# ARM SWEAT MINERAL LOSS AND TOTAL BODY MINERAL DETERMINATIONS IN PREADOLESCENT BOYS

by

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# INTRODUCTION

Minerals are essential nutrients in man. They are incorporated into the body's structure and are involved in the building of enzymes. The healthy human need not be concerned about most mineral needs if he eats a well-balanced diet. But mineral requirements can be affected by many factors, such as rate of growth and body tissue repair, the efficiency of mineral absorption and the rate of excretion, not only in the urine and feces, but also in sweat.

Malnutrition is one of the major world problems. The age group most affected is growing children. Thus, it has become critical that research be done to learn as much as possible about nutrient requirements in growing children so that the world's food stores may be used more efficiently in order to obtain healthy children and adults.

Much data are still missing as to the mineral needs of growing children. Most balance studies have failed to include mineral loss through the skin, which many researchers feel is a significant route for mineral loss. Hence, a study was undertaken to determine the amounts of calcium, copper, iron, magnesium, manganese, potassium, sodium, and zinc lost in the forearm sweat of preadolescent boys. It is hoped that data obtained will aid in the determination of mineral requirements of children and will affirm the need for mineral loss through the integument to be included in balance studies undertaken to find the mineral requirements of growing children. Arm sweat nitrogen was also determined in order to compute total body mineral loss.

## REVIEW OF LITERATURE

The skin is the major barrier between the body and the environment. Its main functions are to keep the external environment out and to serve as an elaborate waste removal mechanism by which the body eliminates certain nutrients and metabolic waste products, such as heat and water. The amount of water and nutrients lost through the integument is mainly due to the rate of perspiration which is regulated by factors such as work, stress, and environmental temperature and humidity.

Sweat is the most dilute of human secretions, containing approximately 99% water (1) and from 0.3 to 1.0% solids, half of which is inorganic (2). Until recently, no one considered the amount of nutrients lost in sweat to be significant. Few researchers included integumental nutrient losses in their balance studies. The data available are conflicting concerning mineral concentration and rates of excretion through the skin.

### Methods of Sweat Collection

One reason that reliable information is not available is that different methods of collection was employed among researchers that result in inconsistent data. Techniques used include scraping sweat from specified body areas using the lip of a glass beaker or test tube (3), whole body sweat collections made by many variations in procedure (4,5), collection of sweat in absorbant pads from specified body areas following pilocarpine iontophoresis (6), and sweat collection in an impermeable bag or glove attached to the arm (7).

The arm bag method is often used because of its convenience and simplicity, and because the impermeable bag aids in preventing contamination. The minerals collected in this manner are then used to extrapolate total body mineral loss. Controversy exists, however, as to whether arm sweat collected in this manner is a reliable indicator of whole body sweat mineral loss. Van Heyningen and Weiner (8) found that sweat collected by the arm bag method was more concentrated than sweat collected under "natural conditions" as described by Comar and Bronner (2). They observed that chloride, urea and lactate were higher in arm sweat than in total body sweat. Consolazio et al. (9) reported that calcium excreted in arm sweat was more concentrated than total body sweat if the sweat collections were less than 16 g. If the collections were greater than 16 g, they felt that arm sweat was a reliable indicator of total body sweat calcium. They also observed that below 15 g of arm sweat, excretion of nitrogen in total body sweat was 86 - 93% that of arm sweat nitrogen loss. Issaksson et al. (10) reported arm sweat loss of calcium and potassium to be representative of total body sweat loss.

Johnston (11) found no significant difference in arm sweat and total body sweat concentrations for chloride and nitrogen. Collins et al. (12) reported that total body sweat rate and arm sweat rate were not significantly different during the first 80 minutes of testing, but after that, the arm sweat rate decreased rapidly until only neglegiable amounts of sweat were recorded by three hours of collection time.

Calcium

Calcium concentrations ranging from 1.0 - 8.0 mg percent have been found in human sweat (1). Consolazio et al. (7) suggested that as much as 30.0 mg/hour may be lost during profuse sweating which would account for approximately 30% of the body's total daily loss. Issaksson et al. (10) reported a mean loss of 120 mg/day from his subjects. He found that by including calcium sweat losses, calcium balances were changed from positive to zero or negative values. Mitchell et al. (3) reported an average dermal excretion of 6.2 mg/hour or 149 mg/day under conditions of minimal sweat loss. All of the above researchers were working with adult males. Johnston et al. (5), working with young women using total body sweat collections, found an average of 8.5 mg/hour (204.7 mg/day). Because of their conclusions and the conclusions of other researcheres concerning the significance of calcium excretion in sweat, the National Research Council (13) has included sweat loss in the determination of Recommended Daily Allowances for adults. Allowances for the preadolescent age group were extrapolated from adult values, because of the scarcity of data available on cutaneous loss of calcium in children. Data available on calcium loss through sweat for children include work done by Ryan (14) and Walls (15). Ryan, working with preadolescent girls, reported total sweat calcium loss to be 72.7 mg/day. Walls, also working with preadolescent girls, reported arm sweat losses of .26 mg/hour.

Because calcium excretion through the skin increases as the temperature rises, some investigators feel (10,3) that calcium

requirements should be higher for people living in tropical zones. Walker and Richardson (16) investigated this by comparing the weight and height, which they considered to be good indicators of calcium nutritional status, of Zulu children from a hot climate with those from the temperate climate. They found no difference which, they believed, indicated that calcium intake need not be increased to cover greater losses through the skin.

Work has been done on children with cystic fibrosis (17) to determine if mineral excretion through the skin is significantly different in these children as compared to healthy children the same age (2 - 13 years). No significant difference was found. Calcium excretion in the normal subjects was .88 mEq/liter.

Copper and Manganese

Little data are available on the excretion of copper and manganese in sweat. Mitchell et al. (3) found a 24-hour loss of 5.8 mcg of copper per 100 ml of sweat in young adult males. They also found manganese present in the trace amount of 6.0 mcg/100 ml of sweat. The method of sweat collection used was that of running the edge of a beaker over the skin of the subject while in a controlled environment. Walls (15) reported an arm sweat copper loss of .108 mcg/hour and a manganese loss of .035 mcg/hour for preadolescent girls.

Iron

The quantitative importance of cutaneous iron loss is a disputed issue. Mitchell et al. (3), using sweat collected by scraping a beaker across the subjects' chests, reported a dermal loss of iron

of 6.5 mg/day in cell-rich sweat. They felt that this could go as high as 30.96 mg/day when men are placed in a hot humid climate. This work has not been duplicated. Adams et al. (18), using the arm bag method, found iron loss through the skin to be almost negligible in cell-free sweat.

Johnston et al. (11) reported that iron was lost through the skin at only 6% of the rate and 12% of the concentration that Mitchell reported. Since Johnston was using young women, she accredited some of the discrepancy to the fact that the men in Mitchell's study had sweating rates twice that of the women and that since the apocrine glands are associated with hair follicles, the production of iron-rich apocrine sweat would be higher in men than in women. In another study by Johnston et al. (5) also using young women, iron loss through total body sweat was given as 0.075 mg/hour (1.8 mg/day).

In a study by Wheeler et al. (19), sweat loss of iron was found to be 3 mg/day. Collins et al. (20) found that adult men lost amounts of iron equivalent to 1.0% of their daily iron intake through cell free sweat as compared to a loss of only 0.5% of their iron intake through urine. They also reported a loss of 2 mg/day through the skin in a comfortable environment and about twice this amount in a hot environment. Consolazio et al. (9) reported loss of iron in sweat to be 0.13 mg/hour (3.12 mg/day).

The data on iron status and iron excretion through the skin is also inconsistent. Hussain and Patwardham (21) found that women suffering from anemia lost less iron from the integument than non-anemic women. On the other hand, Prasad et al. (22) found no

significant difference in iron excretion in sweat between Egyptian men deficient in iron and those who were not.

Data on dermal loss of iron for children is scarce. Walls (15) reported a loss of .185 mcg/hour in arm sweat in the preadolescent girl.

Magnesium

The magnesium concentration of sweat has been reported to vary from 4.5 to 104 mg percent. Consolazio et al. (23) found the concentration of magnesium in sweat to range from 0.61 to 0.64 mg percent in young adult men and reported that magnesium balance was not greatly affected by including sweat losses in the balance data. Mitchell et al. (3), also using young adult males, stated a loss of between .04 and .4 mg percent of sweat. Costa et al. (24) using men found an average loss of 17 mcg/g of sweat.

Paunier et al. (17), working with children, ages 2 - 13, reported an average loss of 0.16 mEq/liter of sweat when sweating was induced by pilocarpine iontophoresis on the thoracic skin.

Rayn (14), working with preadolescent girls, found a total body sweat loss of 20.4 mg/day. Walls (15) reported an average loss of 1.48 mcg/hour from arm sweat in preadolescent girls.

Potassium

Work has been done by Dill et al. (25) with girls, ages 9 - 19 years and boys, ages 10 - 18 years, to establish the amount of potassium lost under moderately strenuous circumstances. They found that the girls secreted approximately 4.8 mEq of potassium per liter of total

body sweat while the boys lost 5.0 mEq/liter. Walls (15), also working with girls, reported an average loss of .027 mg/hour in arm sweat.

Lobeck and Huebner (6), working with subjects from 1 month to 60 years of age, found that adult women excreted more potassium than either adult males or children and that adult males had the lowest values. There was no difference in sweat potassium losses between the girls and boys. The highest potassium values were found in the lowest sweating rates of all ages. The potassium concentration was 11 mEq/liter in children and adult females and 7 mEq/liter in adult males. The children with cystic fibrosis lost significantly more potassium (15.0 mEq/liter) than the healthy children. Sweat collections were made following pilocarpine iontrophoresis to the arm.

Swartz and Thaysen (26), using adult men and women, found values similar to that of Lobeck and Huebner, $9.4 \pm 2.5$ mEq/liter. They did not give values for each sex separately. Collections of potassium were made from the arm, but sweating was induced by the intradermal injection of Micholye. Unlike Lobeck and Huebner, Swartz and Thaysen found that the sweat concentration of potassium remained constant regardless of the sweating rate.

Seutter et al. (27) found large variations in the potassium loss of the young men they were working with, 5.0 to 59.0 mEq/liter. In this study, unlike the previous ones reported, sweat samples were acquired by thermal stimulation of the subjects. Collins et al. (12) also studied the cutaneous loss of potassium in young adult men and found that about 10% of the normal potassium intake was lost through

the skin. From their work, they felt that the possibility of an imbalance between potassium intake and output could occur when cumulative sweat losses of potassium exceeding 10 mEq/day were combined with low intakes, 25 mEq/day, common in rice-eating countries.

Sodium

A review of literature on the chemical composition of sweat by Robinson et al. (1) found reports of sodium concentration varying from 5 to 148 mEq/liter, depending on a number of factors; such as, sweat rate, skin and deep temperature, activity, heat, water, salt balance and skin site. On normal individuals, sweat losses of sodium in hot weather can be large enough to result in significant sodium depletion. According to Comar and Bronner (2), as early as 1923, Moss observed that miner's cramps were caused by drinking plain water to replenish water loss with no thought to the replacement of salt loss. Collins et al. (20) produced a sodium loss of 24 mEq/day in six young men subjected to a comfortable environment and an average of 51 mEq/day in a hot environment. Consolazio et al. (23) reported a loss of 0.601 gm/hour when the subjects were exposed to 100°F temperatures.

Dill et al. (25), working with boys and girls, found sodium loss through total body sweat to be 27.8 and 25.1 mEq/liter respectively in an environment simulating desert conditions while walking approximately 100 meters/minute. Lobeck and Huebner (6), working with children and adults, induced sweating by pilocarpine iontophoresis in an air-conditioned room with a temperature of 72°F and a relative

humidity of 60 to 70%. They obtained an average value of 20 mEq/liter sodium loss through sweat in children under 11 years of age. They also reported an increase in sodium concentration of sweat with increase of age in their subjects. In adults, greater variability in sodium sweat loss was found among individuals. They found no difference in sodium sweat loss due to gender in children under age 20. Walls (15) found an average sodium loss of 28.31 mcg/hour in arm sweat of young girls under conditions of moderate exercise and environmental conditions.

Zinc

Few data are available on the loss of zinc through the skin. Prasad et al. (22), working with young adult men, found a loss of 93 mcg/100 ml of sweat collection taken from the arm.

The Food and Nutrition Board, in making their 1968 Recommended Dietary Allowances (28), mentioned one study done in a tropical area in which 2 to 3 mg of zinc was lost per day in sweat. Walls (15) found an average loss of .90 mcg/hour in arm sweat. The Food and Nutrition Board used work done on zinc sweat loss in children by Schlage and Wortberg in computing the 1974 Recommended Daily Allowances (13) of zinc for children, but this study was unavailable for review.

Much work is yet to be done in the area of integumentary mineral loss, especially in relation to the growing child. Minerals are essential to man, and all avenues of loss must be explored to aid in the setting of recommended daily requirements.

Nitrogen

Nitrogen loss through sweat is well documented but little is known about nitrogen loss through sweat in growing children, since most work has been done with adults. Conzolazio et al. (29) reported nitrogen losses through sweat to be between 149 and 241 mg/hour. Spence et al. (30), working with preadolescent girls on low protein diets, found integumentary nitrogen losses from 235 to 275 mg daily. Howat (31), also working with preadolescent girls, found individual sweat nitrogen losses ranging from 126 mg to 172 mg/day.

## EXPERIMENTAL PROCEDURE

### Organization

This metabolic study was completed in the Department of Human Nutrition and Foods at Virginia Polytechnic Institute and State University. The study was conducted on the Virginia Polytechnic Institute and State University campus between June 20 and July 24, 1974. Subjects were housed in dormitory facilities and fed at the Human Nutrition and Foods metabolic unit in the College of Home Economics. The study was conducted as a camp for preadolescent boys with 24-hour supervision by camp counselors who had received prior training concerning the metabolic guidelines of the study. Recreational activities, including swimming, fishing, softball, field trips, hobbies and crafts were provided. Parents were allowed to visit on Sundays and take the boys off campus for worship services, if desired. Both the parents and children were reminded that the subjects were not to consume anything while away from camp.

Twelve boys participated in the metabolic study. They were between the ages of 8 and 9 with a mean weight and height of 31.0 kg and 131.4 cm, respectively. Prior to the beginning of camp, each subject was given a physical examination by a physician to assure a normal state of health and development. Preliminary information for each subject also included a diet history, childhood illnesses, personal traits, food allegies, ancestry and a record of previous health problems.

A physician was on call at all times for emergencies and a registered nurse checked the boys each morning for minor medical problems.

Diet

The diet consisted of foods generally accepted by this age group with nutrient intake sufficient to meet or exceed the National Research Council's Recommended Dietary Allowances for preadolescent boys. Vitamin supplements (One-a-Day with Iron) and mineral supplements were given to insure that the only dietary restriction was level of protein. Ion-free water was used for food preparation, drinking, and laboratory procedures. This water was prepared by passing distilled water through a mixed bed of ion-exchange resins. This water was installed in the dormitory, eating facilities and recreational areas for consumption by the subjects and for rinsing excretion receptacles.

The first three days of the study were used as adjustment days with all subjects placed on a 30 g protein diet. The subjects were then placed randomly into three groups and rotated through three dietary treatments of 30, 60, and 90 g of protein during the three experimental periods. (Table 1).

Calories were adjusted for each subject to assure weight maintenance or gain. Daily food composites were kept for each group and assayed for mineral and nitrogen content for correlation with cutaneous mineral and nitrogen loss (Table 2).

Environment

No control of temperature or humidity was attempted, since it was felt that data collected should simulate normal conditions as nearly as possible. Temperature and humidity readings were obtained for the specific hours of arm sweat collection from records kept by

Table 1: Cycle of Rotation of Subjects Through Experimental Treatments

| Periods | Dates | Dietary Treatment Protein g | Subjects |
|---|---|---|---|
| I | June 20 - June 22 (3 days) | 30 g | All subjects |
| II | June 23 - July 2 (10 days) | 30 | Group A |
| | | 60 | B |
| | | 90 | C |
| III | July 3 - July 12 (10 days) | 30 | Group C |
| | | 60 | A |
| | | 90 | B |
| IV | July 13 - July 23 (11 days) | 30 | Group B |
| | | 60 | C |
| | | 90 | A |

Table 2: Mineral Intake[a] during Three Dietary Treatments

| Minerals | Dietary Treatment | | |
|---|---|---|---|
| | 30 g | 60 g | 90 g |
| Calcium | 1099 | 1076 | 1160 |
| Copper | 0.4 | 0.5 | 0.8 |
| Iron | 27.8 | 29.4 | 31.2 |
| Magnesium | 179.0 | 216.2 | 300.0 |
| Manganese | 37.2 | 32.0 | 48.2 |
| Potassium | 1769.9 | 2115.6 | 2332.0 |
| Sodium | 1672.2 | 2148.1 | 2791.9 |
| Zinc | 5.0 | 7.5 | 9.3 |

[a] Intake for each mineral is in milligrams per day

the Agricultural Engineering Department at the Experimental Station on the Virginia Polytechnic and State University campus (Table 3).

During all three collections, the subjects were resting either in an upright sitting position while watching movies or with heads down on a table. It was hoped that this would omit the variables of exercise, which could affect sweating and mineral loss, and the chance of loosing samples because of bags rupturing.

Collection Procedure

Arm sweat collections were made immediately following the last day of each experimental period to allow for physiological adjustments to each dietary treatment. Total body sweat loss was also collected during this study following the procedure outlined in Appendix I. Total body nitrogen loss is given for each group and dietary treatment in Appendix II-A. Sweat from the arm was collected in an impermeable bag by a procedure similar to that employed by Walls (15). This technique afforded protection from possible environmental contamination which is inherent in most total body sweat collection techniques for mineral analysis. Total body sweat mineral loss was calculated from total body sweat nitrogen loss, arm sweat nitrogen loss and arm sweat mineral loss using the following equation.

$$\frac{\text{arm sweat mineral loss}}{x} = \frac{\text{arm sweat nitrogen loss}}{\text{total body sweat nitrogen}}$$

$$x = \text{total body sweat mineral loss}$$

Table 3: Average Temperature and Relative Humidity during the Hours of Arm Sweat Collection

| Period | Date | Time | Temperature $^{o}F$ | Relative Humidity |
|---|---|---|---|---|
| I | July 3 | 9:00 - 11:00 | 72.0 | 77.5% |
| II | July 13 | 9:00 - 11:00 | 68.0 | 71.0% |
| III | July 24 | 9:00 - 11:00 | 62.5 | 96.0% |

Both arms of the subjects were prepared and secured in the arm bags beginning with the right and progressing to the left when placing the bags on and when taking them off, to aid in calibrating the time each arm bag was worn to sixty minutes. Each arm was wiped off with a damp cloth which had been prepared to reduce mineral content. The arm was then washed with 100 ml of a 0.005% polyethylene laurel alcohol solution and rinsed with 200 ml of ion-free water. This wash was discarded. The arm was dried with a prepared towel and placed in a polyethylene freezer bag up to the elbow. A rubber band was used to secure the bag in place. The arm bags were worn for one hour while the subjects either slept or watched movies.

The bags were removed and the subjects' arms were again washed with 100 ml of 0.005% laurel alcohol detergent and a prepared wash cloth. The arms were rinsed with 200 ml of ion-free water and a wash cloth; wash and rinse water were saved for analysis. The aliquot from both arms were pooled together in the right arm bag and 2 ml of concentrated sulfuric acid was added to the aliquot to bring the pH to 1.0 to insure the retention of nitrogen in the sample. A blank was prepared following the same procedure used for the arm sweat collections, except that the plastic bags were not worn by the subjects. These mixtures were allowed to equilibrate for a five-hour period after which the samples were filtered to remove desquamated skin cells, hair and fiber filaments. From each solution, duplicate samples were taken for mineral analysis (200 ml each) and nitrogen determinations (50) ml each).

Treatment of Materials

Since it was imperative that all materials used in mineral analysis be free from extraneous minerals, all towels, washcloths, arm bags, lab glassware, and utensils were treated to reduce mineral contamination as much as possible.

Washcloths and towels were first washed in a washing machine with low mineral detergent (Acationox), rinsed in tap water and dried. They were soaked for 24 hours in ion-free water, wrung out and placed in 0.05% nitric acid soak. They were then soaked three times in ion-free water for a period of 24 hours for each soaking. Two treated wash cloths were then placed in treated bags containing ion-free water and the mixture was allowed to equilibrate for five hours. Samples were then taken from these and analyzed for mineral content. The towels and washcloths were not dried after preparation because of possible contamination from dryers or the atmosphere, but were placed in treated plastic bags until used.

The polyethylene freezer bags used for arm sweat collections were first rinsed in ion-free water; acid washed in a 50% nitric acid solution and rinsed four times with ion-free water. They were allowed to drip dry in a closed room and then stored in treated plastic bags. Two bags were then taken from the lot and filled with 200 mls of ion-free water. These were allowed to equilibrate for five hours and samples were taken for mineral analysis.

Lab glassware and utensils were treated using a procedure similar to that used with the arm bags. The glassware and utensils were first washed and rinsed in a dishwasher and allowed to dry. They were then

acid washed in a 50% nitric acid solution, rinsed four times with ion-free water; and allowed to drain dry. Whenever feasible, the glassware and utensils were stored in treated plastic bags until used.

Mineral and Nitrogen Determinations

Determination of arm sweat total nitrogen was made using the micro-Kjeldahl method (32).

Arm sweat mineral loss was analyzed in the following manner. The filtered 200 ml sample was evaporated to dryness on a hot plate set at 350°F. The precipitate remaining after evaporation was wet ashed by the addition of concentrated nitric acid and hydrogen peroxide until all organic material was oxidized. To insure complete oxidation, 3 ml of concentrated nitric acid and 2 ml of concentrated perchloric acid were then added and evaporated until a while precipitate remained. This precipitate was then dissolved in 2 ml of concentrated hydrochloric acid and hot water and brought up to a volume of 25 ml.

The concentration of each mineral was determined using a Perkin-Elmer Model 305 Atomic Absorption Spectrophotometer according to the recommended procedure (33). The sample containing the minerals was aspirated into a flame which caused a population of neutral atoms to accumulate in the flame. Light produced by specific cathode lamps was absorbed by these neutral atoms in proportion to the concentration of the neutral atoms in the flame. This absorption was measured and used to determine the concentration of metallic elements in the solution. Standard curves of absorbance were plotted using prepared standards. The concentration of mineral in the sample was calculated

according to the formula:

$$\text{Element (mcg/ml)} = \frac{\text{(sample absorbance)(Std. concentration)}}{\text{standard absorbance}}$$

Statistical Analysis of Data

Means and standard deviations were calculated for all mineral and nitrogen analysis. An analysis of variance at a 5% significance level was used to analyze the statistical significance of different levels of protein and mineral intakes on the amount of minerals excreted through arm sweat. Analysis of variance was done within each group and for the subjects as a whole to compare their mineral loss on each dietary treatment.

## RESULTS AND DISCUSSION

The average cutaneous mineral excretion from the forearm of three groups of subjects consuming three levels of intake for each mineral are given in Tables 4 - 7. There were no significant ($\alpha = 0.05$) effects of protein or mineral intake on excretion through sweat on any minerals when running an analysis of variance on the subjects as a whole. Sodium (Group B) and zinc (Group A) were found to be significant when analysis was done within groups only, but these were isolated cases in the statistical analysis and are not considered to be relevant. With the large number of variables being analyzed, it is thought that these cases were significant only by chance.

Large variations in arm sweat excretions for individuals and within groups were seen in every mineral. This is a phenomena well documented in mineral research literature (7,9,10,16,24,25). Several researchers have seen a correlation between rate of sweating and mineral excretion. Lobeck and Huebner reported their highest potassium concentrations in the lowest rates of sweating in all age groups tested (6).

Consolazio et al. (9) and Mitchell (34) found that calcium excretion decreased as sweating rates increased. Since it was observed in this study that the subjects perspired at different rates evidenced by the varying amounts of moisture collected inside the arm bags, this could be one factor involved in the wide range of results found. Temperature and humidity which affect the excretion of some minerals (4,9,19,23,31) are not considered to have been a factor in the wide

Table 4: Average Excretion of Calcium and Copper in Forearm Sweat during Three Levels of Intake[a] and for Three Groups of Subjects

| Subjects | | Intake of Ca[a] | | | Intake of Cu[a] | | |
|---|---|---|---|---|---|---|---|
| | | 1099 | 1076 | 1160 | 0.4 | 0.5 | 0.8 |
| Group A | mcg/hour | 4.2 | 4.7 | 11.0 | 0.2 | 0.1 | 0.2 |
| | ± SD | ±1.6 | ±0.9 | ±10.4 | ±0.1 | ±0.0 | ±0.2 |
| | mcg/day | 100.7 | 111.9 | 264.0 | 4.6 | 3.5 | 4.0 |
| | ± SD | ±39.3 | ±22.8 | ±249.7 | ±2.6 | ±1.1 | ±3.7 |
| Group B | mcg/hour | 5.5 | 8.9 | 8.9 | 0.1 | 0.4 | 0.6 |
| | ± SD | ±3.7 | ±4.4 | ±4.4 | ±0.1 | ±0.5 | ±0.7 |
| | mcg/day | 133.1 | 213.3 | 213.3 | 3.1 | 10.6 | 13.2 |
| | ± SD | ±88.9 | ±104.4 | ±104.4 | ±1.6 | ±10.8 | ±15.9 |
| Group C | mcg/hour | 4.1 | 7.7 | 4.1 | 0.2 | 0.2 | 0.7 |
| | ± SD | ±1.8 | ±6.7 | ±1.5 | ±0.1 | ±0.1 | ±0.5 |
| | mcg/day | 97.7 | 184.8 | 97.7 | 3.8 | 4.2 | 16.9 |
| | ± SD | ±34.9 | ±161.9 | ±34.9 | ±1.2 | ±2.4 | ±13.1 |
| Overall Mean | mcg/hour | 4.7 | 7.4 | 7.8 | 0.2 | 0.3 | 0.5 |
| | ± SD | ±2.6 | ±4.8 | ±6.0 | ±0.1 | ±0.3 | ±0.5 |
| | mcg/day | 113.2 | 178.5 | 187.4 | 3.7 | 6.7 | 12.1 |
| | ± SD | ±61.6 | ±113.9 | ±143.0 | ±1.7 | ±7.6 | ±13.0 |

[a] Intake given in milligrams per day

Table 5: Average Excretion of Iron and Magnesium in Forearm Sweat during Three Levels of Intake[a] and for Three Groups of Subjects

| Subjects | | Intake of Fe[a,b] | | | Intake of Mg[a] | | |
|---|---|---|---|---|---|---|---|
| | | 27.8 | 29.4 | 31.2 | 179.0 | 216.2 | 300.0 |
| Group A | mcg/hour | 1.1 | 1.5 | 1.8 | 1.5 | 0.9 | 1.4 |
| | ± SD | ±0.8 | ±1.8 | ±1.0 | ±0.3 | ±0.4 | ±1.1 |
| | mcg/day | 26.6 | 35.5 | 43.7 | 35.4 | 21.0 | 33.4 |
| | ± SD | ±17.6 | ±43.1 | ±25.1 | ±7.8 | ±8.8 | ±27.2 |
| Group B | mcg/hour | 1.2 | 0.7 | 1.2 | 0.9 | 1.4 | 1.3 |
| | ± SD | ±0.6 | ±0.4 | ±0.9 | ±0.6 | ±0.6 | ±0.4 |
| | mcg/day | 28.1 | 17.2 | 29.2 | 20.5 | 34.3 | 31.2 |
| | ± SD | ±15.0 | ±8.4 | ±20.7 | ±14.3 | ±13.6 | ±9.9 |
| Group C | mcg/hour | 1.0 | 0.9 | 1.5 | 0.8 | 1.0 | 2.2 |
| | ± SD | ±0.5 | ±0.4 | ±1.0 | ±0.1 | ±0.8 | ±0.6 |
| | mcg/day | 23.4 | 20.8 | 35.9 | 19.5 | 23.9 | 53.9 |
| | ± SD | ±12.8 | 9.8 | ±13.9 | ±3.2 | ±18.4 | ±14.4 |
| Overall Mean | mcg/hour | 1.1 | 1.0 | 1.5 | 1.0 | 1.1 | 1.6 |
| | ± SD | ±0.6 | ±0.9 | ±0.8 | ±0.5 | ±0.6 | ±0.8 |
| | mcg/day | 26.2 | 23.0 | 35.1 | 23.9 | 27.5 | 39.4 |
| | ± SD | ±13.7 | ±21.2 | ±19.0 | ±11.7 | ±14.5 | ±18.5 |

[a] Intake given in milligrams per day

[b] Daily supplement of 18 mg

Table 6: Average Excretion of Manganese and Potassium in Forearm Sweat during Three Levels of Intake[a] and for Three Groups of Subjects

| Subjects | | Intake of Mn[a] | | | Intake of K[a] | | |
|---|---|---|---|---|---|---|---|
| | | 37.2 | 32.0 | 48.2 | 1769.9 | 2115.6 | 2552.1 |
| Group A | mcg/hour | 0.1 | 0.1 | 0.1 | 11.5 | 14.8 | 29.8 |
| | ± SD | ±0.0 | ±0.0 | ±0.0 | ±6.6 | ±3.7 | ±20.8 |
| | mcg/day | 1.1 | 1.0 | 2.2 | 275.5 | 356.2 | 714.0 |
| | ± SD | ±0.1 | ±0.7 | ±0.2 | ±157.7 | ±88.5 | ±498.0 |
| Group B | mcg/hour | 0.6 | 0.1 | 0.1 | 20.3 | 14.7 | 23.5 |
| | ± SD | ±0.0 | ±0.0 | ±0.0 | ±7.3 | ±4.3 | ±8.9 |
| | mcg/day | 1.4 | 1.3 | 1.8 | 486.4 | 353.8 | 563.5 |
| | ± SD | ±0.3 | ±0.3 | ±0.3 | ±176.0 | ±103.2 | ±212.8 |
| Group C | mcg/hour | 0.1 | 0.1 | 0.1 | 16.9 | 20.0 | 18.3 |
| | ± SD | ±0.0 | ±0.0 | ±0.0 | ±8.5 | ±12.1 | ±4.3 |
| | mcg/day | 1.8 | 1.5 | 1.7 | 406.4 | 478.8 | 439.7 |
| | ± SD | ±0.4 | ±0.7 | ±0.3 | ±203.5 | ±291.7 | ±103.7 |
| Overall Mean | mcg/hour | 0.1 | 0.1 | 0.1 | 17.0 | 16.5 | 23.3 |
| | ± SD | ±0.0 | ±0.0 | ±0.0 | ±7.8 | ±7.5 | ±11.5 |
| | mcg/day | 1.5 | 1.5 | 1.9 | 407.0 | 396.1 | 559.9 |
| | ± SD | ±0.4 | ±0.5 | ±0.3 | ±186.2 | ±180.0 | ±276.1 |

[a] Intake given in milligrams per day

Table 7: Average Excretion of Sodium and Zinc in Forearm Sweat during Three Levels of Intake[a] and for Three Groups of Subjects

| Subjects | | Intake of Na[a] | | | Intake of Zn[a] | | |
|---|---|---|---|---|---|---|---|
| | | 1672.2 | 2148.1 | 2791.9 | 5.0 | 7.5 | 9.3 |
| Group A | mcg/hour ± SD | 37.3 ±13.3 | 28.4 ±9.8 | 35.3 ±16.6 | 1.2 ±0.1 | 1.0 ±0.5 | 1.3 ±0.3 |
| | mcg/day ± SD | 896.0 ±320.8 | 680.8 ±235.2 | 848.3 ±399.2 | 28.5 ±3.2 | 23.9 ±11.2 | 23.1 ±6.1 |
| Group B | mcg/hour ± SD | 40.6 ±9.6 | 55.7 ±15.8 | 34.3 ±4.9 | 1.5 ±1.5 | 1.8 ±0.8 | 2.1 ±1.3 |
| | mcg/day ± SD | 973.6 ±229.2 | 1335.6 ±379.4 | 823.7 ±117.4 | 36.2 ±37.0 | 43.9 ±18.9 | 51.4 ±31.3 |
| Group C | mcg/hour ± SD | 29.6 ±14.8 | 37.3 ±22.3 | 58.6 ±22.3 | 1.0 ±0.4 | 1.2 ±0.6 | 1.7 ±0.6 |
| | mcg/day ± SD | 710.2 ±355.2 | 894.0 ±535.5 | 1407.0 ±534.0 | 23.3 ±10.2 | 29.3 ±14.7 | 40.9 ±15.3 |
| Overall Mean | mcg/hour ± SD | 36.1 ±12.2 | 42.7 ±19.7 | 42.7 ±18.2 | 1.3 ±1.0 | 1.4 ±0.7 | 1.7 ±1.0 |
| | mcg/day ± SD | 866.4 ±294.2 | 1025.0 ±472.1 | 1024.3 ±437.9 | 30.0 ±23.7 | 34.0 ±17.1 | 40.9 ±23.8 |

[a] Intake given in milligrams per day

variation of mineral excretion because of the similarity of temperature and humidity during the three collection days, except for humidity on the third day (Table 3). No significant increase in mineral excretion was recorded for the third collection day.

Total body sweat loss for each mineral (Tables 8 - 11) was extrapolated using data collected for arm sweat mineral and nitrogen loss (Appendix II-B) and total body nitrogen loss (Appendix II-A). Great variations are evident here also, due to the wide range found in the mineral data and nitrogen data used for calculations.

Cutaneous Calcium Loss

Arm sweat calcium losses ranged from 0.9 - 22.0 mcg/hour (22.1 - 528.0 mcg/day). This was found in two individuals during the fourth experimental period. The subject excreting 0.9 mcg/hour was consuming 1160 mg calcium and 90 g protein, while the other subject was consuming 1099 mg calcium and 30 g protein. There were considerable variations in excretion among the individuals themselves. One subject lost from 3.1 to 16.7 mcg/hour while another lost from 2.4 to 22.0 mcg/hour. The average total body sweat calcium loss was 685.5 mcg/day with individual values ranging from 91.9 - 2488.2 mcg/day.

Arm sweat values compare favorably with the work done by Walls (15) who found calcium arm sweat losses ranging from 3.39 - 35.32 mcg/hour. Her average excretions were somewhat higher, 10.9 mcg/hour as compared to 6.6 mcg/hour found in this study, but this can be explained by comparing levels of physical activity in both studies. Her subjects were engaged in active play, while the boys in this study were sitting passively.

Table 8: Total 24-hour Body Loss[a] of Calcium and Copper as Computed from Forearm Mineral Loss, Arm Nitrogen Loss, and Total Body Nitrogen Loss[b] at Three Levels of Protein and Mineral Intake

| Subjects | | Calcium | | | Copper | | |
|---|---|---|---|---|---|---|---|
| | Mineral Intake[c] | 1099 | 1076 | 1160 | 0.4 | 0.5 | 0.8 |
| | Protein Intake[d] | 30 | 60 | 90 | 10 | 60 | 90 |
| Group A | | 287.5 ±176.4 | 327.4 ±63.9 | 1355.3 ±1070.6 | 13.1 ±7.6 | 10.8 ±6.0 | 15.5 ±10.9 |
| Group B | | 1045.6 ±874.7 | 403.6 ±148.9 | 919.0 ±445.5 | 23.3 ±17.4 | 18.4 ±13.3 | 45.2 ±35.7 |
| Group C | | 564.3 ±213.4 | 1015.8 ±1010.6 | 151.7 ±54.3 | 22.7 ±9.0 | 24.7 ±15.1 | 32.4 ±33.3 |
| Overall Mean | | 695.6 ±635.3 | 588.6 ±622.8 | 772.3 ±724.1 | 20.5 ±12.7 | 18.6 ±12.7 | 33.8 ±30.5 |

a Total body mineral loss given as mcg/day ± SD

b Total body mineral loss = arm mineral loss/(arm nitrogen loss/total body nitrogen loss)

c Intake given in milligrams per day

d Intake given in grams per day

Table 9: Total 24-hour Body Loss[a] of Iron and Magnesium as Computed from Forearm Mineral Loss, Arm Nitrogen Loss, and Total Body Nitrogen Loss[b] at Three Levels of Protein and Mineral Intake

| Subjects | | Iron | | | Magnesium | | |
|---|---|---|---|---|---|---|---|
| | Mineral Intake[c,d] | 27.8 | 29.4 | 31.2 | 179.0 | 216.2 | 300.0 |
| | Protein Intake[d] | 30 | 60 | 90 | 30 | 60 | 90 |
| Group A | | 64.6 ±36.5 | 112.4 ±140.9 | 194.8 ±47.2 | 94.5 ±17.4 | 58.3 ±9.2 | 159.0 ±93.0 |
| Group B | | 176.5 ±102.6 | 36.5 ±20.7 | 148.1 ±128.5 | 160.0 ±140.4 | 66.5 ±27.2 | 145.1 ±84.1 |
| Group C | | 148.5 ±118.4 | 122.8 ±60.9 | 60.5 ±41.2 | 116.1 ±38.3 | 133.1 ±114.8 | 90.7 ±48.1 |
| Overall Mean | | 139.2 ±100.4 | 84.2 ±81.1 | 130.6 ±99.6 | 129.0 ±91.9 | 86.7 ±71.1 | 130.5 ±75.3 |

[a] Total body mineral loss given as mcg/day ± SD

[b] Total body mineral loss = arm mineral loss/(arm nitrogen loss/total body nitrogen loss)

[c] Intake given in milligrams per day

[d] Intake given in grams per day

Table 10: Total 24-hour Body Loss[a] of Manganese and Potassium as Computed from Forearm Mineral Loss, Arm Nitrogen Loss, and Total Body Nitrogen Loss[b] at Three Levels of Protein and Mineral Intake

| Subjects | | Manganese | | | Potassium | | |
|---|---|---|---|---|---|---|---|
| | Mineral Intake[c] | 37.2 | 32.0 | 48.2 | 1769.9 | 2115.6 | 2332.0 |
| | Protein Intake[d] | 30 | 60 | 90 | 30 | 60 | 90 |
| Group A | | 2.9 ±0.8 | 5.2 ±2.2 | 11.7 ±5.2 | 680.4 ±260.5 | 1039.4 ±243.2 | 3020.1 ±1238.6 |
| Group B | | 9.8 ±5.1 | 2.6 ±0.5 | 7.9 ±2.6 | 2964.4 ±651.9 | 671.0 ±119.3 | 2363.1 ±616.2 |
| Group C | | 11.0 ±4.8 | 9.0 ±3.9 | 2.8 ±1.2 | 2410.0 ±1358.6 | 2630.0 ±1045.6 | 688.7 ±213.6 |
| Overall Mean | | 8.5 ±5.2 | 5.4 ±3.7 | 7.2 ±4.5 | 2208.6 ±1257.6 | 1416.1 ±1068.2 | 1969.2 ±1182.1 |

a Total body mineral loss given as mcg/day ± SD

b Total body mineral loss = arm mineral loss/(arm nitrogen loss/total body nitrogen loss)

c Intake given in milligrams per day

d Intake given in grams per day

Table 11: Total 24-hour Loss[a] of Sodium and Zinc as Computed from Forearm Mineral Loss, Arm Nitrogen Loss, and Total Body Nitrogen Loss[b] at Three Levels of Protein and Mineral Intake

| Subjects | | Sodium | | | Zinc | | |
|---|---|---|---|---|---|---|---|
| | Mineral Intake[c] | 1672.2 | 2148.1 | 2791.9 | 5.0 | 7.5 | 9.3 |
| | Protein Intake[d] | 30 | 60 | 90 | 30 | 60 | 90 |
| Group A | | 2300.5 ±319.2 | 1922.5 ±61.4 | 4045.2 ±1145.2 | 78.5 ±23.4 | 65.6 ±11.8 | 114.3 ±30.8 |
| Group B | | 6616.6 ±3165.5 | 2549.1 ±557.9 | 3656.2 ±1034.0 | 272.5 ±350.1 | 81.4 ±21.9 | 236.2 ±173.5 |
| Group C | | 4060.8 ±2301.2 | 5142.4 ±2299.9 | 2185.8 ±694.1 | 136.1 ±65.4 | 155.8 ±26.8 | 66.8 ±31.5 |
| Overall Mean | | 4685.7 ±2914.6 | 3256.9 ±1887.5 | 3263.3 ±1190.7 | 178.6 ±230.7 | 102.2 ±44.7 | 149.3 ±132.8 |

[a] Total body mineral loss given as mcg/day ± SD

[b] Total body mineral loss = arm mineral loss/(arm nitrogen loss/total body nitrogen loss)

[c] Intake given in milligrams per day

[d] Intake given in grams per day

Total body sweat calcium loss is much lower than that reported in the research literature (120 - 205 mg/day). These were adult values, but even Ryans' work with preadolescent girls is higher, 72.7 mg/day as compared to .68 mg/day. Some question of extraneous mineral contamination does arise in Ryan's work though, since she analyzed for mineral loss by taking samples from clothing worn by the girls as outer garments.

Cutaneous Copper and Manganese Loss

Due to the scarcity of research in this area and inconsistences in recording data among researchers, only one study has been done on copper and manganese excretions through sweat that can be compared to this study for analysis of results. Walls (15) reported a range of copper excretion for individual subjects of 0.04 - 0.66 mcg/hour. These figures are within the somewhat broader range found in this study of 0.1 - 1.7 mcg/hour. The highest value was found during collection period 3 and the lowest during collection period 4 even though each subject was on a 90 g protein diet and identical copper intake (0.8 gm/day). Total body copper loss averaged 24.3 mcg/day with a range of 4.2 - 106.5 mcg/day.

Walls (15) reported manganese in the forearm sweat of individual subjects ranging from 0.005 - 0.074 mcg/hour. Again, no significant difference in these values and those recorded in this study can be seen (0.04 - 0.10 mcg/hour). Total body manganese loss was estimated at 7.0 mcg/day with a range of 1.8 - 17.7 mcg/day.

Cutaneous Iron Loss

Total body sweat iron loss was lower in this study, 118.8 mcg/day, than those given by researchers (3,9,18,19) working with adults. The closest values were those of Johnston et al. (9) at 0.075 mg/hour or 1.8 mg/day (1800 mcg/day). Johnson was working with young adult women. In this study, sweat was collected from the forearm which would include only secretions from the eccrine glands. Johnston (11) collected sweat from the entire body which would possibly contain a high proportion of perspiration secreted by apocrine glands, which might account for higher iron excretion. It is also possible that the growing child may retain more iron due to his growing state than the adult women.

Arm sweat iron losses ranging from 0.3 - 3.6 mcg/hour were seen during collection periods 2 and 3, respectively. Iron intake during these periods was 27.8 mg and 29.4 mg, while protein intake was 30 g and 60 g. Walls (15) reported a much lower range of iron excretion in the girls of her study (0.014 - 0.529 mcg/hour). No explanation can be given for this discrepancy.

Cutaneous Magnesium Loss

Arm sweat magnesium losses ranged from 0.3 - 2.8 mcg/hour from subjects on 30 g and 90 g protein intake respectively, and similar magnesium intakes. This range is not as extensive as that found in Wall's (15) subjects. Total body sweat loss averaged 115.4 mcg/day (16.2 - 300.0 mcg/day) which is considerably less than that reported by Ryan (14) at 20.4 mg or 20,400 mcg/day. Ryan's subjects were much

more active than were the subjects in this study which may account for some discrepancy in the two reports. Also, the question of contamination of Ryan's samples still exist.

Cutaneous Potassium Loss

Total body sweat potassium loss averaged 1864.8 mcg/day with a range of 401.7 - 4396.7 mcg/day. Arm sweat potassium loss ranged from 4.7 - 50.9 mcg/hour as compared with Walls (15) at 9.78 - 62.51 mcg/hour. It is interesting to note that subject 118 was lowest and subject 115 was the highest in excretion of both iron and potassium during the same collection periods. This did not hold true among the other minerals, nor among other subjects.

Cutaneous Sodium Loss

Sodium concentration in sweat varies greatly, depending on a number of factors such as sweat rate, skin and deep temperature, activity, heat, water, salt balance, and skin site. Because of these factors and inconsistences in the recording of data among reports, only two studies can be compared with this study. Consolazio et al. (23) reported a loss of 0.601 gm/hour when their subjects (young adult men) were exposed to 100°F temperatures. This value far exceeds the total body sodium loss of .001 - .01 g/day reported in this study. Of course, the subjects of this study were exposed to moderate temperatures, ranging from 62.5°F to 72.0°F (outdoor temperature), as opposed to the extremely adverse temperatures of Consolazio's study which accounts for much of the discrepancy.

Walls (15) who reported sodium losses in arm sweat in the range of 9.95 - 57.9 mcg/hour was much closer to the 15.8 - 91.0 mcg/hour found in this study.

Cutaneous Zinc Loss

Few data are available on the excretion of zinc and virtually none in the area of integumental losses in children. Walls (15) found a range of 0.10 - 3.71 mcg/hour for zinc lost in arm sweat as compared to 0.4 - 3.8 mcg/hour in this study. Total body sweat zinc loss was found to range between 24.9 - 892.3 mcg/day and average 143.3 mcg/day.

## SUMMARY AND CONCLUSIONS

The cutaneous sweat losses of calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc were studied in twelve preadolescent boys participating in a two-month metabolic study (June 20 - July 23) at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. The subjects consumed diets containing 30, 60, and 90 g protein and various mineral concentrations. Mineral loss through arm sweat was determined and used to extrapolate total body mineral loss from arm sweat mineral and nitrogen loss, and total body sweat nitrogen loss. The influence of protein and mineral intake on mineral excretion in sweat was also studied.

Sweat for mineral and nitrogen analysis was collected using polyethylene freezer bags which covered forearms and hands of the subjects. The bags were worn by the subject for one hour and then his arms were rinsed with a laurel alcohol detergent solution and ion-free water. The rinse solution was filtered and samples were taken for mineral and nitrogen analysis. Each mineral sample was evaporated to dryness and wet ashed. Mineral concentrations were determined by atomic absorption spectrophotometry. Arm sweat nitrogen determinations were made using the micro-Kjeldahl method.

Statistical analysis ($\alpha = 0.05$) showed that the level of mineral and protein in the diet had no effect on the amount of mineral excreted in arm sweat, except in the case of sodium (Group B) and zinc (Group A). These were isolated cases in the analysis and are considered to have been significant by chance only, due to the large number of variables being analyzed.

Large variations in arm sweat excretions for individuals and within groups, were seen in every mineral. The mean excretion of arm sweat and total body sweat mineral excretions in the subjects are as follows; 6.7 mcg/hour and 685.5 mcg/day of calcium; 0.3 mcg/hour and 24.3 mcg/day of copper; 1.2 mcg/hour and 118.8 mcg/day of iron; 1.3 mcg/hour and 115.4 mcg/day of magnesium; 0.07 mcg/hour and 7.0 mcg/day of manganese; 18.9 mcg/hour and 1864.8 mcg/day of potassium; 40.5 mcg/hour and 3735.3 mcg/day of sodium; 1.5 mcg/hour and 143.4 mcg/day of zinc. Arm sweat results are in accordance with those found by other researchers working with children. Total body results are much lower than those found in research done with adults.

Additional research needs to be done with children to determine cutaneous mineral loss and its role in dietary requirements for growing children. Methods for determining cutaneous mineral loss need to be found which will lead to consistent and more accurate observations.

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# APPENDICES

# APPENDIX I

## Total Body Sweat Nitrogen Collection and Analysis Procedure

Total body sweat collections were made for a two-day period at the end of each experimental period. The bathing schedule was identical for each experimental period. Immediately following breakfast on day 9 of experimental Periods II and III and day 10 of experimental Period IV, each subject was washed in a 20 gallon polyethylene container with 4 liters of tap water containing 2 ml of 10% polyethylene laurel alcohol detergent and rinsed thoroughly with additional tap water. This bath water was discarded.

The subjects were dried with a nitrogen-free towel and dressed in nitrogen-free clothing. Immediately following breakfast on day 10 of experimental Periods II and III and on day 11 of experimental Period IV, the subjects were given a second bath, similar to the first Each subject was bathed, including the hair, in 4 liters of tap water containing the detergent, and rinsed in 3 liters of water. The subjects were dried with a nitrogen-free towel and dressed in second set of nitrogen-free clothing to begin the second 24-hour collection. To the bath water of the second washing was added the subject's clothing, towel, and washcloths plus 4 liters of 0.05% acetic acid to prevent the evaporation of ammonia. This mixture was allowed to equilibrate for 8 hours. At this time, two aliquots were taken, a 500 ml aliquot which was filtered to remove any organic contaminants and acidified to a pH of 1.0 - 2.0 to pervent action of microorganisms, and a 1 liter aliquot which was acidified and frozen for later nitrogen determination.

On day 1 of experimental Periods III and IV and on day 1 following experimental Period IV, each subject was bathed and rinsed; clothing, towels, washcloths and bath water were treated as described in the second soaking.

Clothing apparel for each subject during sweat collection consisted of trousers, long-sleeved shirts, underwear, socks and shoes. This clothing for the first 24-hour collection and a duplicate outfit to be worn during the second 24-hour collection day was furnished by the subjects and/or by the Department of Human Nutrition and Foods to insure proper material and a minimum of dye. Clothing was worn during the entire 24-hour period of collection with the exception of trousers, which were removed for sleeping.

The same bedding remained on beds during the 48-hour period of sweat collection. At the end of the collection period, sheets and pillowcases were removed and soaked overnight in their respective containers in 6 liters of 0.05% acetic solution. Two aliquates were removed for nitrogen determination and treated in the same manner previously described for the bath water.

On each sweat collection day, a pretreated washcloth, moistened in tap water, was provided for each subject to wipe his hands and face before each meal. This cloth was kept in a plastic bag and added to the respective bath water at the end of each 24-hour collection period.

In order to avoid any excretory contamination of clothing, all subjects were instructed to cleanse the nearby skin area with a cotton swab moistened in tap water following each voiding. Determination of

total body sweat nitrogen concentration was done using the Kjeldehl method of analysis.

Appendix II-A: Average 24-hour Excretion of Nitrogen in Total Body Sweat during Three Levels of Protein Intake for Three Groups of Subjects

| Subjects | | Protein Intake | | | Overall Mean |
|---|---|---|---|---|---|
| | | 30 g | 60 g | 90 g | |
| Group A | mg/day | 241.6 | 230.2 | 363.0 | 278.3 |
| | ± SD | ±45.1 | ±44.6 | ±57.6 | ±76.8 |
| Group B | mg/day | 364.0 | 205.6 | 344.8 | 304.8 |
| | ± SD | ±113.3 | ±24.8 | ±33.8 | ±103.2 |
| Group C | mg/day | 259.0 | 376.2 | 187.0 | 274.1 |
| | ± SD | ±59.5 | ±37.1 | ±33.8 | ±91.0 |
| Overall Mean | mg/day | 298.4 | 268.6 | 296.8 | 287.9 |
| | ± SD | ±97.0 | ±85.9 | ±97.0 | ±91.8 |

Appendix II-B: Average Excretion of Nitrogen in Forearm Sweat during Three Levels of Protein Intake for Three Groups of Subjects

| Subjects | | Protein Intake 30 g | Protein Intake 60 g | Protein Intake 90 g | Overall Mean |
|---|---|---|---|---|---|
| Group A | mg/hour ± SD | 3.9 ±1.6 | 3.2 ±0.6 | 3.3 ±1.7 | 3.5 ±1.2 |
| | mg/day ± SD | 94.7 ±37.2 | 78.4 ±12.7 | 79.9 ±39.5 | 84.3 ±29.0 |
| Group B | mg/hour ± SD | 2.4 ±0.7 | 4.5 ±1.1 | 3.4 ±1.2 | 3.4 ±1.2 |
| | mg/day ± SD | 57.7 ±17.2 | 107.4 ±26.0 | 81.9 ±27.6 | 82.3 ±30.6 |
| Group C | mg/hour ± SD | 1.9 ±0.5 | 2.8 ±0.9 | 5.0 ±0.9 | 3.2 ±1.5 |
| | mg/day ± SD | 45.4 ±10.8 | 66.4 ±21.7 | 120.2 ±20.7 | 77.3 ±36.9 |
| Overall Mean | mg/hour ± SD | 2.6 ±1.2 | 3.6 ±1.1 | 3.9 ±1.4 | 3.4 ±1.3 |
| | mg/day ± SD | 62.9 ±28.1 | 86.5 ±27.8 | 94.2 ±32.4 | 81.2 ±31.7 |

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# ARM SWEAT NIMERAL LOSS AND TOTAL BODY MINERAL DETERMINATIONS IN PREADOLESCENT BOYS

by

Marian E. Harrison

## ABSTRACT

The cutaneous sweat loss of calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc of preadolescent boys on diets containing 30, 60, and 90 g protein and various mineral concentrations were studied. Arm sweat collections were made using the arm bag technique. Mineral and nitrogen concentrations were determined by atomic absorption spectrophotometry and the micro-Kjeldhl procedure, respectively. Total body mineral loss was extrapolated from arm sweat mineral and nitrogen loss and total body nitrogen loss. The influence of protein and mineral intake on mineral excretion in sweat was also studied.

Statistical analysis ($\alpha = 0.05$) showed no effect of protein and mineral intake on cutaneous mineral excretion. Arm sweat results are in accordance with those found by other reserachers working with children but total body mineral losses are much lower than those found in research done with adults.