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METABOLIC ASPECTS OF CALORIC RESTRICTION (500 calories)
Body Composition Changes

HARRY J. KRZYWICKI, MS
C. FRANK CONSOLAZIO
HERMAN L. JOHNSON, PhD
and
NORMAN F. WITT, PhD

BIOENERGETICS DIVISION
DEPARTMENT OF NUTRITION

AUGUST 1979

LETTERMAN ARMY INSTITUTE OF RESEARCH PRESIDIO OF SAN FRANCISCO CALIFORNIA 94129

Human Subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 70-25 on use of volunteers in research.

John M. Marshall Jr. 4 Sept 1979
(Date)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Body composition changes in 8 healthy adult males (19 to 21 years of age) were studied while subsisting on a daily liquid diet containing 340 kcal from carbohydrate and 160 kcal from protein for a 10-day period. Half of the subjects (Group I) were denied minerals with the remaining half (Group II) receiving a daily mineral supplement.

Body weight losses were still severe (5.51 and 4.67 kg) in Groups I and II, respectively. This loss was further partitioned into 3.59 kg

20. Abstract (cont)

of fat, 1.4 kg of water, and 0.39 kg of dry protein in Group I, while Group II showed losses of 2.76 kg of fat, 1.32 kg of water and 0.39 kg of dry protein.

The observed total body water (D_2O dilution) loss was lesser in both groups than observed in previous studies. The largest amount of water was lost by the group which was denied minerals. This indicates the water sparing and fat utilizing effects of limited carbohydrate and protein with mineral supplementation.

The skinfold thicknesses of both groups were also decreased during caloric restriction. Lesser changes were noted when minerals were included in the diet. The data indicate that the small quantity of protein in the diet was somewhat beneficial in sparing body protein.

ABSTRACT

Body composition changes in 8 healthy adult males (19 to 21 years of age) were studied while subsisting on a daily liquid diet containing 340 kcal from carbohydrate and 160 kcal from protein for a 10-day period. Half of the subjects (Group I) were denied minerals with the remaining half (Group II) receiving a daily mineral supplement.

Body weight losses were still severe (5.51 and 4.67 kg) in Groups I and II, respectively. This loss was further partitioned into 3.59 kg of fat, 1.4 kg of water, and 0.39 kg of dry protein in Group I, while Group II showed losses of 2.76 kg of fat, 1.32 kg of water and 0.39 kg of dry protein.

The observed total body water (D_2O dilution) loss was lesser in both groups than observed in previous studies. The largest amount of water was lost by the group which was denied minerals. This indicates the water sparing and fat utilizing effects of limited carbohydrate and protein with mineral supplementation.

The skinfold thicknesses of both groups were also decreased during caloric restriction. Lesser changes were noted when minerals were included in the diet. The data indicate that the small quantity of protein in the diet was somewhat beneficial in sparing body protein.

PREFACE

C. Frank Consolazio, 1913-1976, one of the world's foremost nutritional physiologists, began his scientific career in 1929 as a laboratory technician at the Harvard Fatigue Laboratory in Boston. In 1947, he joined the Federal service as a physiologist. He served at Army medical nutrition laboratories in Chicago and in Denver where he became the Chief, Bioenergetics Division. He continued in this capacity at the Letterman Army Institute of Research, San Francisco, where he was an active member of the staff at the time of his death. Mr. Consolazio authored more than 200 scientific publications and participated in approximately 100 human nutrition-related field studies. His contributions to science and, in particular, to military nutrition are a lasting memorial to a man who was not only an outstanding scientist, but also a beloved friend, and an inspiration to those who knew him and were privileged to work with him.

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INTRODUCTION

This is the third in a series of studies being conducted on the effects of short-term caloric restriction and its relationship to body composition. In the first study (1), the six adult males subsisted on water only for the 10-day restriction period. Large weight losses resulted. These were comprised of almost equal amounts of body fat and fat-free mass, as well as some loss of body water and protein. Other biochemical changes included the loss of electrolytes and marked ketosis (2,3). In the second study (4), the young male adults subsisted on 420 kcal/day of carbohydrate with and without mineral supplements. Although body weight losses were still observed, ketosis was not evident but body protein was still being catabolized at almost the same rate as reported in the first study (1). Mineral supplements alleviated water losses although hypohydration was still noted (5,6).

The present study was designed to minimize the deleterious effects of caloric restriction (i.e., protein catabolism and water imbalances) by the addition of a small quantity of protein to the all-carbohydrate diet used in the second study. Only body composition changes will be reported and these will be discussed as body compartment changes.

METHODS

Eight healthy adult male volunteers, ranging in ages from 19 to 21 years were observed during three consecutive phases: a) 8 days of control, b) 10 days of calorie restriction, and c) 8 days of rehabilitation. A liquid diet of 3,600 kcal was fed during the control and rehabilitation periods, while a 500 kcal/day liquid diet containing 85 gm of carbohydrate and 40 gm of protein was fed during restriction. Four men (Group I) were denied minerals and the other four (Group II) received a daily mineral allowance. Complete details of the experimental design and methods of chemical analysis have been described (6,7).

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1. Krzywicki, H.J. et al. Am J Clin Nutr 21:87, 1968
2. Consolazio, C.F. et al. Am J Clin Nutr 20:672, 1967
3. Consolazio, C.F. et al. Am J Clin Nutr 20:684, 1967
4. Krzywicki et al. Am J Clin Nutr 25:67, 1972
5. Consolazio, C.F. et al. Am J Clin Nutr 21:793, 1968
6. Consolazio, C.F. et al. Am J Clin Nutr 21:803, 1968
7. Johnson, H.L. et al. Am J Clin Nutr 24:913, 1971

Methods for measuring body composition by this laboratory have been previously described (8-12). These include estimates of total body fat, dry protein, mineral, and water as derived by formula from observed body density. Total body potassium (K) was estimated from ^{40}K counting in the State of Colorado Public Health Department whole body counter (13) and total body water was estimated from deuterium oxide (D_2O) dilution (14). Dry body protein was also estimated from ^{40}K and creatinine as suggested by Chinn (15); and from creatinine excretion as reported by Graystone (16). Statistical consideration of body compartment changes during control, restriction, and rehabilitation phases were effected through use of the paired "t" test and ANOVA (17).

RESULTS

TABLE 1 depicts mean body composition data for the four subjects of Group I (no mineral supplements). Total body K from ^{40}K measurements and total body water values from D_2O dilution were also included. Body density increased significantly by 0.010 gm/ml after caloric restriction, and remained significantly higher (0.012 gm/ml) than control levels after 8 days of rehabilitation. Body weight decreased significantly by 5.51 kg after restriction. Although significantly increased (1.91) kg during rehabilitation, these weights remained significantly lower (3.6 kg) than the control weights. The slight differences in body weight presented here and by Johnson et al (7) for the same subject reflect different times of weighing and are inconsequential.

Significant body fat losses (3.59 kg) were noted during caloric restriction. A further and significant loss of 0.35 kg of fat occurred during refeeding. Calculated total body waters were significantly reduced by 1.4 kg after caloric restriction and returned to control levels with 8 days of rehabilitation. The mean dry protein mass was slightly but significantly decreased (0.39 kg) with restriction and did not differ from control levels with refeeding. Minerals also exhibited a slight but significant loss of 0.13 kg during restriction and control

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8. Allen, T.H. et al. J Appl Physiol 14:1005, 1959
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levels were attained with refeeding. An insignificant 10 gm reduction of total body K from ^{40}K counting occurred during restriction and although unchanged with rehabilitation, the difference was now significant. When K is expressed as gm/kg of body weight only the rehabilitation values were significantly lower than the restriction levels. A significant loss of 3.83 kg in total body water (D_2O dilution) was noted with restriction and was virtually all regained (3.41 kg) during rehabilitation.

Similar body compositional data for Group II (mineral supplemented) are shown in TABLE 2. Body density increased significantly by 0.008 gm/ml during restriction, and exhibited little change during rehabilitation. These subjects were an average of 1.08 kg lighter than Group I, and exhibited a significant loss of 4.67 kg during the restriction period. Although 0.93 kg was regained after rehabilitation, body weights remained significantly lower than control values.

The 2.76 kg of body fat loss was significant and continued during rehabilitation. Total body water was calculated to have decreased significantly by 1.32 kg, which then approached control values after rehabilitation. The dry protein mass was significantly reduced by 0.39 kg during restriction, and the 0.23 kg gained with rehabilitation returned the values to normal. Similar changes were noted in the mineral compartment (0.13 kg loss) which returned to control values during refeeding. A significant total body K loss of 11.0 gm from ^{40}K counting was noted in this group during restriction. This remained unchanged during rehabilitation; however, this loss was insignificant when related to body weight. The significant loss of 1.96 kg of total body water (D_2O) exceeded the calculated value (1.32 kg). With refeeding, approximately 0.9 kg of water was regained in both instances.

TABLE 3 denotes the results of an analysis of variance for calculated body water as 73% of the fat free mass and as observed from D_2O dilution when considering both caloric restriction, rehabilitation, and the effects of mineral supplements. These observed water values differed significantly from the derived values ($P < 0.05$). The interactions between the effects of caloric restriction and method of water analysis and between effects of mineral supplementation and method of water analysis were also significant at the 0.05% level.

Metabolic balances for K and Na and the daily excretion of creatinine are presented in TABLE 4. Potassium balance was negative for both groups during the control period and increased almost two-fold during the first day of caloric restriction, and then decreased to -0.57 gm/day in both groups by Day 10. The mean K balance after restriction was -1.38 and -1.58 gm/day for Groups I and II, respectively. Both groups showed positive balances during rehabilitation, and the retention of 1.58 gm of K/man/day by Group I was greater than that observed in Group II (0.91 gm).

Small negative Na balances were observed during the first two days of restriction in both groups. Although more Na was retained in Group II, positive balance was also achieved in Group I by Day 5. Positive balances continued during restriction (except for Days 9 and 10 in Group II), and greater positive balance was maintained in both groups with refeeding. The mean balance was -0.01 and +0.05 gm/day for Groups I and II, respectively. Creatinine excretion was similar in both groups during all phases of the study. Mean excretion for the control period was 2.17 and 1.88 gm/day, which remained essentially unchanged (1.92 and 1.90 gm/day) for 10 days of restriction, and was slightly lowered to 1.79 and 1.70 gm/day with refeeding in Groups I and II, respectively.

The dry protein mass of the body is shown in TABLE 5 as predicted from ^{40}K whole body counting and creatinine excretion can be compared with the corresponding densitometric protein values shown in TABLES 1 and 2 providing these predicted values are reduced by 4.5% to correct for minerals. All three values were comparable for Group I during control; however the creatinine derived values were approximately 10 to 15% lower than the other control Group II values. During restriction, these values differed by as much as 10% or more from each other, as was also noted during rehabilitation in both groups.

TABLE 6 describes percent decreases in various anthropometric measurements. Group II showed a lesser decrease in all body circumferences and skinfold sites tested. The changes were significantly lower from control values in all instances.

DISCUSSION

As noted in the 420 kcal study (4), weight loss was 15% greater when minerals were denied, however, the losses were less severe than the 9.5% loss observed during starvation (1). The addition of 40 gm of protein to the diet resulted in losses of 7.6 and 6.5% in Groups I and II, which were not too dissimilar from the 8.1 and 5.9% losses observed during the 420 kcal study (4).

Weight losses in Group I closely approximated values reported by Brozek et al (18) (7.7% loss after 12 days on a 580 kcal carbohydrate intake). Observations by Grande et al (19) show 4.5% losses in body weight when men were fed 1,000 carbohydrate kcal/day for 16 days; they also had negative water balances in spite of a 4.5 gm/day NaCl intake. Thus, neither 1,000 kcal, 40 gm of protein or minerals precluded weight loss.

The weight lost was calculated to be comprised of 65 and 59% fat for Groups I and II in this study which was markedly different from the 22

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18. Brozek, J. et al. J Appl Physiol 10:412, 1957
19. Grande, F. et al. J Appl Physiol 12:202, 1958

to 24% of the loss attributable to fat when only 420 kcal of carbohydrate was fed (4). This approximated a threefold increase in fat utilization (3.59 kg this study Group I versus 1.24 for 420 kcal and 2.7 kg this study Group II versus 0.98 kg on 420 kcal with minerals). Brozek et al (18) reported fat loss constituted 40% of the total body weight lost (or 190 gm/day), while our Group I lost 360 gm/day and Group II lost 276 gm/day of fat. This suggests fat stores were mobilized and utilized to a greater extent when protein was added to the diet. Body fat losses in this study resembled those observed during 10 days of starvation. No explanation can be offered for the continued body fat loss in either group during the first 4 days of rehabilitation phase of the study, except the subjects' continued strenuous exercise. It is not impossible that some body fat could have been utilized for energy while metabolic pathways were adjusted to increased caloric intake. Allen and Musgrave (20) felt that decreases in body fat and water in a two-component system were adequate for describing the estimated ranges of energy expenditure of 24 obese individuals fed a 400 kcal diet.

Water losses were reduced in this third study. However, each group's losses differed by only 0.08 kg from one another. These values were computed by using factors for normal individuals (9), and it is assumed they may be correctly applied in this study. The body water loss estimated from deuterium dilution in Group I was almost twice that of Group II, and appeared to exceed the derived water losses by 1 kg. Obviously from TABLE 3, treatment, method of calculation, and mineral supplementation significantly affected these results. Again, these estimates were not too dissimilar from those observed in subjects subsisting on 420 kcal/day for 10 days (4). They serve mainly to emphasize the fact that some hypohydration occurs with caloric restriction. These losses were also verified by the negative water balance data reported by Johnson et al (7). Although minerals appeared to conserve water, only a minor difference in total body water was observed (Group I, 2.4%; Group II, 2.0%) when based on percent of body weight.

The statistical evaluation presented in TABLE 3 shows that hypohydration was affected by the three experimental variables, caloric restriction, mineral supplementation, and the technique of body water analysis (derived from 73% of the fat free mass and from D_2O dilution). Hypohydration in turn affects the density of the total body or fat free mass, and suggests that formulae involving density will need modification. Losses in protein and water are assumed to be proportional by current formulae. However, this has not been substantiated in the present study and the body weight losses may have been erroneously partitioned. Certainly, it indicated further studies are needed in this area.

Our protein values are in agreement with Brozek et al (18) who reported that 9% of the body weight loss was protein. Our data show that

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20. Allen, T.H., and P.W. Musgrave. Am J Clin Nutr 24:14, 1971

390 gm of dry protein constituted 7.1 and 8.4% of the body weight lost in Groups I and II. In view of the fact that the protein estimate is calculated as only 20.2% of the fat free mass, small changes could be masked in the densitometric technique.

Dry protein values can also be computed (TABLE 4) from ^{40}K counting and creatinine excretion (8), or creatinine alone (9). Group I values agreed well (0.6 and 1.4%) with densitometry estimates by these two techniques during the control period, but differed by 3.8 and 14.0% in Group II. The estimates were much poorer during the restriction period, ranging from 1.2 to 10.1% and 9.0 to 10.4% in Groups I and II, respectively. Rehabilitation data were inconclusive, since the values differed from 7.0 to 21.0% from the densitometric measurements. It appears that such prediction equations serve best the population from which they were derived. However, all estimates seem to indicate that the dry protein pool was approximately 11.0 kg.

The body potassium loss from ^{40}K counting (TABLES 1 and 2) was 10 and 11 gm compared to 13.8 and 15.8 gm in Groups I and II as measured by balance studies. Although these techniques differ by approximately 25 to 37%, it is becoming difficult to assess the accuracy of either method; however, the more direct ^{40}K technique appears to be a more accurate measurement.

The subjects of both groups exercised rather strenuously throughout the study, and with the reduced caloric intake certain physical and anthropometric changes were expected. The biceps' girth of both groups did not show any lesser change than was observed during the 420 kcal/day study (4) and was reduced approximately 3.8% after restriction. The calf and forearm girths were reduced by 3 to 4% instead of 3 to 5%, as noted in the 420 kcal study. The decrease in the circumferences of the waist and buttocks also did not differ greatly from that observed earlier (4). The triceps' skinfold losses were greater than those of the scapula in both groups in the current study. This also exceeded the losses noted in the 420 kcal/day subjects; however, no explanation can be offered for this observation. The percent decrease of all the circumferential measurements from Group I was greater than those observed for Group II. A possible explanation of this is that a greater degree of hypohydration occurred in Group I due to lack of mineral supplementation.

CONCLUSIONS AND RECOMMENDATIONS

Total body weight losses during 10 days of caloric restriction (500 kcal/day comprised of 85 gm of carbohydrate and 40 gm of protein) amounted to 6.5 and 7.6% of the man's initial body weight, depending upon whether or not the diet was supplemented with minerals.

The weight that was lost was comprised of 59 to 65% fat, 7.1 to 8.4% dry protein, and 25 to 28% water. Body water losses were reduced when the diet included supplemental minerals.

The addition of 40 gm of protein to the calorie-restricted diet increased the utilization of fat as much as threefold as the source of energy in comparison to an earlier study using only carbohydrate in the diet.

Body anthropometric measurements showed the expected changes during the loss and gain of body weight.

Although the inclusion of protein and minerals in the low calorie diet reduced protein catabolism and body hypohydration, the rapid rate of weight loss would preclude the suggestion that normal soldiers could be expected to subsist on only 500 kcal per day for 10 days.

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LIST OF TABLES

APPENDIX A

TABLE 1. Body composition data[a] before and during caloric restriction and after rehabilitation.

	Group I - Unsupplemented Diet		
	Control 8 days	Restriction day 10	Rehabilitation day 8
Density, gm/ml	1.069 ± 0.007	1.079[b] ± 0.008	1.081[b] ± 0.006
Body weight, kg	72.98 ± 14.73	67.47[b] ± 13.78	69.38[b] ± 13.42
Fat, kg	11.33 ± 3.19	7.74[b] ± 3.30	7.39[b] ± 2.26
Water, kg[f]	45.00 ± 9.07	43.60[e] ± 8.34	45.27 ± 8.92
Dry protein, kg	12.45 ± 2.46	12.06[e] ± 2.31	12.52 ± 2.46
Mineral, kg	4.19 ± 0.84	4.06[e] ± 0.77	4.21 ± 0.82
Total K, gm	159.2 ± 16.3	149.2 ± 20.2	149.0[d] ± 16.8
K, g/kg body weight	2.22 ± 0.26	2.23 ± 0.17	2.17[e] ± 0.18
Water, kg (D_2O)	49.78 ± 8.07	45.95[b] ± 7.58	49.37 ± 8.92

a = Mean and SD of 4 men.

b = Significantly different from control ($P < 0.001$).

c = Significantly different from control ($P < 0.005$).

d = Significantly different from control ($P < 0.025$).

e = Significantly different from control ($P < 0.010$).

f = Calculated from densitometry.

TABLE 2. Body composition data[a] before and during caloric restriction and after rehabilitation.

	Group II - Supplemented Diet		
	Control 8 days	Restriction day 10	Rehabilitation day 8
Density gm/ml	1.072 ± 0.013	1.080[b] ± .013	1.081 ± 0.012
Body weight, kg	71.90 ± 6.71	67.23[b] ± 6.46	68.16[d] ± 6.54
Fat, kg	10.43 ± 4.78	7.67[c] ± 4.58	7.47 ± 4.15
Water, kg[f]	44.87 ± 1.93	43.55[d] ± 1.51	44.29 ± 2.16
Dry protein, kg	12.42 ± 0.53	12.03[e] ± 0.41	12.26 ± 0.59
Mineral, kg	4.18 ± 0.18	4.05[d] ± 0.14	4.13 ± 0.20
Total K, gm	149.5 ± 3.8	138.5[d] ± 8.8	138.2 ± 4.4
K, gm/kg body weight	2.09 ± 0.21	2.07 ± 0.17	2.04 ± 0.15
Water, kg (D_2O)	45.71 ± 3.86	43.75[d] ± 2.26	44.66 ± 2.75

a = Mean and SD of 4 men.

b = Significantly different from control ($P < 0.001$).

c = Significantly different from control ($P < 0.005$).

d = Significantly different from control ($P < 0.050$).

e = Significantly different from control ($P < 0.025$).

f = Calculated from densitometry.

TABLE 3. Analysis of variance for observed and calculated estimates of total body water.

Source of Variance	Degree of Freedom	Mean Squares	F Values
T	1	36.2313	22.945**
M	1	33.4767	12.922*
S	1	20.7529	0.140
TM	1	4.7509	11.612*
TS	1	1.9061	1.207
MS	1	18.4984	7.121*
TMS	1	1.6245	3.960

T = Control vs. restriction

M = Calculates vs. observed H_2O

S = No mineral supplement vs. mineral supplement

* = Significant $P < 0.05$

** = Significant $P < 0.01$

TABLE 4. Potassium and sodium balances; creatinine excretion in urine before and during caloric restriction and after rehabilitation (average gm/man/day).

	Potassium		Sodium		Creatinine	
	Group		Group		Group	
	I	II	I	II	I	II
Control						
Days 1 - 4	-1.55	-1.58	-0.15	+0.20	2.31	1.89
5 - 8	-2.32	-1.41	+0.34	+0.27	2.03	1.86
Mean	-1.93	-1.49	+0.10	+0.23	2.17	1.88
Restriction						
Days 1 - 2	-3.56	-4.17	-0.99	-0.71	1.93	2.02
3 - 4	-1.26	-1.07	-0.05	+0.29	1.95	1.89
5 - 6	-0.64	-1.31	+0.28	+0.60	1.92	1.94
7 - 8	-0.87	-0.81	+0.39	+0.22	1.95	1.86
9 - 10	-0.57	-0.56	+0.32	-0.16	1.86	1.81
Mean	-1.38	-1.58	-0.01	+0.05	1.92	1.90
Rehabilitation						
Days 1 - 2	+2.59	+1.06	+2.27	+0.69	1.81	1.70
3 - 4	+2.09	+1.56	+1.19	+1.19	1.60	1.58
5 - 6	+1.88	+1.12	+0.18	+0.28	1.88	1.82
7 - 8	-0.22	-0.08	-0.13	+0.33	1.86	1.70
Mean	+1.58	+0.91	+0.79	+0.62	1.79	1.70

TABLE 5. Estimation of dry body protein from total body potassium, creatinine excretion and densitometry (before and during caloric restriction and after rehabilitation).

	Control 8 days	Restriction 10 days	Rehabilitation 8 days
	Group I - Unsupplemented Diet		
^{40}K and Creatinine	11.95	11.38	11.25
Densitometry	11.88	11.52	11.95
Creatinine	11.71	10.37	9.66
	Group II - Supplemented Diet		
^{40}K and Creatinine	11.41	10.44	10.60
Densitometry	11.86	11.48	11.71
Creatinine	10.15	10.26	9.19

TABLE 6. Percent[a] decrease in selected anthropometry after 10 days of caloric restriction.

	Group I	Group II
<u>Circumferences</u>		
Biceps	3.85[b]	3.72[b]
Forearm	3.18[c]	3.07[c]
Calf	4.27[b]	2.98[b]
Waist	6.85[e]	6.00[c]
Buttocks	3.91[d]	2.96[d]
<u>Skinfold Thicknesses</u>		
Triceps	26.04[c]	22.38[c]
Scapula	16.26[c]	14.72[d]

a = Means of 4 men.

b = Significantly different from control ($P < 0.001$).

c = Significantly different from control ($P < 0.005$).

d = Significantly different from control ($P < 0.025$).

e = Significantly different from control ($P < 0.010$).

GLOSSARY OF TERMS

Anthropometry	- The study of body measurements (lengths, diameters, and circumferences of the various segments of limbs and trunk) especially on a comparative basis.
ANOVA	- Analysis of variance, a statistical test for significance of differences among three or more means.
Body Compartment	- One of the parts that the body can be divided into according to its chemical composition, such as fat, protein, minerals or water.
Body Component	- Constituent parts of the body which can be added together to form the total body, such as fat and fat-free mass; fat, muscle, water, and minerals.
Body density	- The grams of body weight per milliliter of volume determined by dividing the person's body weight by the volume of water displaced, his body corrected for his residual lung volume. No estimates or corrections for intestinal gas were made in this study.
Body fat	- The estimated mass of body fat derived from density or ^{40}K counting.
Body mineral	- The total mass of minerals of the body, mainly found in the skeleton.
Body potassium or body K	- The total amount of potassium found in the body, mainly associated with proteins (muscle and other organs).
Body protein	- The mass of body muscles and other organs less their fat and minerals, usually includes both the dry protein and the associated water (water comprises about 73% of body muscle weight).
Body water	- The total amount of water in the body, 72% of the lean body mass.
Creatinine	- Urinary excretory product derived mainly from muscle turnover and catabolism, although dietary intake of muscle protein will contribute varying amounts.

Densitometric values	- Estimates of body compartment or component size based upon body density.
Deuterium oxide or D_2O	- "Heavy water" comprised of two atoms of deuterium (non-radioactive or stable isotope of hydrogen having twice the weight of hydrogen) and one of oxygen used as a tracer for determining total body water mass.
Dry protein or dry body protein	- Body protein minus its associated water.
Fat-free mass	- Total body mass minus the fat component. Fat-free mass includes protein, water, and minerals.
Hypohydration	- Loss of body water so that the body contains less than normal concentrations of water.
^{40}K	- Gamma emitting radiosisotope of potassium normally amounting to 0.119% of all potassium.
^{40}K counts	- The number of gamma rays detected per minute that are derived from ^{40}K. In this study, an iron-room whole body counter was used to detect gamma rays.
Metabolic balances	- Differences between total intakes and excretions of specific balances calculated on a daily basis for each person. A positive balance occurs when intake exceeds excretion, indicating that a nutrient is being retained. A negative balance occurs when excretion exceeds intake and the body is being depleted of a nutrient.
Mineral compartment	- Total body content of minerals, mainly found in skeleton and generally estimated by anthropometric measurements of specific bones.
Paired "t" tests	- Statistical test for the difference between two means based upon the differences between two measurements of a given parameter on the same subject at different times. Significance of differences is dependent upon consistence of changes between subjects.

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