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The kangaroo rat as a model for Type I decompression sickness

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Hills, B. A., and B. D. Butler. 1978. The kangaroo rat as a model for Type I decompression sickness. Undersea Biomed. Res. 5(4): 309–321.—This study involved 720 exposures of 70 kangaroo rats trapped in West Texas and showed that decompression-induced tail biting in this animal provides a good animal model for marginal limb bends in man. That this phenomenon can be reversed by recompression and pathological examination of the tail both indicated that a similar mechanism is probably involved in kangaroo rats and humans. Quantitatively, the most susceptible 20% of kangaroo rats can reproduce the no-stop decompression limits for man for exposure times ranging from 5 min to 8 h, for both air and helium-oxygen. Even the average minimum no-tail-biting depth of 46.2 fsw (2.40 ATA) for this species is much closer to the minimum bends depth of man than to the equivalent depth for other animals of its size, and is as good as the goats'. Its size and habits make the kangaroo rat much more convenient than other animals to use as a model for marginal decompression sickness, and particularly attractive economically for testing long helium-oxygen schedules and other means of decompression sickness prevention.

animal models
limb bends

It is highly desirable to have a good animal model for decompression sickness on which to test any new diving table before it is used in human chamber trials or offshore. This procedure would not only reduce the risk to divers, but it would greatly reduce the enormous cost associated with modifying an unsafe schedule by direct testing on man.

Goats have been widely employed by the Royal Navy since the turn of the century (Boycott and Damant 1908) because they are one of the few species in which lifting of the hoof in pain can be taken as a fairly good indication of one of the more marginal forms of decompression sickness, i.e., limb bends. Limb bends are the presenting symptom in at least 90–95% of cases of decompression sickness in man (Duffner, Van der Aue, and Behnke 1946). Hence the goat is a more suitable model than many smaller animals, such as the guinea pig, rabbit, rat, or mouse, for which death or recovery is about the only end point, and nothing short of serious neurologic impairment can be detected with any degree of certainty. Moreover, these manifestations are produced in these smaller animals by decompressions far in excess of those needed to induce hoof-lifting in goats (Hills 1970) or limb bends in man (Crocker, Goodenough, and Davidson 1951). However, with the advent of very deep diving, and hence very long decompressions, it became necessary to keep experimental animals in test chambers for long periods of time. Unfortunately, the goat can be overcome by the ammonia released from its urine unless effective drainage facilities are available and very large quantities of gas are used to ventilate the chamber—an excessive cost when testing tables for depths beyond the limits of air diving. Ideally, therefore, a small animal is needed which can not only simulate limb bends but which does not require a regular supply of food and water for several weeks and does not urinate or produce feces that emit toxic vapors. Such an animal is the kangaroo rat—sometimes called "the rat that never drinks"—which also seldom urinates. During pressure trials to select a better model for dysbaric osteonecrosis by studying animals with relatively long bones (Eguro, Hills, and Goldner 1974), one or two kangaroo rats were observed to bite their tails. In a pilot study (Hills and Butler 1976), this event proved to be reproducible and, moreover, the tailbiting ceased upon minimal recompression. This pressure-reversibility indicated that the phenomenon might be an analog for limb bends, so this study was undertaken to evaluate it and to compare the conditions for its occurrence with those for marginal decompression sickness in man.

MATERIALS

Equipment

For individual hyperbaric exposures, each kangaroo rat is placed in one of three cylindrical chambers (4 in. i.d. × 12 in. in length) fabricated in clear Plexiglas, with a pressure capability equivalent to 1000 fsw (31 ATA). Thus the whole animal is clearly visible during the entire run. Each of the three chambers has aluminum ends fitted with numerous penetrations to permit pressurization, continuous ventilation, and recording of the relevant environmental parameters.

For multiple exposures to test the same decompression procedure upon many rats (up to 20), a Plexiglas "condominium" is used comprising a complex system of walls providing 20 closed rectangular compartments, each measuring 5 in. × 4 in. × 4 in. Isolation is necessary since any two animals placed together will fight, regardless of sex. To minimize heliox consumption, holes are drilled between adjacent compartments so that they lie in series with respect to the flow of gas. This minimizes the volume of fresh gas needed to flush the system when switching breathing mixes.

All compartments have a common flat sheet of thin Plexiglas as the front panel, through which all animals can be viewed at all times. Pressurization is effected by placing the complex in a regular pressure chamber (4 ft. i.d.) with capability of simulating 2000 fsw. Thus the walls of the condominium do not have to withstand pressure; further economy is achieved by compressing the large chamber with air while flushing only the compartments with heliox. By maintaining the condominium at a pressure slightly (1–2 cmH_2O gauge) above that in the large chamber, there is no back flow of air into the compartments. Each compartment has a little sand in the bottom and a supply of food to last for several days, since these particular animals do not require water or the removal of feces or urine.

The breathing mixtures used in both individual and multiple exposures were air and heliox comprising 80% He and 20% O_2.

The kangaroo rat

The kangaroo rat is a small, docile desert rodent named for the way it uses its long hindlegs in hopping. It is not a marsupial but belongs to the family Heteromyidae, of which several species are found in the southern, more arid areas of the North American continent. They inhabit regions of Texas, Nevada, New Mexico, and Mexico, while they appear on the list of endangered species in California and Arizona. All these regions are areas of very low rainfall and humidity. The animals used in this study had to be trapped by the authors where they abound in West Texas, and are of two species, the Merriam kangaroo rat (*Dipodomys merriami* Mearns) and the Ord kangaroo rat (*Dipodomys ordii* Woodhouse), which tend to occupy the same territory.

In their natural habitat, their range often extends from a creosote-bush, whose roots hold together the loose alluvial soil, sand or loam, in which they dig their burrows, to adjacent areas with no vegetation for saltatorial locomotion. In many instances the area they inhabit is rangeland for grazing livestock. The kangaroo rats used in these trials were trapped at night since they are nocturnal, with peaks of activity 2½ h after sunset and 2½ h before dawn. They prefer areas with perennial grass, where the seeds provide their main food source. Further details of their ecology can be obtained from Reynolds (1958).

The average adult male kangaroo rat is 239.5 mm in total length, of which 140.1 mm is tail; the hind foot is 37.1 mm. The female is slightly smaller. Average weight is 43 g for males and 39 g for females, and an increase of 10–22 g has been noted in animals kept in captivity. Average life span in the wild is between 2.3 and 3 years; 5½ years is the record for a captive animal. Indigenous to West Texas, kangaroo rats of the merriami and ordii species have proved to be well suited to captivity, and can be trapped without too much difficulty. Other species have been caught in the coastal dunes of Texas, but the pilot study indicated that these were neither as sensitive to decompression nor were their responses as reproducible. This evaluation is therefore restricted to those kangaroo rats trapped in West Texas.

Their physiology

Kangaroo rats have been of particular interest to renal physiologists for many years because they are capable of sustaining themselves without water for several weeks at a time, although this has been known to produce ill effects (Howell and Gersh 1935). Their metabolic water production is sufficient for intermittent periods of drought. The rats sleep in a curled position, burying their noses in abdominal fur to recover some of the expired moisture from the preceding breath. Heart rate is about 420 beats per min and respiration rate about 140 breaths per min.

Kangaroo rats also use very little water for thermal regulation, tending instead to use their complex system of nasal passages rather than their tails for heat transfer (Schmidt-Nielson 1975). They have hairy tails, tufted at the end, which differ from the tails of other rats, in which blood flow varies greatly according to the animal's thermal state. The tail is probably the most appropriate site to monitor the animal's response to decompression since the subcutaneous tissue contains much tendon and tendon has been implicated as the tissue responsible for marginal limb bends in man (Hills 1969, 1977).

Care and feeding

Once trapped, kangaroo rats are kept in individual cages (14 in. × 8 in. × 6.5 in.) in a darkened room at about 70°F for a month for quarantine purposes and to allow them to acclimatize to captivity. Type of bedding has been found to be an important factor in their well-being, 2–3 in. of a mixture of 70% fine sand (#5) and 30% dried clay (30/60 Aalum) proving satisfactory if it is replaced every 3–4 weeks. Each cage is also provided with a 6 in. length of opaque PVC tubing (3 in. i.d.) in which the animals hide whenever they sleep.

Food consists of a mixture of rolled oats and sunflower seeds; 1½ ounces is given every other day and excess food and fecal pellets are removed by filtering the bedding every 7–10 days. Vitamin-mineral pellets and water are kept in the cages at all times. Provided these basic requirements are satisfied, the animals are not difficult to keep, but these conditions have proven inadequate to induce them to breed in captivity.

METHODS

Evaluation of the kangaroo rat from West Texas as a model for bends has been undertaken in three stages: qualitative assessment of the reason for tail-biting, evaluation of inherent susceptibility (performed by comparing the minimum tail-biting depth with the minimum bends depths for men and goats), and a kinetic assessment made possible by a comparison of the no-stop decompression limits for both species.

Tail-biting

When tail-biting occurs after decompression, it consists of spasmodic episodes of rapid, repeated, vigorous biting on the same area of the long tail. The two upper front teeth form deep indentations in the skin, although they seldom cut it, as though the animal were aggressively probing some 'deeper' tissue in an attempt to relieve an unwanted sensation or source of irritation. Each episode consists of a series of these 'deep' bites in rapid succession in the same location on the tail for a minimum of four seconds. These sequences can be readily distinguished from the normal grooming procedure, in which the teeth impinge superficially on the skin of the tail as they are used to 'comb' it from end to end. This behavioral pattern is easily recognized simply by watching each animal before it is decompressed or exposed to pressure. Each of the 73 kangaroo rats was carefully observed for an hour before selection for these trials, and three were eliminated because their grooming procedure might be misconstrued as tail biting.

The rapidity of each episode of 'deep' tail bites in the same location on the tail is shown in Fig. 1 for a fairly typical case; in this case the tail-biting was induced by a no-stop decompression from an air exposure considered marginally unsafe by human standards, i.e., just beyond the bounce-dive curve for man determined by the U.S. Navy (Van der Aue, Keller, Brinton, Gilliam, and Jones 1951). The tail-biting ceased soon after recompression and the condition was totally alleviated by a regular air treatment designed for man—Table 5 from the U.S. Navy Manual (1975), or an abbreviated form of it. Each of the 200–300 cases of tail biting responded similarly to this treatment. Tail-biting was often preceded by excessive scratching, particularly around the rear of the thighs, joints, abdominal area and lower back.

Pathological investigation

To investigate the mechanism of tail-biting, three adult kangaroo rats were given no-stop decompressions from successively greater air exposures on alternate days until each displayed tail-biting. Upon return to normal pressure, each was closely observed and a felt-tip pen was used to mark the region (5–10 mm in length) of its long (130–150 mm) tail to which the biting

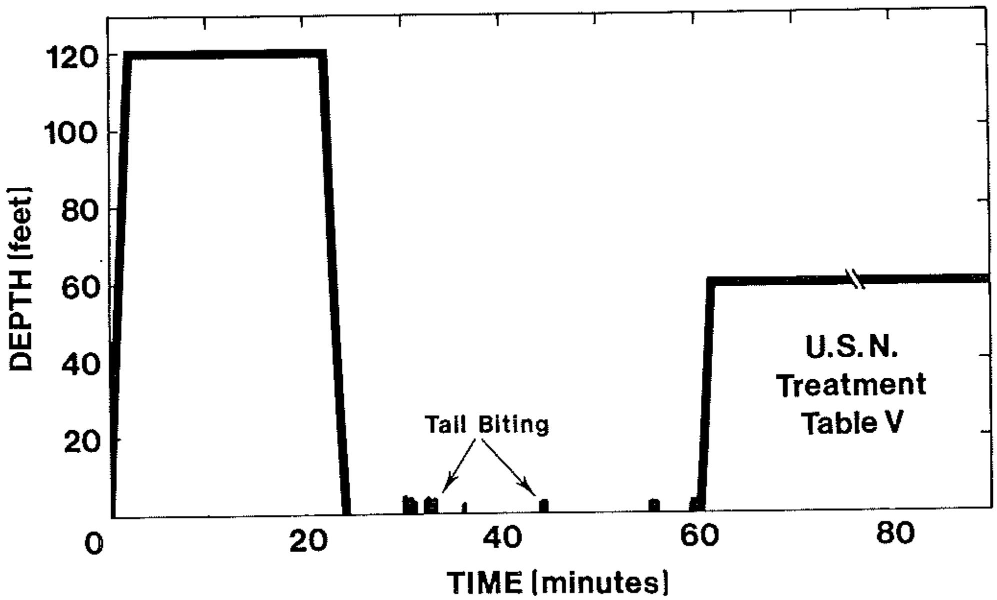

Fig. 1. Record demonstrating intermittency of tail-biting observed in kangaroo rat after a marginally unsafe exposure of 20 min at 120 fsw (4.64 ATA) on air. Note absence of tail bites within first 5 min of decompression and after recompression.

was directed. The animals were then killed by chloroform, since this technique has been shown by Smith-Sivertsen (1976) not to produce bubbles in small animals. The tail was then excised, and the skin removed and placed alongside the remainder. Examination by microscope revealed microbubbles (up to 100μ in diameter) between the fibers of the tendon bundle. These were larger in the region where the animals had been biting and tended to be more profuse around fatty inclusions. An occasional microbubble was seen elsewhere along the tail, but none in the skin itself. Because of lack of contrast, the microbubbles proved too difficult to photograph with the equipment available.

In five other rats similarly killed after tail-biting, the excised tails were almost completely exsanguinated by stroking them in a proximal direction. Bubbles were observed in the expressed blood in only two of the five animals.

Minimum bends depths

The quantitative evaluation of the kangaroo rat as a model consists essentially of comparing various environmental histories which just produce tail-biting in these animals with those which produce marginal symptoms of decompression sickness in man.

The simplest parameter which has been used to describe the inherent susceptibility of any individual diver is his minimum bends depth (MBD), or, for an aviator, minimum bends altitude. This measure combines all individual factors affecting tolerance to decompression into one index, or at least those factors independent of time, since upon return to normal pressure, the subject will tolerate the least depth if left there for sufficient time to attain a steady state. This concept of minimum bends depth has been popular since it was introduced by Haldane (Boycott, Damant, and Haldane 1908) and its variation among professional divers is well documented (Crocker et al. 1951).

To determine its minimum tail-biting depth (MTBD), each kangaroo rat was simply placed in a pressure chamber and compressed to 30 fsw (1.91 ATA) at 5 fsw/min (0.152 atm/min) and held at that pressure for 8 or 14 h, followed by rapid return to normal pressure (at 60 fsw/min). Rats failing to display tail-biting after decompression were then subjected to the same procedure two days later, except that they were exposed to a pressure 5 fsw (0.152 atm) greater. This was continued until they did display tail-biting, thus "titrating" the MTBD to within 5 ft (0.152 atm).

The same procedure was repeated on the same animals after they had been in captivity for at least three months; their weights were recorded at the time of each titration. Kangaroo rats were given work-up exposures and maintained in an adapted state according to procedures found desirable for acclimatization in goats (Hills 1970).

Bounce dive curves

Though the MBD is a good index for inherent susceptibility, a good animal model should also follow the same time scale as man if it is to be of much value in testing decompression tables. The depth-time relationship is, perhaps, most simply demonstrated for divers by the no-stop decompression limits, i.e., the very characteristic dose-time relationship (bounce-dive curve) separating exposures that do from those that do not give bends after no-stop decompression to the surface. These standard curves (Figs. 4 and 5) are readily available for man for both air dives (Van der Aue et al. 1951) and exposures on 80:20 $He:O_2$ (Duffner 1958).

The boundaries separating exposures which produce tail-biting in kangaroo rats from those that do not have been determined in just the same way as the bounce-dive curves were obtained for man in the studies quoted above. The procedure was modified a little by titrating conditions roughly perpendicular to the bounce dive curve to obtain the clearest differentiation between tail-biting and no-tail biting points. At long exposure times, it is therefore better to keep time constant and titrate depth, as described earlier for the MTBD. However, for short exposure times a much 'sharper' titration is obtained, and hence a better defined portion of the curve, if the depth is fixed and exposure time is titrated, e.g., in minute intervals.

Since any differences in the kinetics of inert gas uptake between man and kangaroo rat will be emphasized for short uptake periods, many more rats have had their exposure times titrated at the maximum depth employed, namely, at 190 fsw (6.76 ATA), than were used to determine the whole bounce-dive curve.

In the titrations, no rat was used on successive days, to avoid any residual effect of previous exposures other than a possible general acclimatization to decompression discussed above. Compression and decompression rates were 60 fsw/min (1.82 atm/min).

RESULTS

A total of 720 chamber dives have been made (579 on air) using 70 kangaroo rats whose weights ranged from 30 to 65 g. This does not include the eight animals killed and mentioned in the qualitative assessment. Symptoms consisted of tail-biting except for decreased respiration, syncope, and paralysis which occurred in one rat after a marginally unsafe decompression, i.e., an exposure no more than 5 fsw (0.152 atm) deeper or 1 min longer than one which had proven safe. These same neurologic symptoms were produced in a second animal by purposefully exceeding the absolute pressure by 160%, and a third kangaroo rat died after such an exposure.

Minimum tail-biting depth

Thirty-one kangaroo rats were titrated within one month of capture to establish minimum tail-biting depths on air according to the protocol described earlier. Of these, 9 failed to bite their tails even after rapid decompression from an 8-h exposure at 70 fsw (3.12 ATA). The other 22 had an average minimum tail-biting depth of 59.1 fsw (2.79 ATA) and a maximum no-tail-biting depth of 55.5 fsw (2.68 ATA). When the titrations were repeated at least three months later (depicted as broken lines in Fig. 2), two had already expired of natural causes, while another 9 died during the trials. For the remaining 11, minimum tail-biting depth had been reduced from 58.6 to 46.2 fsw (2.78 to 2.4 ATA) and the maximum no-tail-biting depth from 53.6 to 43.2 fsw (2.71 to 2.31 ATA), while mean weight increased from 40.6 to 49.6 g, i.e., by 22%. Only one animal showed the reverse trend in MTBD (#61 in Fig. 2) and only one lost weight between titrations (#55 in Fig. 2). Average weight for all 23 animals in which a comparison was possible increased from 41.9 to 53.7 g, i.e., by 28%. A paired *t* test showed a highly significant statistical correlation ($P < 0.01$) between the decrease in MTBD and weight gain. The variation in MTBD also decreased during captivity, and the standard deviation was reduced from ± 9.51 fsw (± 16% of 58.6 fsw) to ± 2.52 fsw (± 5.5% of 46.2 fsw), i.e., from ± 0.288 atm to ± 0.076 atm.

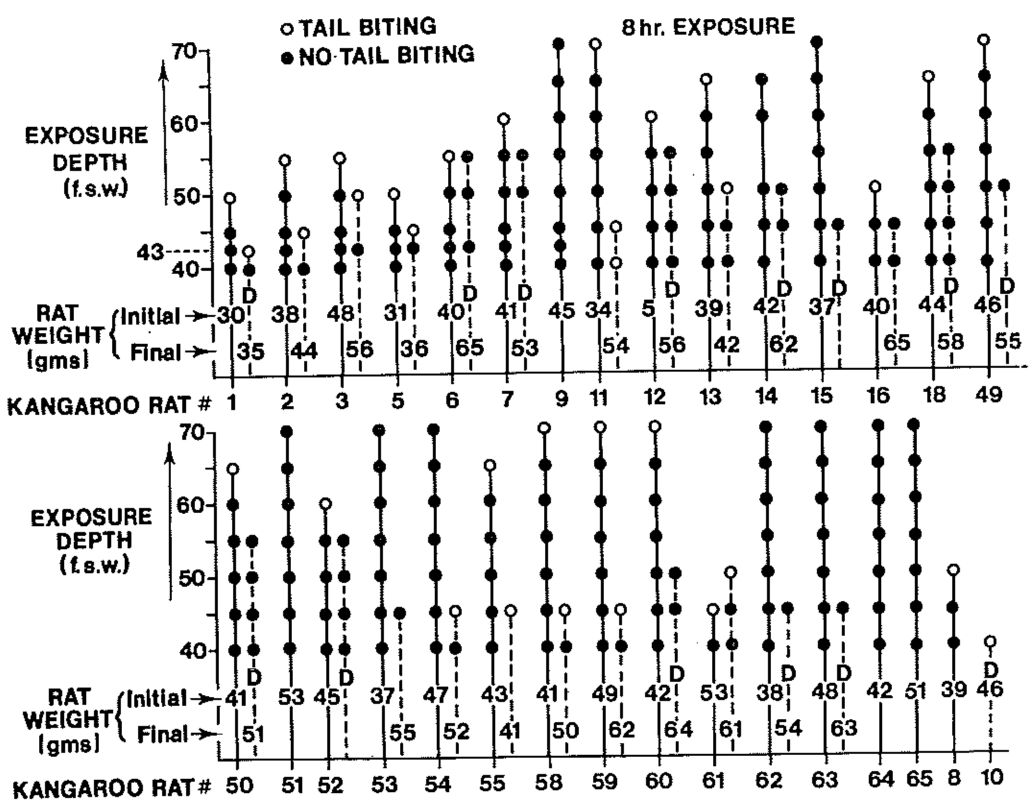

Fig. 2. Titrations of individual kangaroo rats to determine their minimum tail-biting depth (MTBD) by increasing depth of successive 8-h exposures on air until no-stop decompression induced tail-biting. Full lines (and weights) refer to titrations completed within 1 month of capture; broken lines (and weights) refer to titrations started no sooner than 3 months after capture. D means that rat died of unknown causes apparently unrelated to decompression.

Much of the initial deviation in MTBD seemed to occur among groups of rats trapped on different occasions, so a special expedition was made to trap more animals when their natural food supply was most abundant (November) and they would be at their highest annual weight. Of the additional seven kangaroo rats trapped in West Texas in November, six displayed tail-biting at 45 fsw (2.36 ATA); their average weight was 45.0 g ± 13%.

Combining these seven animals from the last expedition with the others yields a total of 17 kangaroo rats out of 38, i.e., exactly 45%, that displayed tail-biting for a no-stop decompression from a steady state at 45 fsw (2.36 ATA) on air. Twenty-one percent of the combined group showed tail-biting at 40 fsw (2.21 ATA).

Short-duration exposures

To test the kangaroo rat for exposures at the other end of the bounce-dive curve, 16 were exposed to 190 fsw (6.76 ATA) on air, and the exposure time was titrated in minute intervals. Results are shown in Fig. 3. Only two rats failed to display tail-biting for a 6-min exposure when newly trapped. When the trials were repeated three months later (broken lines in Fig. 3), however, both rats (Nos. 1 and 3) showed tail-biting after an exposure time of 5 min. For 13 others of the group of 16, the minimum exposure time for tail-biting increased from an average of 4.71 to 4.86 min with captivity; the standard deviations were ± 0.61 and ± 0.77 min, respectively (± 13% and ± 16%). The same animals increased in weight during that time from

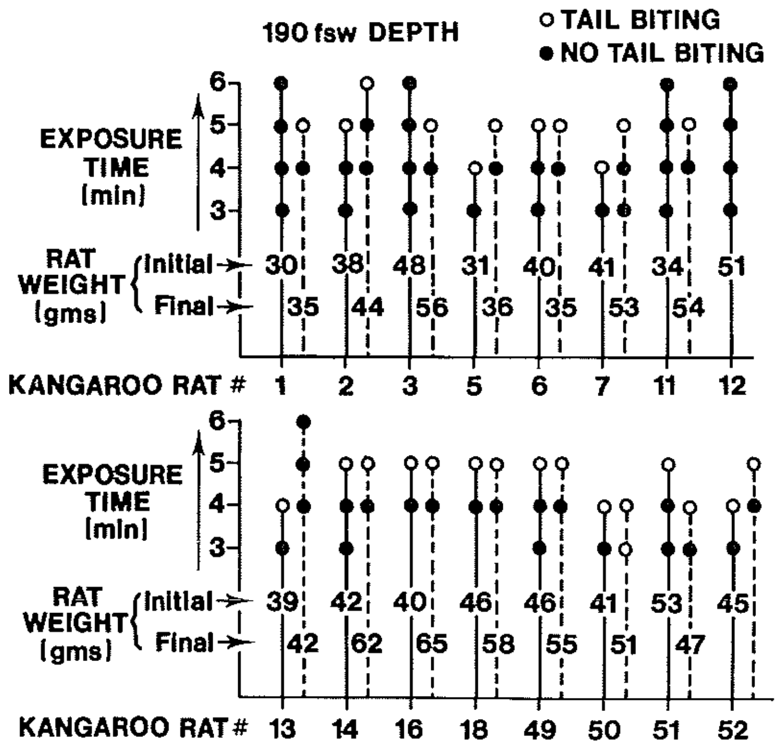

Fig. 3. Titrations of individual kangaroo rats to determine maximum safe exposure time at 190 fsw (6.76 ATA) on air for no tail-biting after no-stop decompression to normal pressure. Full lines (and weights) refer to titrations completed within 1 month of capture; broken lines (and weights) refer to titrations started no sooner than 3 months after capture.

an average of 40.8 ± 5.6 g to 52.7 ± 9.2 g, i.e., a weight gain of 29%. There was no correlation of any statistical significance between change in exposure time and gain in weight, nor could any such correlation be found between changes in exposure time at 190 fsw (6.76 ATA) (Fig. 3) and changes in MTBD (Fig. 2).

Having tested both extremes of the no-stop decompression limits, i.e., the 190-fsw point and the 8-h point most intensely, the rest of the bounce-dive curve for air was determined upon three kangaroo rats (Nos. 1, 2, 7). This involved further titrations of exposure times at additional depths of 175, 120, 75, and 60 fsw (6.30, 4.64, 3.27, and 2.82 ATA). The curve for rat No. 2 is fairly typical of the others and is shown in Fig. 4, which compares tail-biting and no tail-biting points with the no-stop decompression limits for man as determined by Van der Aue et al. (1951).

The same animals were then used for the same titrations on heliox (80:20 $He:O_2$) to determine the no-stop decompression limits for that breathing mixture. Tail-biting and no tail-biting points are shown in Fig. 5 for kangaroo rat No. 7 and compared with the no-stop limits for man on this mixture, as determined experimentally by Duffner (1958).

Staged decompression

Though the kangaroo rat had been tested exhaustively over the whole time scale for no-stop decompression, it was still desirable to test it on a staged decompression to see whether any unexpected problems might arise. A total of 40 rats were used in two runs in the 20-compartment condominium for an exposure of 30 min at 500 fsw (16.15 ATA), followed by 820 min of decompression involving four breathing mixtures (7:7:86 O_2:N_2:He, 14:14:72 O_2:N_2:He, air and 100% O_2). No problems were encountered and no rats bit their tails. The same schedule subsequently proved safe for professional divers in 12 chamber exposures. All rats were in good condition at the end of the exposure and no pulmonary problems could be detected.

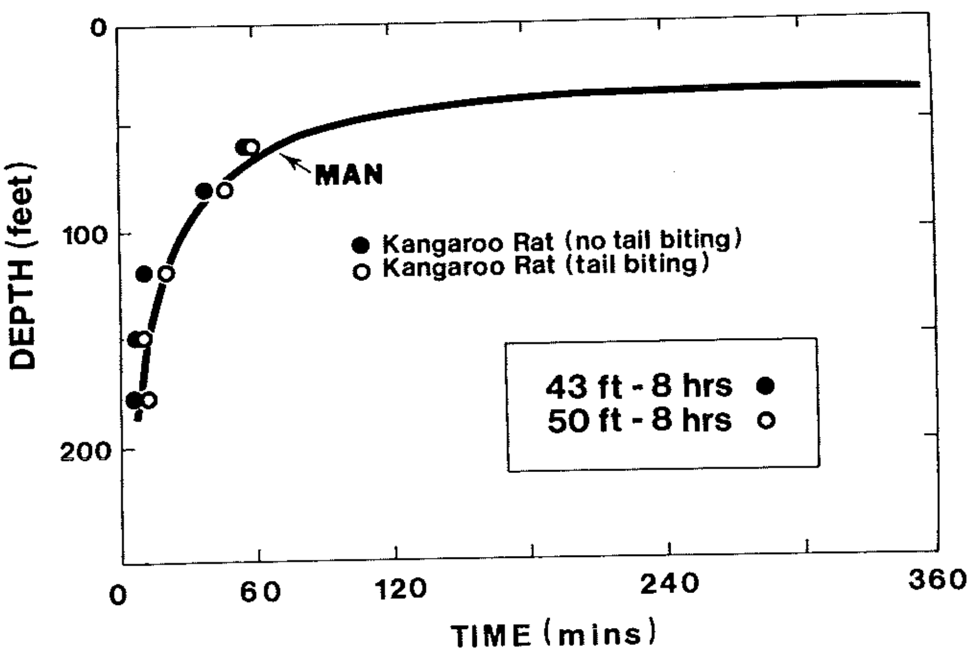

Fig. 4. No-stop tail-biting limits on air titrated for one of the more susceptible 40% of kangaroo rats over whole time span from 5 min to 8 h, compared with safe no-stop decompression limits, i.e., bounce-dive curve determined for air diving on man by Van der Aue et al. (1951) and represented here by full line.

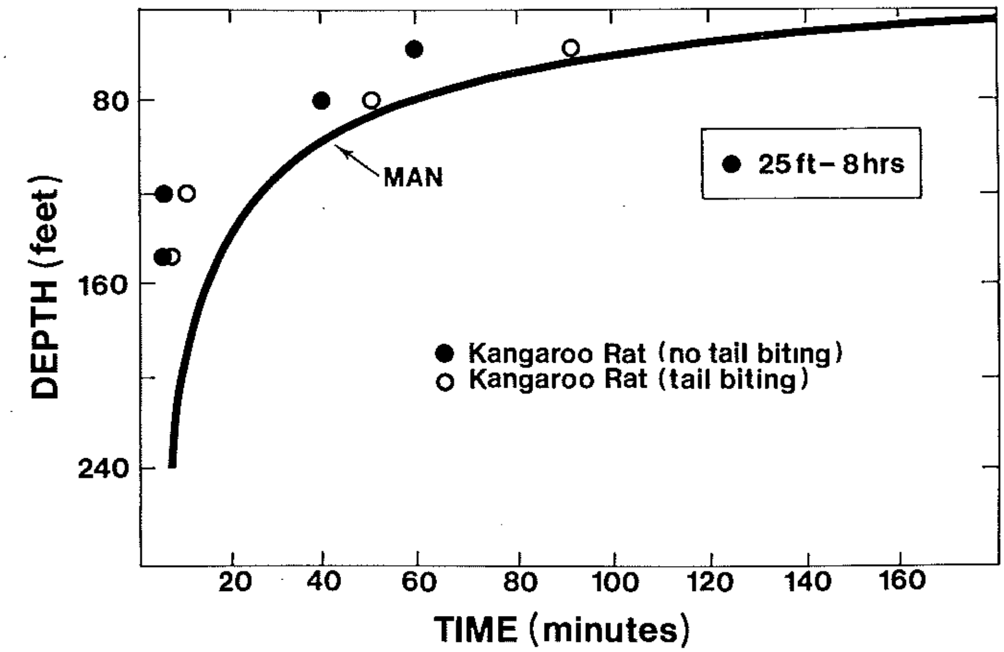

Fig. 5. No-stop tail-biting limits on 80:20 $He:O_2$ titrated for one of the more susceptible 40% of kangaroo rats over whole time span from 5 min to 8 h, compared with safe no-stop decompression limits, i.e., heliox bounce-dive curve determined on man by Duffner (1958) and represented here by full line.

DISCUSSION

The kangaroo rat is fairly easy to trap, and keeping it in captivity presents no problem once its few basic needs have been recognized. The animal is docile, much easier to handle than the normal laboratory rat, and has proven to be particularly clean. This makes it ideal for testing long decompressions since it eliminates any need to open the compartments for many days, making it quite inexpensive to test a long heliox schedule even in trials employing as many as 20 animals simultaneously.

The nature of the bites, the occurrence of the tail-biting episodes after decompression (Fig. 1), and the alleviation of the tail-biting behavior by recompression leave little doubt that tail-biting is a decompression-induced phenomenon. Moreover, the greater likelihood that tail-biting would occur after a deeper exposure (Fig. 2) or a longer exposure (Fig. 3), i.e., after greater uptake of inert gas, indicates that the mechanism probably resembles that of decompression sickness in man. This resemblance was further substantiated by pathological investigation, which revealed microbubbles between the tendon fibers in the exact location on the tail where the animal had bitten repeatedly. This seems particularly compatible with the hypothesis that extravascular bubbles pressing on nerve endings in a well-innervated, tight connective tissue cause limb bends in man (Inman and Saunders 1944). There is also much quantitative evidence to implicate tendon as the tissue type responsible for limb bends (Gersh, Hawkinson, and Rathbun 1944; Hills 1969). The kangaroo rat is probably experiencing bends pain in its tail, and it is fortunate that it can show this discomfort to any observer by biting the painful place in such a characteristic manner. This ability to demonstrate a marginal discomfort so clearly is a great advantage over other small animals, for whom death or serious neurologic symptoms are the first signs of distress—hardly a realistic criterion for comparison with the marginal symptoms (usually mild limb bends) which one strives to avoid when formulating decompression schedules for man.

However, whether this explanation of tail-biting is correct or not, the end point must correspond to marginal decompression sickness in man (this means Type I, since limb bends are the presenting symptom in 90–95% of all cases (Duffner et al. 1946) and form a significantly higher proportion when only *marginal* cases are considered). Tail-biting in the kangaroo rat occurs for a minimum exposure depth (MTBD) very much closer to the MBD for man than that of any other small animal. Moreover, the kangaroo rat's MTBD is better than that of dogs, while the most sensitive 20% of kangaroo rats have MTBDs closer to man's MBD than the goat's; this is not true for the average of all kangaroo rats as caught, according to a comparison with the data of Flynn and Lambertsen (1971) depicted in Fig. 6. The tail-biting criterion puts the kangaroo rat way out of line with other species when other criteria are used (Fig. 6). Tail-biting is not meaningful in other small animals since other rats and mice have widely fluctuating blood flows in their tails to maintain thermal balance, and guinea pigs and rabbits have no tails of any size. Hoof-lifting in the goat is probably as good a model as tail-biting in the kangaroo rat, but it is difficult and expensive to obtain goats and then to select only those most sensitive to decompression.

The most susceptible 20% of kangaroo rats have a minimum tail-biting depth significantly closer to the MBD of man but still not equal to the MBD of the weaker subjects, such as the 32–40 + fsw (1.97–2.21 + ATA) for naval 'volunteers' (Crocker et al. 1951). Only the less sensitive subjects tend to become professional divers, however, so that most can withstand no-stop decompression from 40 fsw (2.21 ATA) on air. A kangaroo rat that bites its tail after decompression from an exposure of 8 h at 45 fsw (2.36 ATA) would therefore be acceptable.

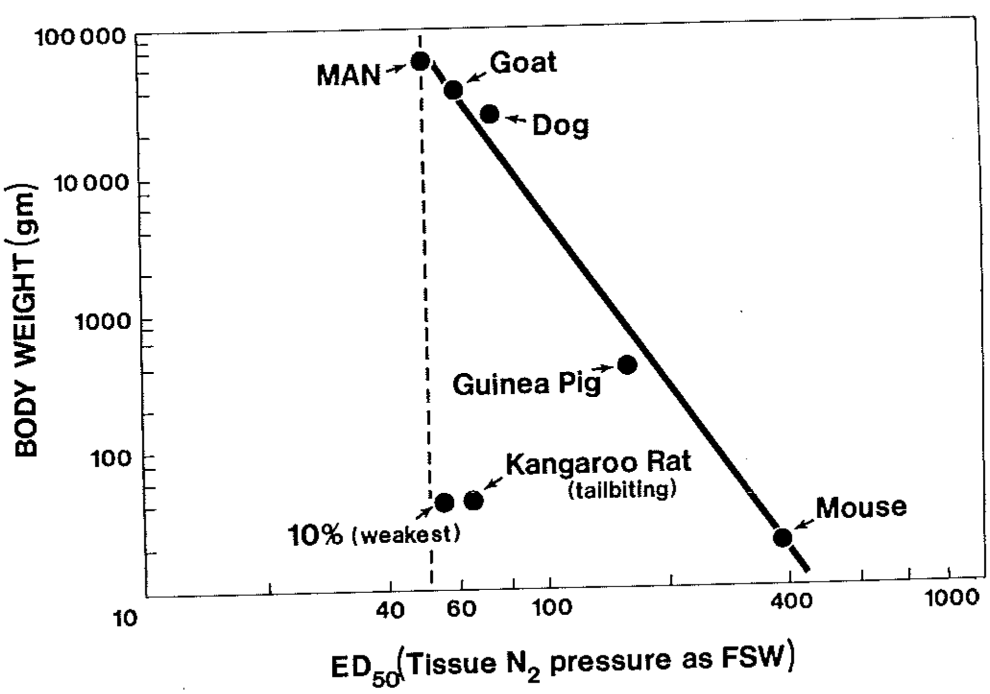

Fig. 6. Comparison of relative susceptibilities of various species to decompression sickness according to data of Flynn and Lambertsen (1971), to which points have been added from this study to represent tail-biting in the kangaroo rat.

This means that 45% of the kangaroo rats used in these trials would be acceptable, even though most of these had been 'sensitized' by captivity. As caught, 20% would be acceptable. We suggest that all animals be exposed to 45 fsw (2.36 ATA) for 8 h soon after they are caught, and only those displaying tail-biting should be retained for trials. The remainder should be rejected, or re-tested after 3 months on a generous diet if it is difficult to procure more animals.

This discussion of sensitivity applies only to decompression from steady state, but the time titrations for 190 fsw (6.76 ATA) gave a 4.86 min maximum exposure time compared with 5 min for man (U.S. Navy Manual, 1975), so that, if anything, the average kangaroo rat is slightly more sensitive than the professional diver at this extreme end of the no-stop limits. On the rest of the bounce-dive curve there is very little difference for either air (Fig. 4) or heliox (Fig. 5). These comparisons between man and a more susceptible kangaroo rat, i.e., one from the group with the lower 20% of MTBD values, are regarded as most significant because the no-stop decompression limits are unique relationships fundamental to the underlying physiological mechanism.

Hence it is probably fair to conclude that while tail-biting in the kangaroo rat is not a perfect analog for marginal decompression sickness in man, it is better than most other animal models; it is also much more convenient than the alternatives and certainly much cheaper for testing long heliox schedules. The kangaroo rat's small size and clean habits, combined with its sensitivity to decompression, raise the possibility of developing a living meter to be carried by a diver in much the same way that miners used to take canaries into the coal pits to warn them of noxious gases.

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Hills, B. A., and B. D. Butler. 1978. Le kangourou-rat comme modèle de maladie de décompression, Type I. Undersea Biomed. Res. 5(4): 309–321.—Ce travail rapporte les résultats de 720 expositions hyperbariques de kangourou-rats, et montre que le rongement de la queue provoqué par la décompression peut servir de modèle de la maladie de décompression chez l'homme. (Les animaux sont pris au piège au Texas.) La disparition du phenomène après la récompression, et l'examen anatomopathologique, nous font croire qu'il s'agit dans les deux cas d'un seul mécanisme physiologique. Le 20% des animaux "plus faibles" reproduisent les limites de décompression continue pour l'homme pour des durées d'exposition de 5 à 8 heures en air comme en hélium-oxygène. La profondeur moyenne minimale qu'on peut atteindre sans provoquer le rongement (46,2 fsw = 2,40 ATA) est beaucoup plus proche à celle de l'homme que les profondeurs d'autres animaux d'une taille semblable. (Elle ressemble en effet à celle du bouc.) Grace à se petite taille et ses hatitudes de vie, le kangourou-rat est un modele très convenient de la maladie de décompression peu sévère. Son utilisation est aussi très économique pour les épreuves de protocoles étendus à l'héliox ainsi que d'autres moyens prophylactiques.

modèle animal
arthralgie de la maladie de décompression

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