, 46 animals were randomly selected and placed into one of four groups (Table 1). Each phase lasted 107 days: a 3-day adjustment period, a 14-day surgical recovery period (R1–R14), and a 90-day treatment period (T1–T90). On receipt from the vendor, the animals were inspected, injected in the back of the neck with a microchip identifier (Bio Medic Data Systems, Maywood, NJ), and weighed. Animals were group housed (2 animals/cage) in standard vivarium cages without bedding for 1 h. Food and water consumption were measured by weight (Ohaus, Florham Park, NJ) and recorded at 23 ± 1°C, a temperature similar to normal housing environments. Once in the room, animals were left in vivarium cages (1 animal/cage) without bedding for 1 h. Food and water were provided ad libitum. At T46, animals were exposed to the cold room (3 ± 1°C) for 2 h and then were immediately returned to standard housing conditions.

### Table 1. Phases 1 and 2 implant and telemeter descriptions

<table>
<thead>
<tr>
<th>Group/ Implant Weight, g</th>
<th>n</th>
<th>Configuration</th>
<th>Volume, cm³</th>
<th>Dimensions of Individual Implant, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong></td>
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<tr>
<td>NOC</td>
<td>10</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>SOC</td>
<td>10</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>2 x 2.5-g implants</td>
<td>2.5</td>
<td>16 x 8 x 10</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>2 x 7.5-g implants</td>
<td>7.5</td>
<td>29 x 9 x 15</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
<td>2 x 12.5-g implants</td>
<td>12.5</td>
<td>46 x 10 x 15</td>
</tr>
<tr>
<td>35</td>
<td>10</td>
<td>2 x 17.5-g implants</td>
<td>17.5</td>
<td>34 x 10 x 30</td>
</tr>
<tr>
<td>45</td>
<td>10</td>
<td>2 x 22.5-g implants</td>
<td>22.5</td>
<td>43 x 10 x 31</td>
</tr>
<tr>
<td><strong>Phase 2</strong></td>
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</tr>
<tr>
<td>NOC</td>
<td>6</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>SOC</td>
<td>20</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>11</td>
<td>9</td>
<td>11-g telemeter</td>
<td>6</td>
<td>See Fig. 1</td>
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<tr>
<td>23.5*</td>
<td>9</td>
<td>11-g telemeter and 12.5-g implant</td>
<td>17.5</td>
<td>See Fig. 1</td>
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</tbody>
</table>

Data Sciences implant (mock telemeters) and telemeter (active telemeter measuring physiological parameters) weight, configuration, volume, and dimensions for phases 1 and 2. n, No. of rats; NOC and SOC, nonoperated and sham-operated control group, respectively; NA, not available. Implants were coated with a silicone elastomer and rounded at 1 end. *Telemeters weighing 23.5 g were used instead of those weighing 25 g because the 11-g active telemeters would provide both blood pressure and biopotential data. In addition, the 11-g group was used to provide control telemetry data because this size telemeter has been used readily in biomedical research.

Light-dark cycle (8:00 AM–8:00 PM, lights on) was used. Animals were fed Purina Rat Chow no. 5012 and provided water ad libitum. Body weight and food and water consumption were recorded daily throughout the adjustment and recovery periods, the first week of the treatment period, and every third and fourth day thereafter for the remainder of the study. Food and water consumption were measured by weight (Ohaus, Florham Park, NJ).

In phase 2, before the cold-exposure experiment, animals were removed from the animal room and transported on a cart to a control room. This was done on 4 days to acclimate the animals to the movement. The control room was located next to the cold room and was used to collect baseline and recovery data. Control room temperature was monitored with a digital thermometer (Fisher, Pittsburgh, PA) and recorded at 23 ± 1°C, a temperature similar to normal housing environments. Once in the room, animals were left in vivarium cages (1 animal/cage) without bedding for 1 h. Food and water were provided ad libitum. At T46, animals were exposed to the cold room (3 ± 1°C) for 2 h and then were immediately returned to standard housing conditions.

**Surgeries**

Phase 1. Surgeries were conducted aseptically at the Animal Care Facility at NASA-Ames Research Center. Animals were anesthetized with isoflurane (Anaquest, Liberty Corner, NJ) by using an anesthesia chamber (Viking, Ford Lakes, NJ) with regulated gas flow (2–5% isoflurane mixture). Animals were shaved and wiped several times with betadine on the dorsal side. A skin incision was made in the middle of the back along the dorsal spine. The subcutaneous tissues were blunt dissected on either side of the spine to allow placement of one implant on each side in a saddle-bag configuration. The implants were secured by suturing two tabs adhered to each implant into the tissue fascia by using 4–0 ethilon suture. The area was flushed with saline-betadine solution, and the incision was closed with metal clips (Becton-Dickinson, Sparks, MD). The same procedures were performed for the SOC groups, except that implants were not involved. Animals were monitored while they were recovering from anesthesia for irregularities in respiration, thermoregulation, and signs of postoperative pain. Both the implant and incision sites were monitored daily for signs of seromas and/or lesions. Skin staples were removed 10 days after surgery.

Phase 2. The preoperative anesthetic procedures employed in phase 2 were identical to those used in phase 1. A saddle-bag configuration (identified in phase 1) was used in the rats implanted with the 23.5-g-size telemeter. In the control group configuration, the 11-g telemeter was placed on the animal’s right side and sutured to the fascia above the thoracic and/or lumbar vertebrae. In both groups, a pressure-sensitive catheter was routed through the abdominal wall via a small incision on the lateral aspect of the abdomen. A midline abdominal incision was made, and the descending aorta was separated carefully from the vena cava and the surrounding fascia. The aorta was lifted gently with a metal probe to stop blood flow for a maximum of 3 min, a time period that avoided hindlimb paralysis due to ischemia. Once the blood flow had been restricted, a small incision was made in the aorta and the catheter was gently slid into the aorta lumen below the renal arteries. A 5-mm² cellulose patch was placed at the entrance of the catheter into the aorta, and two to three drops of medical-grade tissue adhesive (3M, St. Paul, MN) were used to seal the site. To verify catheter placement, an AM radio tuned to 550 kHz was held over the telemeter. A fluctuating tone from the radio was indicative of the cardiac
cycle and verified that the catheter was properly placed. Two biopotential leads (bandwidth 100 Hz) were used for ECG recordings. Each lead was composed of two stainless steel coiled wires, each covered with silicone tubing. The leads were routed subcutaneously to the abdominal side of the animal. After 1.5 cm of the silicone insulation was removed from the end of each lead and silicone tip covers at the tips of each lead were secured, the negative lead was sutured in the area of the right shoulder and the positive lead in the area of the left groin (lead II ECG configuration) (7). Care was taken to ensure adequate slack in the leads to allow flexion of the back and growth of the animal. Closure methods and postoperative monitoring were the same as described for phase 1.

The sham surgeries in phase 2 consisted of two skin incisions: a dorsal incision as described for phase 1 and a midline incision through the abdominal wall. In addition, the intestines were shifted to one side and then replaced before closure to mimic the catheter-implant procedure.

After surgery, the animals were given a subcutaneous injection (0.05 mg/kg) of buprenorphine hydrochloride (Buprenex). As an additional analgesic, Tylenol with codeine (1 ml/200 ml water) was added to the water bottles for a period of 5 days. Once recovery was complete (usually within 14 days), the animals were returned to group housing.

Telemetry System

Twenty telemeters (Fig. 1) were used in phase 2. The telemeters were used to measure HR, MAP, temperature, ECG, and activity. Activity was measured by changes in signal strength as the animal moved around the cage. For example, any distance that the rat moved was generated into a digital pulse. The pulses were counted per minute (cpm) by the acquisition system, with the number of pulses being approximately proportional to the distance that the animal moved. A pulse was generated from a change in locality; thus activities such as grooming, eating, and drinking were not included in the activity signal. Each telemeter had a corresponding receiver (model RLA1000 or RLA1020, DSI, St. Paul, MN) that was placed underneath the vivarium cage. Receivers were connected by cables to a BCM100 (DSI) consolidation matrix that was connected to a data-acquisition card (Dataquest LabPro, DSI) located within the data-collection computer (Optiquest 2000ST).

Telemetry Data

Telemetry data were obtained intermittently throughout the experiment from samples collected under standard housing conditions (17). The telemetry data included in the present paper, with the exception of the cold-exposure data, were collected during T11–T22 of the treatment period. Temperature and MAP data were recorded daily at 3-h intervals. Data collected when the lights were on consisted of 10-s samples averaged and collected at 9:00 AM, 12:00 PM, 3:00 PM, and 6:00 PM. Data collected when the lights were off consisted of 10-s samples averaged and collected at 9:00 PM, 12:00 AM, 3:00 AM, and 6:00 AM. During the cold-exposure test, activity, subcutaneous temperature, MAP, and HR data were obtained from 10-s signal averages, collected every 15 min for 1 h before exposure, for 2 h during exposure, and for 2 h in the control room. At the end of the 2-h recovery period, the animals were returned to group housing under standard environmental conditions.

Dissections

Dissections were performed at T90 of both phases 1 and 2. The rats were anesthetized with methoxyflurane (Mallinckrodt Veterinary, Mundelein, IL) and killed by decapitation. Before decapitation of the animals, blood samples were drawn by cardiac puncture, kept on ice, and centrifuged for hematocrit analysis (Roche Helios, Somerville, NJ), which included white blood cells (WBC; 10^3/mm^3), red blood cells (10^6/mm^3), hemoglobin (g/100 ml), hematocrit (%), platelets (10^3/mm^3), lymphocytes (%WBC), granulocytes (%WBC), and monocytes (%WBC). Organs (heart, liver, adrenal glands, thymus, spleen, kidneys, and testes), skeletal muscles (tibialis anterior, gastrocnemius, soleus, and triceps brachii), and bones (humerus and femur) were removed, trimmed of excess fat and connective tissue, and weighed wet. The skeletal muscles were stored at −70°C for subsequent analysis.

Muscle Protein and Water Content Analyses

In both phases 1 and 2, total noncollagenous muscle protein was determined by using a Bicinchoninic Acid Protein Assay Reagent Kit (Pierce, Rockford, IL). Muscle dry weights were determined after two sections (each weighing 19–25 mg) of each muscle were removed. Muscle sections were dried in an
oven set at 105°C until there were no further changes in weight.

Statistics

All statistics were performed by using the Statistica software program (Statsoft, version 4.1, Tulsa, OK). Body weight, food consumption, water consumption, and telemetry data over time were compared by using a two-way ANOVA adjusted for repeated measures and Newman-Keuls post hoc tests. The data obtained from the dissections were compared by using a one-way ANOVA and Newman-Keuls post hoc tests. Differences with a P ≤ 0.05 were considered significant.

RESULTS

Phase 1

Animal health: skin lesions and seromas. Four days after the phase 1 surgeries, 80% of the rats in the 45-g-implant group and 90% of rats in the 35-g-implant group had developed skin lesions. The lesions were superficial scratches on the middle of the implant site, with a minimal amount of bleeding. Some lesions were also found at the dorsal incision site. Animals in the other groups had minor lesions that healed with treatment (i.e., topical antibiotics). Mild seromas were observed in both the 25- and 15-g-implant groups; however, the swelling dissipated within the first 10 days of the recovery period. Severe seromas were observed in one rat in the 45-g-implant group, and two rats in the 35-g-implant group. These cases were considered severe because the swelling persisted throughout the recovery period.

Body weights/food and water consumption. Rats in the 35- and 45-g-implant groups had significantly lower body weights than did those in the SOC and NOC groups (Fig. 2). The attenuated growth rate began at R2 in both groups and remained lower throughout the recovery period. The rats exhibiting the most discernible loss in body weight also had the most severe lesions and seromas and were removed from the study at T1 and euthanized. Although these animals had lower body weights, their food and water consumption were similar to that in both sets of control animals (Table 2).

Body weights and food and water consumption of animals in the 25-, 15-, and 5-g-implant groups were similar to those in the control groups throughout the recovery period.

Organ, muscle, and bone weights. At T90, there were no differences in absolute (mg) or relative (mg/100 g body wt) organ, muscle, or bone weights among the experimental groups and control animals (data not shown).

Muscle protein and water content. There were no differences among the groups in total noncollagenous muscle protein, or water, except that the tibialis anterior muscles of the 25-g-implant group had less water per gram of muscle (73%) than did the SOC (80%) group (P ≤ 0.05). No other differences were observed among groups in the soleus, gastrocnemius, or triceps.

Hematology. There were no differences among groups for any of the hematologic measurements in phase 1.

Phase 2

Animal health: skin lesions and seromas. Skin lesions and seromas were less prevalent in animals in phase 2. One animal in the 23.5-g group developed seromas after surgery, but the swelling disappeared during the recovery period. At T21 the same animal developed a severe lesion at the edge of the telemeter and was euthanized. There was no evidence of seromas and/or skin lesions in the 11-g group. However, on the first day of group housing, one rat in the 11-g control group died from internal hemorrhaging at the site of the catheter insertion.

Body weights and food and water consumption. There were no differences in mean body weight among the four groups (Fig. 3). Animals in each of the groups ate and drank similar amounts throughout the recovery and treatment periods (Table 2).

Organ, muscle, and bone weights. Muscle and bone weights at T90 were similar among the four groups.
The adrenal glands in the 23.5-g group (51 ± 2 mg) were larger than those in the SOC (46 ± 1 mg) and NOC (41 ± 2 mg) groups and similar to those in the 11-g group (45 ± 2 mg). No other differences in organ weights were observed.

Muscle protein and water content. There were no significant differences in noncollagenous protein or water content for any muscle among the groups in phase 2.

Hematology. Although similar WBC counts were found in each group, differences were observed in the differential WBC (Table 3). The 23.5-g group had fewer lymphocytes compared with the 11-g control group and more granulocytes than the 11-g, SOC, and NOC groups. The 11-g group had a lower monocyte count than did the 23.5-g, SOC, and NOC groups. No other differences in hematologic were observed.

Telemetry Data

The 11-g control and 23.5-g treatment groups exhibited similar temperatures during the lights-on and -off phases (Fig. 4A). Temperature in the 23.5-g group increased from 35.8 ± 0.1°C during the lights-on phase to 36.2 ± 0.1°C during the lights-off phase. Similarly, temperature in the 11-g control group averaged 35.9 ± 0.1°C during the lights-on phase and increased to 36.3 ± 0.1°C during the lights-off phase. MAP was also similar in the two groups (Fig. 4B). During the lights-on phase, MAP in the 23.5-g group averaged 104 ± 0.8 mmHg and increased to 108 ± 0.5 mmHg during the lights-off phase. A similar increase was found in the 11-g group: MAP increased from 105 ± 0.8 mmHg in the lights-on phase to 110 ± 0.7 mmHg during the lights-off phase.

Acute Cold Exposure

No significant differences in activity, subcutaneous temperature, MAP, or HR were found between the 11-g control and 23.5-g treatment groups throughout the experiment. Within the first 15 min of cold exposure, activity in both groups increased significantly from baseline, 63 ± 5 to 240 ± 37 cpm in the 23.5-g group and from 57 ± 5 to 225 ± 43 cpm in the 11-g control group (Fig. 5A).

Mean baseline subcutaneous temperature was 36.9°C in both the 11-g control and 23.5-g treatment groups and began to decline immediately on cold exposure (Fig. 5B). Mean temperature in the 23.5-g group plateaued at 34.3 ± 0.1°C after 15 min in the cold. Temperature in the 11-g group began to reach a steady level of 34.4 ± 0.1°C after 30 min in the cold. Fifteen minutes after the animals were returned to the 23°C environment, the temperature in both groups returned to baseline levels.

MAP in the 23.5-g treatment group increased immediately on cold exposure from a baseline level of 114 ± 1 to 129 ± 1 mmHg and remained elevated throughout the period of cold exposure (Fig. 5C). MAP began to return to baseline levels within 15 min of the recovery time period. MAP in the 11-g control group increased from 115 ± 2 to 128 ± 1 mmHg during the cold period.
exposure and returned to baseline values after 30 min of recovery.

The transition from room temperature to cold increased mean HR from 365 ± 6 to 496 ± 3 and from 367 ± 5 to 496 ± 2 beats/min in the 23.5-g treatment and 11-g control groups, respectively (Fig. 5D). HR in both groups remained significantly elevated throughout the 2 h of cold exposure and began to decline immediately after the animals were returned to the control environment. Mean HR in both groups returned to baseline levels within 15 min of recovery.

DISCUSSION

Although CT provide accurate and reliable data, these systems in general are too small to contain the electronics, receiver, and battery necessary for long-term, multichannel data collection. Thus the purpose of the study was to determine the maximum-size subcutaneous telemeter that would enable long-term and multichannel data collection from a 170-g rat.

The severe skin lesions and seromas that were observed in the 35- and 45-g groups within the first 14 days of phase 1 provided an early assessment of these implant sizes. The lesions were observed in the middle of the implant site, indicating that the animals had caused the lesions by scratching at the skin and suggesting that irritation may have been caused by a lack of vascularization within the subcutaneous pockets of these larger implants. The severe lesions and seromas were limited primarily to the animals in the 35- and 45-g-implant groups. Although some mild seromas were observed in the 25-g-implant group, this is a common reaction to subcutaneous implants (21) and did not affect the viability of this size for the next phase of the study.

In addition to the severe lesions and seromas in the 35- and 45-g groups, 50% of these animals exhibited significantly lower growth rates than did control animals. The remaining animals in the 35- and 45-g groups had growth rates similar to those of control animals, suggesting that the implant size may not have been the only contributor to the lower body weights. The similarity in food consumption among groups suggests the lower growth rate was caused by an increase in energy expenditure. Similarly, studies conducted in rats exposed to chronic loading have shown that, after an initial acclimation period, animals will consume more food per gram of body weight and maintain a lower body mass than will control animals (26). Thus the 35- and 45-g-implant sizes were considered to be unacceptable for chronic use in 170-g rats.

None of these adverse effects were observed in the rats with smaller implants, so the remainder of the discussion will focus on the rats with implants weighing 25 g or less. Organs were weighed to assess any systemic effects of the different implant sizes. For example, animals enduring chronic pain or distress may have smaller thymus glands and spleens and larger adrenal glands (1, 11, 24, 29). Organ weights from phase 1 were similar among all groups. In phase 2, the 23.5-g group had larger adrenal weights than did the NOC and SOC groups, but the weights were not different from the 11-g control group. All other organ weights, including those of the thymus and spleen, were similar to those in control animals. In addition, an adverse reaction to the implants would be reflected in the hematologic data (19, 27). Although there were some differences in the differential WBC among the groups in phase 2, the observed changes are not considered clinically significant (20).

The similar muscle weights among all groups in phases 1 and 2 were somewhat unexpected. Previous studies have shown that chronic skeletal muscle loading will promote hypertrophy (22). At the time of surgery, the 25-g implants were 15% of the animals’ body weight and weighed 6% at the T90 dissection. However, in the absence of physical training, the weight of the implants may have little physiological

Fig. 5. Comparison of group means (±SE) for spontaneous activity levels (A), subcutaneous temperature (B), MAP (C), and heart rate (HR; D) between 23.5-g-implant group (■) and 11-g control group (□). Data were sampled at 15-min intervals for 1 h of baseline (B1–B5), 2 h of cold (T1–T9), and 2 h of recovery (R1–R9). Note: a period of 10 min elapsed from B5–T1 and T9–R1. This time was required to move animals between the 2 rooms and for 1st data samples to be collected.
effect. For example, Rusko et al. (23) loaded rats with 20% of their body mass and exposed one group to 6 wk of treadmill training, and another group served as the sedentary control. The additional load was worn by both groups 24 h a day for the duration of the experiment, with the exception of 2 days to avoid irritation of the skin. Rusko et al. reported minor changes in the oxidative and/or glycolytic potential of the quadriceps femoris, soleus, and gastrocnemius muscles of the loaded sedentary control group. The low muscle water concentration in the animals in the 25-g group (phase 1) was most likely a result of random probability, because the muscle mass and noncollagenous protein data were not significantly different in the 25-g group when compared with the other groups. Although several studies have shown that increasing loads have a positive effect on bone mass in exercised animals (6, 31), bone weight data in the present study showed no differences among groups. Some studies in humans have suggested that bone hypertrophy may be site specific (14, 16). Thus, differences may have been evident within the thoracic and lumbar vertebrae, which supported most of the implant’s weight. Unfortunately, these bones were not examined. The weight of the implant was evenly distributed across the torso, which also may have prevented bone hypertrophy.

In addition to the organ, muscle, bone, and hematologic data, the telemetry results provide further support for the feasibility of using 25-g telemeters for chronic recordings in rats. The patterns of temperature and MAP throughout the lights-on and the lights-off periods were similar in the 11-g control and 23.5-g treatment groups. These data are in agreement with circadian rhythm studies that show that rats in a normal laboratory environment have higher temperature and MAP levels during the dark compared with the light phase of the daily cycle (8, 12, 13, 30).

Animals were exposed to a cold room to assess the ability of the animal to tolerate the 25-g telemeter under stress conditions and to monitor the effect of telemeter weight on the animal’s response to this stimulus. The telemetry data obtained from the cold room were similar in the 23.5-g treatment and 11-g control groups and were consistent with published data on acute cold exposure. For example, Fregly and Sheckman (9) demonstrated an increase in MAP and HR within the first 30 min of cold exposure, as observed in the present study. It should be noted that, in the present study, subcutaneous (not core) temperature was measured, reflecting the external environment more than the internal environment of the animal.

In summary, the present results suggest that subcutaneous implantation of a 25-g (17.5 cm²) telemeter in a 170-g male rat does not compromise the health and well-being of the animal. This size telemeter did not influence growth rate, food and water consumption, organ, muscle, and bone weights, or hematologic status. In addition, the 25-g telemeter did not affect the collection of reliable and accurate data from animals under standard housing conditions and in response to an acute stressor, i.e., cold response. It should be noted that, although the groups were identified by implant and/or telemeter weight, the volume and mass of the telemeter may also play a role in the animals’ ability to tolerate the telemeter. Together, these data validate the feasibility of using a 25-g telemeter for data collection without interfering with the normal physiological responses of the animal.

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