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Effect of body composition and weight gain on performance in the adult dog[1]

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YOUNG, D. R. *Effect of body composition and weight gain on performance in the adult dog*. J. Appl. Physiol. 15(3): 493–495. 1960.—The effect of overfeeding and variations in body composition on resting metabolism and work performance has been examined in the adult dog. At rest, the mean O_2 uptake was 85.5 cc/min. and the R.Q. was .65. These were not substantially altered by 20% gain in weight associated with variations of 12%–20% in body fat content. Work performance was tested during a 50-min. period of treadmill running at a fixed work intensity of 202.9 kg-m/min. Oxygen uptake, work and recovery pulse rates were constant. However, the respiratory quotient increased from .81 to .95 and water loss during work increased from 1.16 cc/Cal. to 1.84 cc/Cal. with gain in weight and adiposity. It is concluded that the most important effect of gain in weight is to promote increased water loss during constant steady-state work.

OVERWEIGHT is an important nutrition-related health problem, and while there is general concern for the extent that excessive weight, and particularly adiposity, may modify tolerance for physical work, surprisingly few tests have been conducted to determine the effect on performance of *a*) increased body mass during gain in weight as well as *b*) changes in body composition.

Results of previous tests agree in demonstrating that the physiologic strain of physical work is in direct proportion to body mass. For example, treadmill tests conducted at fixed speeds and grades with either normal subjects varying in body weights (1–3) or experimental animals with body weights altered by food deprivation (4) have shown that the energy cost of submaximal work is directly related to the body weight.

Relatively little effort, however, has been devoted to determining the direct effect of body composition. With the exception of the recent report by Buskirk and Taylor (5) suggesting no probable effect on the maximal oxygen uptake of variations of 7%–16% in body fat, the extent to which body composition per se may affect performance capabilities is unknown. Accordingly, tests have been undertaken to determine the effect of variations in body composition on work performance.

This report deals with the effect in dogs of overfeeding and the body composition on two levels of physical activity, i.e. at rest and during steady-state work.

METHODS

The experimental animals were eight well-conditioned, purebred, male beagle dogs 8–12 kg in body weight. The dogs were 2 years of age and had been maintained at constant body weights, by controlled feeding, for several weeks prior to testing. The body dimensions of the test animals prior to overfeeding are presented in table 1. During the experimental period of weight gain, the daily allotment of food (Purina) was increased every 10 days by an additional 50 gm/day until the body weights stabilized at a higher level; the feeding process was then reversed until the weights returned to slightly below the initial values. Water intake was permitted ad libitum at all times. The entire procedure required approximately 5 months.

All functional tests were conducted in the postabsorptive state. At rest, O_2 uptake was determined from a 20-minute sample of expired air collected in a chain compensated gasometer. Specially constructed respiratory masks with low resistance valves and connections were used. The respiratory gas samples were analyzed for CO_2 and O_2 in the Haldane apparatus and Beckman oxygen analyzer, respectively.

Work metabolism was determined by collection in duplicate of 4-minute samples of expired air during a standard 50-minute period of treadmill running at a constant rate of progression of 3.63 mph and a work load of 202.9 kg-m/min. A constant work load was achieved by adjusting the degree of treadmill inclination for differences in body weight. Pulse rate and body temperature were obtained with a cardiotachometer and telethermometer, respectively.

Body composition was determined from the gaseous N_2 elimination by a modification of the method of Shaw

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et al. (6). Continuous rebreathing of oxygen from a spirometer was accomplished in the unanesthetized dog by utilizing a special tight-fitting mask permitting only nasal breathing through a double Douglas valve. The mask was connected to the spirometer with corrugated rubber tubing; effluent gas was passed through a CO_2 trap (50% KOH) prior to its return to the spirometer. The volume of the connecting tubes and CO_2 trap was estimated by geometry. Seven minutes were permitted for lung washout and then rebreathing was started and maintained for a period for 3½ hours. Oxygen and carbon dioxide were determined by direct gas analysis and nitrogen was determined by difference. Usually the animals came into equilibrium with 1.20% N_2 and 2.50% CO_2 in a volume of approximately 35 liters. Necessary corrections were made for small amounts of N_2 present initially in the 'pure' oxygen. Fat-free body weight (FFBW) was computed from the relationship, $FFBW = 1.138\ W_{kg} - 0.0218\ N_2$ cc; body water was taken as 72% of the fat-free body weight.

Responses to treadmill running were determined in the morning, and body composition was determined on the afternoon of the same day. All tests were conducted in the air-conditioned performance laboratory (70°F; 55% R.H.).

RESULTS

Body composition. The body composition of eight dogs was measured at various stages of overfeeding. While occasional data were discarded because of mask leakage resulting in unreasonably high values for body N_2, replicate tests indicated that estimates of body fat from the dissolved N_2 in the body were reasonably reliable. For example, duplicate measures of body composition in one dog weighing 10.36 and 10.39 kg on successive days provided estimates of 13.55% and 12.42% for fat, respectively. The body composition of the animals at various stages of weight gain is presented in table 2. As is to be expected in utilizing an empirical relationship, body fat is perfectly correlated with body water content, $r = -.999$.

Changes in the body dimensions were studied systematically in two dogs. Estimates of body composition made after the maximum gain in weight are shown in table 3. In the two animals studied there is considerable variability in the increase in water and fat components of the body. The relative gain as water and fat varied from 32.3% to 49.7% and 51.6% to 31.5%, respectively. On the other hand, the gain in protein and minerals was relatively consistent at 17.5%.

Resting metabolism. A total of 67 measurements of resting gas exchange were obtained during the experimental period of controlled variations in body weight. The gross oxygen uptake in cubic centimeter per minute was correlated with body weight, $r = +.496$ ($P < .01$). However, within the range of body weights studied, i.e. 8.48–14.16 kg, only 25% of the variability in O_2 uptake was associated with variations in weight; consequently, there is justification in considering only average values. The over-all mean oxygen uptake was 85.5 cc/min. with a standard deviation of ±16.8. When corrected for body weight the mean resting metabolism was 8.03 cc/kg/min. with a standard deviation of ±1.43.

The respiratory quotient (R.Q.) showed no systematic relationship to changes in body weight nor to variations in O_2 uptake. The mean R.Q. was .65 ± 0.08.

Responses to a fixed work load. Performance was tested during a 50-minute period of treadmill running. Average body weight and the physiologic responses to exertion

TABLE 1. *Physical Dimensions in Centimeters of 8–12-Kg Beagle Dogs*

Foreleg length (acromion of scapula to accessory carpal digit)	21.8±0.68
Hind-leg length (third trochanter of femur to tuber calcis)	20.8±1.19
Spine length (nuchal crest of skull to 1st coxygeal vertebra)	62.9±6.57
Chest girth	47.4±2.74

Spine length and chest girth are correlated with body weight, $r = +.900$.

TABLE 2. *Body Composition in Eight Dogs*

Body Weight, kg	N_2, cc	Body Water, %	Fat, %
8.59	120	59.9	16.8
8.90	130	59.0	18.0
10.15	142	60.0	16.6
10.35	141	60.5	15.9
10.39	125	63.0	12.4
10.58	131	62.5	13.2
12.03	176	58.9	18.1
15.01	231	57.0	20.8

TABLE 3. *Changes in Body Composition During Weight Gain in Two Dogs*

Maximum Wt. Gain, kg	% Gain as		
	Water	Fat	Protein +minerals
0.31	32.3	51.6	16.1
2.98	49.7	31.5	18.8

TABLE 4. *Body Weight and Physiologic Responses to a 50-Minute Treadmill Test (202.9 kg-m/min.) in Eight Beagle Dogs*

Body wt., kg	10.36±1.24	12.40±2.09
O_2 Uptake, cc/min.	748±53.3	753±53.5
R.Q.	.81±0.07	.95±0.10*
Ventilation, l. (STPD)/min.	51.435±4.760	56.111±11.400
Work pulse/min.	225±13.0	230±14.0
Δ Rectal temp., °F	+2.25±0.60	+3.07±0.77
Water loss, cc/cal.	1.16±0.49	1.84±0.37†
Recovery pulse/min.‡	167±14.0	174±15.0

* Differs significantly, $P < .01$. † Differs significantly, $P < .05$. ‡ Mean 4-min. recovery pulse.

prior to and following weight gain are presented in table 4.

The average weight gain was 19.7%. Oxygen uptake, pulse rate and changes in body temperature during work were unaffected by gain in weight; the mean values for these responses were 750 cc/min., 227 beats/min. and +2.66°F., respectively. Consequently, it may be inferred that for fixed work loads the cardiorespiratory responses are unaffected by gain in weight. On the other hand, the R.Q. and water loss during work showed a significant increase with gain in weight.

Increased water loss during work in the dog is of particular interest. While the major route of water loss is through vaporization of water from the oral and respiratory surfaces, significant quantities are lost through salivation. For example, the 'drip' loss (approximately 30% of the total water loss), collected during work in loose-fitting polyethylene bags suspended under the snout of the dog, showed the following chemical characteristics: pH 8.77, nitrogen 21.7 mg%, sodium 131.0 mg%, potassium 29.0 mg%, magnesium 2.4 mg%, calcium 9.2 mg% and phosphorus 1.8 mg%. Thus, the composition of the fluid indicates the occurrence of active secretions. As is indicated in table 4, there was no significant change in pulmonary ventilation during work as a result of gain in body weight, and since the body temperatures were substantially similar it is likely that water lost from the respiratory tract was constant. Therefore, it is suggested that the excess fluid loss during work was brought about largely by increased salivation.

The work R.Q. was in general related to water loss. Prior to weight gain the mean work R.Q. was .81; after maximum gain in weight the R.Q. was elevated to .95. It is well known, particularly in domestic animals, that an elevated respiratory quotient is associated with deposition of fat and gain in weight through feeding diets high in carbohydrate. In the present series, the R.Q. measured at rest was independent of adiposity and quite uniform at .65, suggesting a preponderance of fat oxidation. During work, an R.Q. of .95 indicates a preponderance of carbohydrate oxidation which may be causally related to increased water loss. Further studies are necessary to elucidate the underlying mechanisms.

DISCUSSION AND CONCLUSIONS

The effect on performance of moderate weight gain has been examined in the dog.

Estimates of body composition in two dogs indicate, as has been suggested in man (7), that deposition of tissue in the adult through food intake is marked not only by substantial increases in the fat and water components of the body but also in the protein-mineral content. In two animals studied the average relative increase in water, fat and protein-mineral components was 42%, 42% and 18%, respectively. This leads to the tentative conclusion that in addition to gain in water and adipose tissue there is an increase in lean body mass. Following this line of reasoning a bit further one would anticipate alterations in the resting O_2 uptake with changes in lean body weight. While the correlation between variations in resting metabolic rate and body weight is highly significant ($r = +.496$; $P < .01$), only a minor portion of the total variability in O_2 uptake may be associated with body composition.

Body composition per se does not appear to seriously modify the responses to daily moderate bouts of aerobic work. When the necessary corrections are made to eliminate a systematic effect of body weight on physical work, the O_2 consumption, work and recovery pulse rates are constant. There is, however, a significant increase in water loss during work in the overweight dog, and probably an increased requirement for water.

The respiratory quotient during work showed a significant increase with weight gain. The factors associated with this response are somewhat obscure and further tests are needed to determine its significance in reference to energy and water metabolism.

While it is clear that frank obesity will alter tolerance for work through loss of vital capacity from encroachment by omental and mediastinal fat on the thoracic space, increases in body fat from 12% to 21% appear to affect performance only to the extent of promoting increased water loss during work. Thus, the increased energy expenditure and heart rate commonly observed in overweight subjects at work is probably due solely to the burden of additional weight, and in this respect the additional quantity of body water must be equally as responsible as the gain in fat.

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