A STUDY OF THE MAGNESIUM CONTENT OF URINE AND BLOOD SERUM OF WOMEN IN RELATION TO BODY WEIGHT

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This is to certify that the

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A STUDY OF THE MAGNESIUM CONTENT OF URINE AND BLOOD SERUM OF WOMEN IN RELATION TO BODY WEIGHT

By

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INTRODUCTION

Experimental magnesium deficiency in rats was demonstrated first by Kruse et al in 1932; following this, biochemical studies have shown that magnesium plays an essential role in many enzyme systems. Magnesium is a constituent of enzymes of the vitamin B complex and is an activator of several enzyme systems, as, for instance, the phosphatase enzyme (Stearns, 1951.)

In a study of 440 pathological cases, Haury and Cantarow (1942) found that the concentration of blood magnesium of arteriosclerotic and cardiac subjects tended to be higher than for healthy persons, although the range of values was similar for the two groups. These results suggested that magnesium might be involved in obesity since it has been reported that obese individuals show a greater tendency to develop cardiac disturbances than do people of average weight (Downes, 1953.)

That obesity is a significant health problem in the United States is well known. Several metabolic studies have been undertaken in the attempt to understand this problem (Brewer et al, 1952; Young, 1952; Leverton and Gram, 1951; Brown et al, 1946.) In 1951 Brown and Beerstecher studied fourteen metabolic factors in the fasting urine of 10 overweight and in 10 underweight adult men. They demonstrated that the modified creatinine coefficient, pigment to creatinine ratio, urinary phosphate excretion and urinary calcium excretion were sufficiently different in the two groups to suggest that metabolic factors might be involved in obesity. Since magnesium is an important constituent of enzyme systems, the following study was planned to investigate possible relationships of the magnesium content of serum and urine of women to body weight. The fasting blood serum magnesium and urinary excretion of magnesium were determined for 13 women of less than average weight, for 13 women of more than average weight and for 22 women of average weight.

REVIEW OF LITERATURE

Distribution of Magnesium in the Body

There is a paucity of information concerning the distribution of magnesium in the different tissues of the human body. According to Sherman (1952) magnesium comprises 0.05 percent of the elements of which the human body is composed. This figure is based on a compilation of data from several sources. On this basis a man who weighs 75 kilograms would contain 38 grams of magnesium in his body. In an analysis of subjects who had died from accidents or diseases with no apparent disturbances in mineral metabolism Duckworth and Warnock (1942-43) reported that approximately 0.7 percent of the bone ash of the skeletons was composed of magnesium. This percentage differed widely for people of various ages. From the analysis of the magnesium content of the skin (Brown, 1926) and of the heart (Cullen et al, 1933; Wilkins and Cullen, 1934,) Duckworth and Warnock (1942-43) estimated that the value of magnesium in soft tissues was 8.2 grams per 70 kilograms of body weight. Duckworth and Warnock (1942-43) also compiled the magnesium contents of the soft and skeletal tissues for girls from birth to 14 years of age and demonstrated that the skeletal magnesium tended to increase more rapidly than the magnesium content of soft tissues. At birth the ratio of skeletal magnesium to the magnesium in the soft tissue was two to one and at 14 years of age this ratio increased to a value of four to one. At the time of prepubertal growth, there was an increase in the estimated rate of deposition of magnesium in the tissues.

The magnesium content of the body has been studied most extensively in the rat, but investigators have reported contradictory observations with respect to changes in magnesium composition with age. Buckner and Peter (1922) investigated magnesium content of crude ash of rats from two to 40 weeks of age, and found that there was little change in the magnesium content with an increase in age. However, Medes and Humphrey (1927) studied the magnesium content of rats from birth to 150 days, and reported that the magnesium content of the body increased until the ninetieth day after which it remained constant. On the other hand, a rapid increase in the magnesium content of the bodies of rats from birth to four weeks was reported by Greenberg and Tufts (1936.) These workers found that the magnesium content of the rat carcasses remained constant from four to 11 weeks and after this age, there was approximately a 20 percent decrease in body magnesium.

Possible differences in the body content of magnesium due to sex were suggested by Medes and Humphrey (1927) who showed that male rats contained a greater amount of magnesium in their bodies than female rats when compared on the basis of age. No significant difference was observed in the body content of magnesium of male and female rats when compared on a basis of weight. Buckner and Peter (1922) and Greenberg and Tufts (1936) reported that they had observed no marked differences in the content of magnesium in the bodies of male and female rats.

Factors Affecting the Magnesium Content of Blood

Within the last two decades, with the development of newer techniques for the analysis of magnesium in body fluids, many studies have been made of the distribution of magnesium in biological fluids. The following discussion is concerned with factors affecting the content of magnesium in blood serum and plasma.

A compilation of the blood magnesium values of apparently healthy normal adults is presented in Table I. Values reported for only one or two individuals have not been included since the concentrations were within the range of those values cited. The values given in Table I range from 0.96 milligrams per 100 milliliters (0.8 milliequivalents per liter) to 3.51 milligrams per 100 milliliters; the average value is approximately 2.20 milligrams per 100 milliliters. Blood samples were withdrawn during unspecified times of the day, except where noted. Whether or not the sample was venous or capillary blood was not indicated in most cases.

TABLE I

A COMPARISON OF BLOOD MAGNESIUM VALUES

REPORTED FOR HEALTHY INDIVIDUALS

Investigator	Nature of Sample	Magnesium Content of Blood mg/100ml range	Average	meq/l range	Average
SMITH et al, 1950	heparinized plasma			1.01 - 2.12	1.58
SQUIRES, 1950	serum - natives of Buchuanaland	1.08 - 3.51	1.71		
KUNKEL et al, 1947	plasma	2.02 - 2.22	2.14		
SIMONSEN et al, 1947	serum	1.7 - 2.3	2.1		
RADSMA, 1944	plasma: Batavian native students		2.13		
	European born residents		2.81		
	Native students		3.10		
HAURY AND CANTAROW, 1942	plasma: medical students laboratory workers	1.7 - 3.1	2.48		
SNYDER AND KATZENELBOGEN, 1942	fasting serum			1.3 - 2.3	
	composite reported			0.8 - 2.5	
HAURY, 1940	fasting serum, medical students	1.74 - 3.10	2.33		
BERSTEIN AND SIMKINS, 1940-41	serum, non-cardiac patients	1.37 - 3.11	2.12		
HALD AND EISENMAN, 1937	fasting serum, laboratory workers			1.2 - 2.2	1.6
WALKER AND WALKER, 1936	fasting serum	1.60 - 3.00	2.20		
GREENBERG et al, 1933	plasma	2.00 - 3.66	2.74		
HALD, 1933	fasting serum			1.4 - 2.4	1.7
BOGERT AND PLASS, 1923	females	1.90 - 2.70	2.30		
SALVESON AND LINDER, 1923	fasting serum, males			1.7 - 1.9	

Few investigations have been reported on the blood magnesium values with regard to sex. Simonsen et al (1947) found that the average serum magnesium values for 21 female adults was 1.98 milligrams percent and that for 21 adult males, 2.06 milligrams percent. Bogert and Plass (1923) gave an average of 2.3 milligrams percent for the blood magnesium content for women; and Underhill and Dimick (1923-24) reported an average of 2.7 milligrams percent for adult females. Salveson and Linder (1923) found a range of 1.7 to 1.9 milligrams percent for blood magnesium for seven adult males.

The diurnal variations of serum magnesium have been studied by several investigators. Watchorn (1929) demonstrated that there were no significant differences in the values of blood magnesium throughout the day "...provided violent exercise is not taken..." However, it has been observed that cows show a significant diurnal rhythm with the lowest peak at 9 A.M. (Blosser et al, 1951.) No marked changes were noticed when blood magnesium of cows was analyzed at 9 A.M. for nine consecutive days (Blosser et al, 1951.) Hald (1933) determined the fasting magnesium values of one person for three different days, and reported no marked changes in concentrations.

Diverse results have been reported in several publications concerning the effect of temperature on the blood content of magnesium of different animals. Pleshtizer (1936) reported that in man, temperature had but a slight effect on the blood magnesium values. However, Pal et al (1945) found that the blood magnesium values of cattle were higher in summer than in the winter. Suomalainen (1938) noted that the serum magnesium values in the hedgehog were three times larger during winter hibernation than in the summer waking state; this difference may have been due to temperature or to a variation in metabolic activity.

Few studies have been made of the blood magnesium content of peoples of different races. In 1950 Squires reported a wider range of blood magnesium values for adult men of Buchuanaland, South Africa than for white men of the same region. Nevertheless, he obtained an average of 1.71 milligrams percent for the South Africans, which agreed satisfactorily with the averages reported for members of the white race. Radsma (1944) recorded average values of 3.02 milligrams percent for native Batavian students, 2.81 milligrams percent for European born residents, and 2.13 milligrams percent for Batavian native servants.

Studies of the variations in values for blood magnesium during the various stages of pregnancy have been inconclusive. Underhill and Dimick (1923-24) reported similar values for blood magnesium for women in various stages of pregnancy. These workers found an average blood magnesium value of 2.7 milligrams percent for normal non-pregnant women. At the fourth

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and sixth months of pregnancy the blood magnesium content was 2.0 milligrams percent. A slightly higher blood magnesium value of 2.8 milligrams percent was observed during the seventh month of pregnancy and two days post-partum. That blood magnesium decreases slightly during menstruation has been reported by Nava (1950.) Bogert and Plass (1923) reported that there was little difference between the magnesium content of the umbilical blood of the newborn child and that of the venous blood of the mother at birth. According to Miller (1944) values obtained for children tended to be within the upper ranges of values reported for adults.

Subnormal values of serum magnesium have been recorded both in cases of inanition and in cases which show a large increase in body weight (Mellinghoff and van Lessen, 1949.) In 1947 Sunderman reported that the serum magnesium concentration was above average on the forty-fifth day of a voluntary fast by one man. On the fifty day after the cessation of the fast, the value was subnormal, but the serum magnesium returned to average by the forty-third day after the fast. The tendency of serum magnesium to rise in the early part of fasting, followed by a drop with a rapid return to normal on refeeding also was observed by Morgulis (1928) in studies with dogs. No changes in the blood magnesium values were found during a seven day fast of the hedgehog (Suomalainen, 1939.)

The magnesium content of blood of pathological cases has been shown to be within the normal range. In 1940-41 Berstein and Simkins reported a slight increase in serum magnesium in cases with hypertensive heart diseases. In patients with arteriosclerosis with no hypertensive disorders a slight increase also was observed; in individuals with chronic nephritis and renal insufficiency, serum magnesium was elevated to two times the normal values.' In 1944 Miller recorded a case of tetany with a low plasma magnesium value. The subject was a child with osteochrondritis of the capital epiphysis of the femur. This tetany was cured by the administration of magnesium. Hirschfelder (1934) observed cases of convulsions and twitching associated with low plasma magnesium values. Lower blood magnesium values have been reported for patients with bronchial asthma (Haury, 1940.)

In 1942 Haury and Cantarow published a report on the serum magnesium values of 440 pathological patients. High serum magnesium values were recorded in individuals suffering with chronic nephritis, arteriosclerosis with hypertension and hepatic disorders. Low values were observed for patients with toxic thyroid gland and polyglandular disturbances, vasospastic diseases, malignant neoplasm, toxemia of pregnancy and epilepsy. Variable data were obtained from subjects with diabetes mellitis and orthopedic surgical conditions. Serum magnesium values for individuals with endocrine disturbances showed no tendency to deviate from the normal range. From these results, the authors suggested that a low blood magnesium value for a patient might indicate a spasticity of the smooth muscles in the blood vessels, or might be associated with a delay in callus formation, and that a higher value for blood magnesium might be suggestive of the production of intra-articular adhesion and ossification.

Factors Affecting Magnesium Metabolism

In a review of magnesium metabolism, Cantarow and Trumper (1949) stated that about 50 to 80 percent of the total magnesium output of the body is excreted through the feces; the remaining 30 percent is eliminated by the kidney. In an investigation of the urinary excretion of magnesium of 57 patients on admission to the hospital, Berstein and Simkins (1940-41) reported that the average daily excretion ranged from 17.3 milligrams magnesium to 285.0 milligrams magnesium per day, with an average of 105.5 milligrams per day. These results are comparable to those reported by Walker and Walker (1935-36) who found that the average daily urinary excretion of magnesium was 103 milligrams with a range of 32.5 to 307.0 milligrams in a group of normal adults; the urinary excretion of magnesium for medical and surgical patients ranged from five to 243 milligrams per day with an average of 86 milligrams per day. In 1937-38 Weber recorded that the average daily urinary excretion of magnesium ranged from 83.9 to 132.1 milligrams magnesium in eight young adults.

The influence of various dietary factors on magnesium retention and urinary excretion of magnesium has been studied. Several investigations have demonstrated that magnesium, fed in the form of salts such as citrate (Bogert and McKittrick, 1922,) lactate (Carswell and Winter, 1931,) and sulfate (Hart and Steenbock, 1913) seems to be readily absorbed by the intestinal tract. According to Tibbets and Aub (1937) an increase in intake of ammonium chloride resulted in an increase in urinary excretion of magnesium. The studies indicate that an increased absorption might occur in an acid medium. Substances containing oxalates, benzoates and phytates have been reported to produce disturbing effects on magnesium absorption (Stearns, 1951.) However, an investigation conducted by Walker et al in 1938 showed that man might adjust himself to a deficiency of magnesium induced by an increased dietary phytate intake. In a study of the retention of magnesium of four normal men on a high phytate diet, a negative balance was observed within a few days after the subjects were on the diet. Magnesium equilibrium was attained after a period from two to 22 days.

In the early part of the century, the addition of raw and dried milk to the normal diet of adult humans was found to increase the urinary excretion of magnesium (Givens, 1918.) In 1942 McCance et al reported that a high protein diet increased the absorption and therefore the urinary excretion of magnesium.

The relative effects of starch, lactose, sucrose, and of vitamin D on mineral metabolism of rats was studied by Outhouse et al in 1938. These workers reported that lactose stimulated the excretion of urinary magnesium more than did the other saccharides. The amount of magnesium excreted in the urine showed a close correlation with the amount of magnesium ingested. Administration of cod liver oil did not significantly increase the retention of magnesium. Analyses of bone ash indicated that magnesium retention varied inconsistently in relation to the magnesium content of the bones. The authors suggested that magnesium might be stored in the soft tissue. However Duckworth et al (1940) demonstrated in rats that the skeleton may act as a mobile reserve of magnesium in the time of dietary need.

The influence of minerals on magnesium absorption has been reported by De and Basu (1949.) They found that an increase in the diet of calcium, phosphorous, iron, copper or manganese decreased the retention of magnesium to a measurable although slight extent. The favorable effect of the addition of three and one half cups of orange juice to the diet of two girls, 10 and 11 years of age on magnesium retention was demonstrated by Chaney and Blunt (1925;) Coons and Coons (1935) reported a slight increase in magnesium retention in pregnancy when cod liver oil and wheat germ were added to the diet.

It appears then, that an acid medium, lactose and certain of the vitamins seem to exert a favorable effect on magnesium absorption, whereas, starch, sucrose, the presence of certain minerals and the benzoates, phytates and oxalates produce an unfavorable action. Further studies are needed for a clearer understanding of the conditions which affect magnesium absorption.

The possible interrelationship of calcium and magnesium in metabolism was reported first by Meltzer and Auer (1906.) These workers showed that the injection of calcium salts counteracted the effect of anesthesia which could be produced by the injection of magnesium salts. Mendel and Benedict (1909-10) found that the parental injections of either magnesium or calcium increased the urinary excretion of both substances. In 1937 Tibbetts and Aub stated that magnesium lactate injections caused an increase in the urinary and fecal excretion of calcium, and an increase in magnesium excretion. The influence of the ingestion of ammonium chloride and of high inorganic and organic phosphates on the retention of magnesium and calcium also was investigated. Ammonium chloride resulted in a rapid elimination of magnesium and calcium from the bones, but the phosphates apparently had no effect on magnesium or calcium excretion.

Tibbetts and Aub (1937) performed further studies on the effects of exopthalmic goiter and steatorrhea on magnesium metabolism. Patients with these diseases are known to have large calcium excretions. However, no variations in magnesium excretion and blood magnesium values were observed in these studies. The experimenters thereby concluded that magnesium and calcium, though closely related chemically, react differently in the body, and that magnesium is little influenced by the factors which affect calcium excretion.

The effect of calcium and phosphorous intakes on magnesium metabolism was studied on nine healthy college women (Leichsenring et al, 1951.) Results showed that urinary magnesium was significantly correlated with the intake of both calcium and phosphorous. However, there was no significant relationship between fecal calcium and phosphorous with fecal magnesium though the relationship between fecal calcium and phosphorous was significant. A lack of relationship between fecal calcium and phosphorous with fecal magnesium also was reported.

Isolated cases of tetany associated with low blood magnesium values also have suggested a possible interrelationship of calcium and magnesium. Kruse et al (1932) observed symptoms of hyperexcitability induced by magnesium deprivation; this was a form of tetany which is associated with a normal blood calcium. Miller (1944) also described a case of tetany in a patient who had a low blood magnesium.

A recommended daily allowance for magnesium has not been established by the Foods and Nutrition Board of the National Research Council. A suggested magnesium requirement for adults based on the data of Tibbetts and Aub (1937) was 200 to 300 milligrams per day for males with a ten percent reduction for females. Daniels and Everson (1936) estimated that the magnesium requirement for children was 13 milligrams per kilogram body weight. Wang et al (1936) reported that the magnesium requirement of the adolescent female was 300 milligrams of magnesium per day. The data of Coons and Coons (1935) suggested that 350 to 430 milligrams per day are required for pregnant women.

Distribution of Magnesium in Foods

Relatively few investigations of the magnesium content of foods have been published (Holmes et al, 1948; Tilt and Hubbell, 1930; Clouse, 1943; Kramer and Satterfield, 1943; Toscani, 1945; Peterson and Hoppert, 1925, and Sherman, 1952.) Studies which have been reported indicate that the best sources of magnesium are the protein rich foods such as milk, cereals, meats, and legumes. A compilation of magnesium values for individual food items has been made by Sherman (1952) and this table has been used widely in the evaluation of the magnesium content of dietaries (Macy, 1942.)

In a study of the chemical composition of 22 common foods, Hummel et al,(1942) reported that laboratory analyses of the magnesium content of the particular foods tested agreed satisfactorily with values reported by Sherman.

In a survey by the Carnegie Trust of the United Kingdom (Duckworth and Warnock, 1942-43) in which over 1000 urban and rural families were studied, vegetables and cereals seemed to be the main sources of magnesium in the diets of five socio-economic groups studied. However, it was shown that as the socio-economic status of the groups increased, a greater proportion of dietary sources of magnesium was obtained from meats, fish and fruits, and a lesser proportion of the dietary sources was obtained from cereals and vegetables. This survey showed that the lower income groups, representing one third of the total number of people participating in this investigation, had magnesium intakes that were deficient or on the borderline, according to the estimated requirement of 250 milligrams per day for adult males and 220 milligrams per day for adult females (Tibbetts and Aub, 1937.) Sherman (1952) reported that in an examination of 150 American dietaries, the quantity of magnesium consumed per day ranged from 140 to 670 milligrams per day. Because of the wide distribution of this element, it is generally assumed that humans are able to incorporate a sufficient daily dietary supply, providing that the over-all food intake is ample (Stearns, 1951.)

Chemical Methods

Among the methods for the determination of magnesium in biological fluids, the phosphate and the hydroxyquinoline methods have been the most commonly used. In 1909-10, McCrudden described a gravimetric procedure in which magnesium was precipitated as $MgNH_4PO_4.6H_2O$, and the ignited pyrophosphate residue was weighed. This method was adapted to the analysis of magnesium in foods, urine and feces. In 1922 both Briggs and Denis published colorimetric methods of measuring $MgNH_4PO_4.6H_2O$ by the production of a blue color with a molybdate salt.

Berg (1927) introduced a method for the analysis of magnesium based on the principle that magnesium-eight-hydroxyquinoline is precipitated in a hot ammoniacal solution. In 1932 Greenberg and Mackay developed a method of brominating the hydroxyquinoline and titrating the excess bromine with sodium thiosulfate. Yoshimatsu (1929) determined the hydroxyquinoline colorimetrically by using the Folin phenol reagent to produce a blue color. In 1937, Hoffman developed another colorimetric procedure for reading the hydroxyquinoline precipitate, which was based on the principle that the hydroxyquinoline combines with the ferric ions in a weak hydrochloric acid solution to form a green-blue color.

Both the phosphate and hydroxyquinoline methods for the determination of magnesium require the elimination of calcium as calcium oxalate; both methods are relatively time-consuming. In addition, the phosphate method may be criticized since the molybdate salt is relatively unstable, and the hydroxyquinoline method may be criticized since loss of precipitate may occur in carrying out the procedure.

A simpler and, at present, more widely used method, for the determination of magnesium in biological fluids is based on the use of a dye, titan yellow, which becomes red in an alkaline medium, thus forming a stable magnesium-dye-lake. This observation was first made by Kolthoff in 1927, and it was adapted to the analysis of biological fluids by Hirschfelder and Serles in 1934. In this procedure starch was used as a stabilizing agent for the magnesium-dye-lake. In 1946, Garner reported a methodology study on factors affecting the determination of blood magnesium. He found that the concentration of calcium, as it occurs normally in the blood, did not interfere in the determination of magnesium with the titan yellow method. He also observed that the unprecipitated serum proteins (Hirschfelder and Serles, 1934) created a large error. Garner introduced gum ghatti as a more suitable dispersing agent than starch. Hydroxylamine hydrochloride was found to be a successful stabilizing agent by Kunkel et al (1947,) who also reported that calcium and phosphorous do not occur in blood in concentrations great enough to interfere in the production of a stable red magnesium complex.

Within the last decade, micro-methods for the determination of different substances in body fluids by photoelectric or spectrophotometric procedures have been developed extensively. In 1947 Kirk et al devised a horizontal cuvette with a light path ten times that of the five cubic millimeter cuvettes customarily used. Orange and Rhein (1951) adapted the use of this horizontal cuvette to the microdetermination of magnesium, since the concentration of magnesium was found to vary inversely with the length of the light path. Thereby, one-tenth milliliter of serum could be used in a single determination, rather than the two to four milliliters of serum which were required in previous methods. In this micro-method, polyvinyl alcohol was used as the dispersing agent.

More recently a spectrographic method has been described by Smith et al (1950) and a flame spectroscopy procedure by Kapuscinki et al (1952.) However these methods are not well suited to the determination of magnesium in blood because of the relatively low intensity of the lines in the magnesium spectrum.

EXPERIMENTAL PROCEDURE

Experimental Plan

Subjects of this study were women who were considered to be of average body weight in relation to height and age, above average weight and less than average weight. Estimations of variations from average body weight were made according to the Metropolitan Life Insurance Tables as reported by Cooper et al (1947) for women from 18 to 29 years of age and as reported by Sherman (1952) for women 30 years and above. Ages of the subjects ranged from 18 to 53 years.

The subjects were asked to come to the laboratory in the early morning, before breakfast. The subjects were to urinate immediately after rising; one hour later each subject was asked to collect a urine sample, emptying the bladder as completely as possible. This urine sample represented one-hour urinary excretion, collected by the subject in a fasting state. During this period, a capillary blood sample, approximately one milliliter in volume, was collected from a finger prick. The blood was centrifuged and the serum removed for chemical analysis. The urine and serum were analyzed for magnesium.

A recall record of the diet eaten on the day previous to the collection of the urine and serum samples was obtained from each subject. The dietary intake of magnesium was calculated according to the values included in the compilation of magnesium content of foods reported by Sherman (1952.)

Certain corollary investigations were carried out to provide data to help interpret variations in serum and urinary magnesium values among the subjects. The variations of the magnesium content of blood serum throughout the day were studied. Three women of average body weight in relation to height and age were subjects for this series. Blood samples were obtained at 7:30 A.M. (fasting state), 10:00 A.M., 12:00 noon, 3:00 P.M., 6:00 P.M. and at 9:00 P.M. Magnesium content of the blood serum was analyzed.

A study also was made of the possible variations in serum and urinary magnesium for individual women. Seven healthy women of average weight in relation to body height and age were subjects. Blood samples and one-hour urine excretions were collected at weekly intervals for a period of three weeks. The magnesium content of the serum and urine was determined.

A comparison also was made of the magnesium content of serum obtained from venous blood and that obtained from capillary blood. Subjects of this study were subjects of a metabolic study* in progress in the Department of Foods and Nutrition at the same time that the present investigation was made.

Magnesium Content of Blood Serum

The method of Orange and Rhein (1951) was used to estimate the concentration of magnesium in blood serum. Capillary blood was obtained from the finger by pin-prick and collected in small tubes, allowed to stand for an hour or more, then centrifuged at 3000 revolutions per minute for ten or more minutes. Duplicate samples of 0.1 milliliter of serum were pipetted into a three milliliter centrifuge tube. One and one-tenth milliliter of 10 percent trichloroacetic acid was added rapidly. The solutions were mixed by holding the small tube against a stirring rod rotated by an electric motor, and then were centrifuged for ten minutes at 3000 revolutions per minute. The clear filtrate was transferred into a three milliliter centrifuge tube from which one milliliter of filtrate was pipetted and delivered into a five milliliter volumetric flask. This was followed by the successive additions of one milliliter of 0.1 percent polyvinyl alcohol, and one milliliter of 7.5 milligram percent of titan yellow solution. The solution was made to volume with 7.5 percent sodium hydroxide, mixed thoroughly and

* Acknowledgment is made to Betty Hawthorne for permission to use these subjects for this study.

transferred to horizontal cuvettes*, 50 millimeters in length. Optical density was measured by means of the Beckman Spectrophotometer at a wavelength of 550 millimicrons.

Standard solutions of magnesium were prepared from magnesium ammonium phosphate in concentrations which ranged from one to five micrograms of magnesium per five milliliters of solution. The reading range was from 0.000 to 0.700 on the optical density scale.

The procedure for the determination of serum magnesium was checked by the recovery of a known amount of magnesium from serum. Values for various amounts of added magnesium for three sera samples are given in Table II. Recoveries of magnesium averaged 99.86 ± 0.66 percent.

At the beginning of the study it was necessary to freeze some samples of serum for later analysis. No samples were held in the frozen state for more than a two months period. Control samples of serum were analyzed before and after frozen storage for two months and no change in magnesium content was observed.

* Microchemical Specialties Co., Berkeley, California.

TABLE II

THE RECOVERY OF ADDED MAGNESIUM FROM BLOOD SERUM

Sample	Magnesium Content of Serum	Magnesium Added	Magnesium Present*	Magnesium by Analysis	Recovery of Magnesium
	mg/100ml	mg/ml	mg/ml	mg/ml	%
1	.58	.50	1.08	1.08	100.00
	"	.50	1.08	1.08	100.00
	"	1.50	2.08	2.08	100.00
	"	1.50	2.08	2.08	100.00
	"	2.50	3.08	3.16	102.50
2	.60	.50	1.10	1.10	100.00
	"	1.50	2.10	2.09	98.66
	"	2.50	3.10	3.05	98.00
3	.51	.50	1.01	1.01	100.00
	"	1.50	2.01	1.97	95.14
	"	1.50	2.01	2.00	97.00
	"	2.50	3.01	3.17	103.00

Average. 99.86

Standard Deviation . . . . $\pm$ 0.66

* By summation

Magnesium Content of Urine

The macro-method for the determination of magnesium published by Garner (1946) was adapted for the analyses of magnesium in urine.

If there was visible precipitate or blood in the urine, the material was filtered with ash-free Whatman filter paper, number forty. The urine filtrate was acidified with concentrated sulfuric acid and either analyzed immediately or frozen and held for later analysis. In the case of frozen urine samples, the urine was allowed to thaw in the refrigerator overnight. The following morning the samples were allowed to stand at room temperature for a few hours and were mixed thoroughly.

The urine was diluted with distilled water. One milliliter of 0.1 percent polyvinyl alcohol was added to eight milliliters of diluted urine, followed by 1.5 milliliters of 0.05 percent of titan yellow solution, and two milliliters of four normal sodium hydroxide. Solutions were mixed thoroughly and the percent transmission was measured in the Coleman Spectrophotometer in square matched cuvettes. The reading range was from 70 to 100 percentage transmission.

Working standards of magnesium were prepared from magnesium sulfate in concentrations which ranged from one to five grams of magnesium per 100 milliliters of solution. The method for the determination of magnesium was checked by the recovery of known quantities of magnesium from urine; values obtained are reported in Table III. Recoveries of added magnesium to urine averaged 99.77 $\pm$ 4.85 percent.

The effect of freezing on the magnesium content of urine was studied by analyzing the magnesium of urine before freezing and after two weeks of frozen storage. No change in the magnesium content was observed.

TABLE III

THE RECOVERY OF ADDED MAGNESIUM FROM URINE

Sample	Magnesium Content of Urine	Magnesium Added	Magnesium Present*	Magnesium by Analysis	Recovery of Magnesium
	mg	mg	mg	mg	%
1	.0026	.01	.0126	.0120	95.23
	"	.02	.0226	.0203	89.87
2	.0424	.01	.0524	.0520	99.24
	"	.02	.0624	.0600	96.15
3	.0259	.01	.0359	.0355	98.89
	"	.02	.0459	.0450	98.04
4	.0065	.01	.0165	.0148	89.70
	.0300	.01	.0400	.0420	105.00
5	.0230	.01	.0330	.0310	93.94
6	.0335	.01	.0435	.0442	101.61

Average. 96.77

Standard Deviation . . . .± 4.85

* By summation

RESULTS AND DISCUSSION

Variations in Serum and Urinary Magnesium in Individuals

The magnesium content of serum from venous blood and from capillary blood samples from four subjects is given in Table IV. Values for serum magnesium from venous blood agreed closely with values for the magnesium content of serum from capillary blood. The average value for serum magnesium from venous blood for the four subjects was 1.16 milligrams per 100 milliliters and the average value for serum magnesium from capillary blood was 1.17 milligrams per 100 milliliters. Differences between the magnesium content of venous blood serum and capillary blood serum for the individual subjects ranged from 0.00 to 0.04 milligrams per 100 milliliters.

The daily variations in serum magnesium content for three subjects of average body weight in relation to height and age are presented in Table V. These values for serum magnesium are plotted in Figure 1 in relation to the time of day during which the blood samples were obtained. There was not a consistent rhythm in serum magnesium values for the three subjects. All three individuals showed a high serum magnesium concentration at 10 A.M. in comparison to the serum magnesium values obtained in the fasting state. The serum magnesium values for the three subjects were relatively constant at 12 noon, and at 9 P.M. The greatest daily change in serum

TABLE IV

A COMPARISON OF VENOUS AND CAPILLARY SERUM MAGNESIUM

	Serum Magnesium	
Subject	Venous Blood	Capillary Blood
	mg/100ml	mg/100ml
CM	1.27	1.28
ES	0.98	1.02
BHA	1.19	1.18
FK	1.18	1.18

TABLE V

DIURNAL RHYTHM OF SERUM MAGNESIUM

		Serum Magnesium				
Subject	Fasting	10AM	12PM	3PM	6PM	9PM
		mg/ 100ml	mg/ 100ml	mg/ 100ml	mg/ 100ml	mg/ 100ml
NW	1.93	2.08	1.74	1.75	1.83	1.73
NMA	1.36	1.52	1.30	1.36	0.94	1.35
BB	.80	1.18	1.38	1.29	1.53	1.40

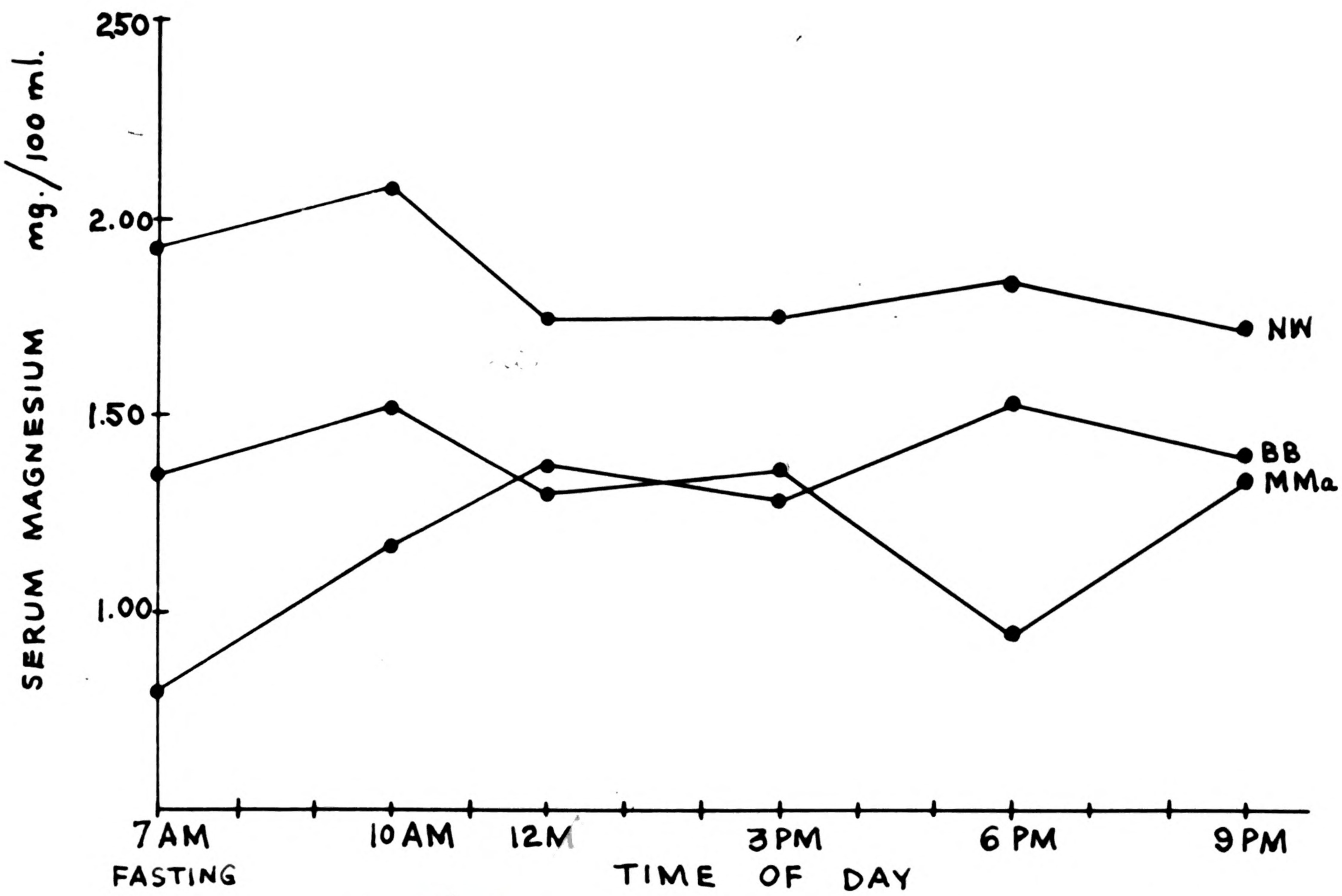

FIGURE 3. GRAPH SHOWING VARIATION IN SERUM MAGNESIUM DURING THE DAY

magnesium content for subject NW was 0.35 milligrams per 100 milliliters; for subject MMa, 0.58 milligrams per 100 milliliters and for subject BB, 0.73 milligrams per 100 milliliters. The lowest serum magnesium value obtained during the day for subject BB was observed in the fasting condition; for subject MMa, at 6 P.M. and for subject NW, at 9 P.M. The highest serum magnesium values observed during the day for subjects MMa and NW were obtained at 10 A.M. and for subject BB, at 6 P.M. These few studies indicate that there was not a rhythmic pattern in serum magnesium values although variations as great as 0.73 milligrams per 100 milliliters were observed for one individual during the day. This is not in agreement with Watchorn (1929) who reported that there was not a significant diurnal change in serum magnesium content.

The weekly variations of the serum magnesium values of seven apparently healthy women are given in Table VI. The average serum magnesium value for the seven subjects on the first day was 1.07 milligrams per 100 milliliters. One week later, the average value was 1.07 milligrams magnesium per 100 milliliters of serum. On the third week, the average value was 1.10 milligrams magnesium per 100 milliliters of serum. Weekly variations for individual subjects ranged only from 0.01 to 0.08 milligrams magnesium per 100 milliliters of serum for six subjects; subject BB showed the highest weekly change of 0.15 milligrams magnesium per 100 milliliters of

TABLE VI

VARIATIONS IN SERUM, URINARY

AND DIETARY MAGNESIUM FOR SEVEN SUBJECTS

Subject	Week I	Week II	Week III	Average
	Serum Magnesium			
	mg/100ml	mg/100ml	mg/100ml	mg/100ml
DK	0.92	0.90	0.95	0.93
BB	1.10	1.12	1.25	1.16
DC	1.13	1.13	1.14	1.13
AH	1.05	1.06	1.04	1.05
AMA	1.10	1.12	1.08	1.10
AW	1.10	1.06	1.11	1.09
MMI	1.11	1.07	1.15	1.11
Average	1.07	1.07	1.10	1.08
	Urine			
	mg/hr	mg/hr	mg/hr	mg/hr
DK	1.33	2.57	2.81	2.23
BB	2.14	0.24	0.58	0.98
DC	1.87	1.24	0.42	1.18
AH	4.45	5.80	7.38	5.88
MMA	1.13	3.89	3.42	2.81
AW	1.34	1.84	2.59	1.92
MMI	4.92	5.00	3.28	4.40
Average	2.45	2.94	2.92	2.77
	Dietary Magnesium			
	mg/day	mg/day	mg/day	mg/day
DK	184	320	267	257
BB	274	204	302	260
DC	187	228	175	197
AH	248	397	348	331
MMA	243	368	---	306
AW	228	158	222	209
MMI	239	163	188	196
Average	229	263	250	247

serum. The data were analyzed statistically by analysis of variance and the analysis indicated that there was not a significant variation in serum magnesium concentration for the individuals during the three successive weeks.

These results indicate that serum magnesium values, determined in a fasting condition on various days, were relatively constant. Similar results have been reported by Hald (1933) who studied fasting venous magnesium values for one subject on three different days. She obtained the following values for serum magnesium: 1.8, 1.6 and 1.6 milliequivalents per liter for three different days.

Table VI presents the magnesium content of a one hour collection of urine for seven women of average body weight for three successive weeks. The subjects were in a fasting condition when the urine collections were made. The average urinary magnesium excretion for the first analysis was 2.45 milligrams per hour. Values ranged from 1.33 to 4.92 milligrams per hour. An average value of 2.94 milligrams magnesium per hour of urine was obtained for the second week with a range of 0.24 to 5.80 milligrams per hour. The third measurement of urinary magnesium gave an average value of 2.92 milligrams per hour with a range of 0.42 to 7.38 milligrams per hour. Statistical analysis of the data by means of the analysis of variance indicated that there were no significant variations in the magnesium values of fasting one hour urine collections for individuals for three successive weeks. (Source of variation: Between weeks, F=0.44.)

Serum and Urinary Magnesium in Relation to Body Weight

Physical description of subjects. The age, height, weight, standard weight in relationship to age and to body height, surface area and the percent deviation of the body weight from the standard weight for all subjects participating in this study are presented in Tables VII to IX, inclusive. Thirteen individuals were considered overweight; body weights of these subjects were 20 percent or more above the weights given in the standard height, age and weight tables. Thirteen individuals were considered underweight; body weights of these subjects were 10 percent or more under the average weight according to the weights given in the standard height, age and weight tables. The remaining 22 individuals were considered of average body weight; body weights of these individuals were within -10 percent to +15 percent of the weights presented in the standard height, age and weight tables. The ages of the subjects ranged from 18 to 53 years, calculated to their nearest birthday. Except for the condition of excess weight and underweight, all subjects were apparently healthy when participating in this study.

The average percent deviation from the standard body weight was +34.8 percent for the overweight individuals, +1.7 percent for the subjects of average body weight and

TABLE VII

PHYSICAL DESCRIPTION OF OVERWEIGHT SUBJECTS

Subject	Age	Height	Weight	Standard Weight for Height	Percent Deviation from Standard Weight	Surface Area
		inches	lbs	lbs	%	m^2
MGA	19	64.6	219.6	124.5	+76.4	2.11
OA	53	66.1	234.5	138.0	+69.9	2.21
FG	20	65.9	190.3	133.0	+43.1	1.97
AG	20	65.2	177.4	130.0	+36.5	1.90
ES	29	63.8	167.9	128.0	+31.2	1.82
BHO	21	65.0	167.6	129.0	+29.9	1.84
SR	27	64.0	163.3	129.0	+26.6	1.80
DS	18	64.0	153.0	123.0	+24.4	1.74
PS	20	62.7	151.6	121.5	+24.3	1.72
BP	20	62.8	150.6	121.5	+24.0	1.71
DM	20	66.3	164.4	134.0	+22.7	1.83
MGL	28	64.0	157.0	129.0	+21.7	1.77
MA	21	63.9	152.8	126.0	+21.3	1.74

TABLE VIII

PHYSICAL DESCRIPTION OF AVERAGE WEIGHT SUBJECTS

Subject	Age	Height	Weight	Standard Weight for Height	Percent Deviation from Standard Weight	Surface Area
		inches	lbs	lbs	%	m^2
MD	19	65.5	146.3	128.0	+14.3	1.71
MW	38	65.3	152.7	135.0	+13.1	1.77
CR	22	64.0	139.8	126.0	+11.0	1.66
JM	22	52.5	133.9	121.5	+10.2	1.61
JR	30	65.0	145.0	134.0	+ 8.2	1.70
BB	22	63.0	130.0	123.0	+ 5.7	1.59
II	22	64.0	132.0	126.0	+ 4.8	1.63
DC	43	63.5	135.0	129.0	+ 4.7	1.62
EW	21	67.0	143.3	137.0	+ 4.6	1.71
HA	21	63.0	127.8	123.0	+ 3.9	1.57
PA	20	69.5	152.6	147.0	+ 3.8	1.80
AR	21	66.0	136.5	133.0	+ 2.6	1.66
AW	25	63.0	128.0	125.0	+ 2.4	1.57
MMA	26	63.5	130.0	127.0	+ 2.4	1.59
WB	37	64.4	132.5	132.5	0.0	1.62
NM	18	61.5	114.4	115.5	- 1.0	1.47
PC	21	63.5	114.5	124.5	- 8.0	1.49
DK	26	60.0	108.0	118.0	- 8.5	1.41
NG	21	64.0	115.0	126.0	- 8.7	1.50
MS	21	64.0	115.0	126.0	- 8.7	1.50
HS	27	67.0	127.0	140.0	- 9.3	1.61
MMI	25	64.0	117.0	129.0	- 9.3	1.51

TABLE X

PHYSICAL DESCRIPTION OF UNDERWEIGHT SUBJECTS

Subject	Age	Height	Weight	Standard Weight for Height	Percent Deviation from Standard Weight	Surface Area
		inches	lbs	lbs	%	m^2
LL	24	61.0	104.3	117.0	-10.9	1.39
PM	34	60.0	105.0	120.0	-12.5	1.39
CM	40	63.2	111.9	128.0	-12.6	1.47
BHA	32	68.5	127.0	148.0	-14.2	1.62
LD	26	60.0	101.1	118.0	-14.3	1.36
MH	19	67.5	115.2	136.0	-15.3	1.53
AC	27	64.0	108.7	129.0	-15.7	1.45
FK	52	65.9	114.4	138.0	-17.1	1.51
TH	22	60.5	96.0	116.0	-17.2	1.33
BC	28	66.1	109.6	136.0	-19.4	1.48
RR	27	59.0	92.8	116.0	-20.0	1.29
DW	34	59.0	92.8	118.0	-21.4	1.29
DV	22	65.8	94.3	132.0	-28.6	1.36

-16.7 percent for the underweight subjects. The total range of the percent deviation from average body weight was -28.6 percent to +76.4 percent.

The average surface area for the overweight subjects was 1.58 square meters calculated according to the formula: $A = 2.40^{.400} \times H^{.530}$ (Brody, 1945.) The average surface area for subjects of average weight was 1.60 square meters and for the underweight subjects, 1.42 square meters.

Serum magnesium. The magnesium content of serum of overweight women is presented in Table X. The average serum magnesium value for the group was 1.25 ± 0.19 milligrams per 100 milliliters with a range of 0.98 to 1.66 milligrams per 100 milliliters. Values for serum magnesium for women of average body weight are given in Table XI. The average serum magnesium value for the subjects of average body weight was 1.20 ± 0.13 milligrams per 100 milliliters with a range of 0.92 to 1.46 milligrams per 100 milliliters. Corresponding values for serum magnesium for the women of less than average weight are presented in Table XII. The average serum magnesium value for the group was 1.20 ± 0.11 milligrams per 100 milliliters with a range of 1.05 to 1.43 milligrams per 100 milliliters. Statistical analyses by the Fisher "t" test indicated that there were no significant differences in the serum magnesium values for the women who were overweight, of average body weight and underweight.

TABLE X

THE MAGNESIUM CONTENT OF URINE AND SERUM OF OVERWEIGHT WOMEN AND THE DIETARY INTAKE OF MAGNESIUM

Subject	Percent Deviation from Standard Weight	Serum Magnesium	Urinary Magnesium*	Magnesium in the Diet
	%	mg/100ml	mg/hr	mg/day
MG	+76.4	1.10	3.55	131
OA	+69.9	1.12	3.02	168
FG	+43.1	1.36	1.42	285
AG	+36.5	1.14	2.37	231
ES	+31.2	0.98	2.14	57
BHO	+29.9	1.40	2.15	342
SR	+26.0	1.39	2.92	292
DS	+24.4	1.41	2.35	176
PS	+24.3	1.28	0.74	266
BP	+24.0	1.15	0.62	219
DM	+22.7	1.04	3.53	225
MGL	+21.7	1.17	3.17	211
MA	+21.3	1.66	3.92	150
Average		1.25	2.45	212
Standard Deviation		± .19	± 1.13	± 75

* Urine sample; one hour; subject in fasting state.

TABLE XI

THE MAGNESIUM CONTENT OF URINE AND SERUM OF AVERAGE WEIGHT WOMEN AND THE DIETARY INTAKE OF MAGNESIUM

Subject	Percent Deviation from Standard Weight	Serum Magnesium	Urinary Magnesium*	Magnesium in the Diet
	%	mg/100 ml	mg/hr	mg/day
MD	+14.3	1.46	1.99	329
MW	+13.1	1.15	3.07	345
CR	+11.0	1.16	5.17	494
JM	+10.2	1.18	0.90	247
JR	+ 8.2	1.28	4.22	248
BB	+ 5.7	1.10	2.44	274
II	+ 4.8	1.22	2.32	296
DC	+ 4.7	1.13	1.87	187
EW	+ 4.6	1.35	2.05	245
HA	+ 3.9	1.39	1.59	189
PA	+ 3.8	1.24	1.50	296
AR	+ 2.6	1.26	2.86	302
AW	+ 2.4	1.10	1.34	228
MMA	+ 2.4	1.10	1.13	243
WB	0.0	1.07	3.06	153
NM	- 1.0	1.36	2.84	147
PC	- 8.0	1.23	2.88	349
DK	- 8.5	0.92	1.33	184
MS	- 8.7	1.29	1.27	415
NG	- 8.7	1.33	1.78	198
HS	- 9.3	1.02	0.70	209
MMI	- 9.3	1.11	4.92	239
Average		1.20	2.32	264
Standard Deviation		± .13	±1.23	± 85

* Urine sample; one hour; subject in fasting state.

TABLE XII

THE MAGNESIUM CONTENT OF URINE AND SERUM OF UNDERWEIGHT WOMEN AND THE DIETARY INTAKE OF MAGNESIUM

Subject	Percent Deviation from Standard Weight	Serum Magnesium	Urinary Magnesium*	Magnesium in the Diet
	%	mg/100ml	mg/hr	mg/day
LL	-10.9	1.13	0.47	295
PM	-12.5	1.25	3.88	239
CM	-12.6	1.24	2.58	157
BHA	-14.2	1.12	3.04	273
LD	-14.3	1.12	3.58	196
MH	-15.3	1.43	4.04	434
AC	-17.5	1.05	2.44	278
FK	-17.1	1.18	2.10	182
TH	-17.2	1.10	0.63	298
BC	-19.4	1.25	1.48	208
RR	-20.0	1.10	2.55	295
DW	-21.4	1.16	2.39	328
DV	-28.6	1.39	4.79	371
Average		1.20	2.61	273
Standard Deviation		± .11	± 1.28	± 78

* Urine Sample; one hour; subject in fasting state.

The lack of relationship between serum magnesium and body weight is apparent from the scatter diagram in Figure 2 in which blood magnesium is plotted against the percent deviation of body weight from the standard weight. The correlation coefficient for serum magnesium of the subjects and the percent deviation of body weight from standard was 0.048. This indicated that there was not a significant relationship between serum magnesium and body weight.

Possible relationships of serum magnesium and the percent deviation of body weight from standard weight were investigated for the three groups of women as well as for the entire group. However there was not a significant relationship between these two factors for any of the three groups. The correlation coefficients were +0.335, +0.285 and -0.284 for the overweight, average weight and underweight women respectively. There also was no relationship between serum magnesium and surface area for the entire group of subjects or for the three groups of overweight, average weight, and underweight subjects.

A comparison of the serum magnesium values for the 48 women participating in this study with the values of blood magnesium reported by other investigators was

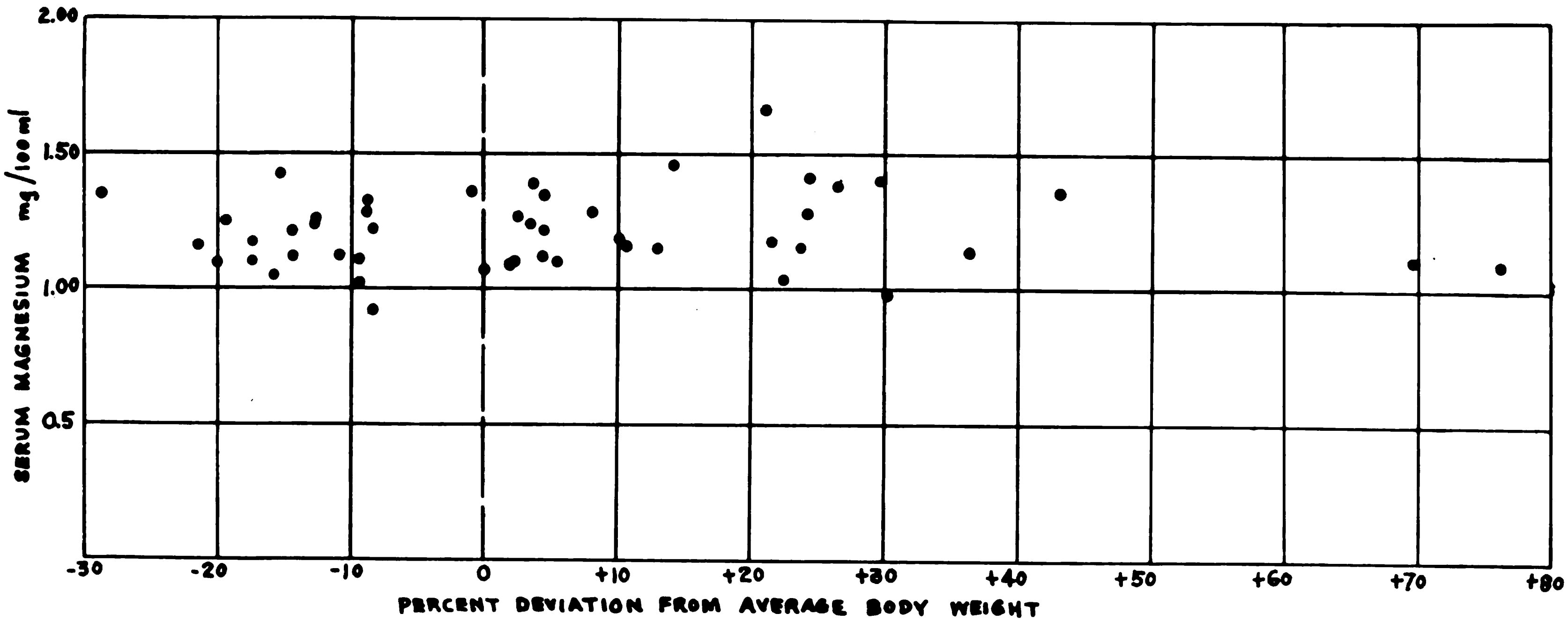

FIGURE 2. GRAPH SHOWING RELATIONSHIP OF BLOOD MAGNESIUM AND THE PERCENT DEVIATION FROM AVERAGE BODY WEIGHT OF 48 WOMEN

made. Blood magnesium values determined by other investigators were presented in Table I and the range of blood magnesium concentration was 0.96 to 3.51 milligrams per 100 milliliters with an approximate average of 2.20 milligrams per 100 milliliters. The fasting serum magnesium values of the 48 women in this study ranged from 0.92 to 1.66 milligrams per 100 milliliters with an average of 1.25 milligrams per 100 milliliters. The fasting serum magnesium values of the 48 women were similar to the lower values for blood magnesium reported by other investigators. However the range of values reported in the literature was greater than the range observed with these subjects. In the investigation of the weekly variations of fasting serum magnesium, no significant changes were observed in the serum magnesium values for three successive weeks. This indicated that the fasting serum magnesium values of women were relatively constant for individuals in a fasting condition over a period of several weeks. In contrast, the daily changes in serum magnesium for three individuals showed individual variations of 0.35, 0.58 and 0.73 milligrams per 100 milliliters. These results suggest that the daily changes in serum magnesium values of individuals are subject to greater variations than the serum magnesium concentrations in individuals who are in a fasting condition. Since many of the blood magnesium values reported in Table I were determined at intervals throughout the day, it might be expected that the published values would vary more widely than the values for serum magnesium which are reported here.

Urinary magnesium. Tables X through XII present the magnesium values of one hour urine collections for the 48 women. The average urinary magnesium excretion was 2.44 milligrams per hour. Table X gives the urinary magnesium values for the overweight subjects. The average value of urinary magnesium was 2.45 ± 1.13 milligrams per hour with a range of 0.62 to 3.92 milligrams per hour. The urinary magnesium values for the subjects of average body weight are presented in Table XI. The average concentration of urinary magnesium was 2.32 ± 1.23 with a range of 0.70 to 5.17 milligrams per hour. Table XII records the urinary magnesium values for the underweight subjects. The average value of urinary magnesium was 2.61 ± 1.28 milligrams per hour with a range of 0.47 to 4.79 milligrams per hour.

The relationship between urinary magnesium and the percent deviation of body weight from the standard weight was investigated. It is evident from the diagram in Figure 3 in which urinary magnesium is plotted against the percent deviation of body weight from standard weight, that there is a lack of relationship between these two factors. The

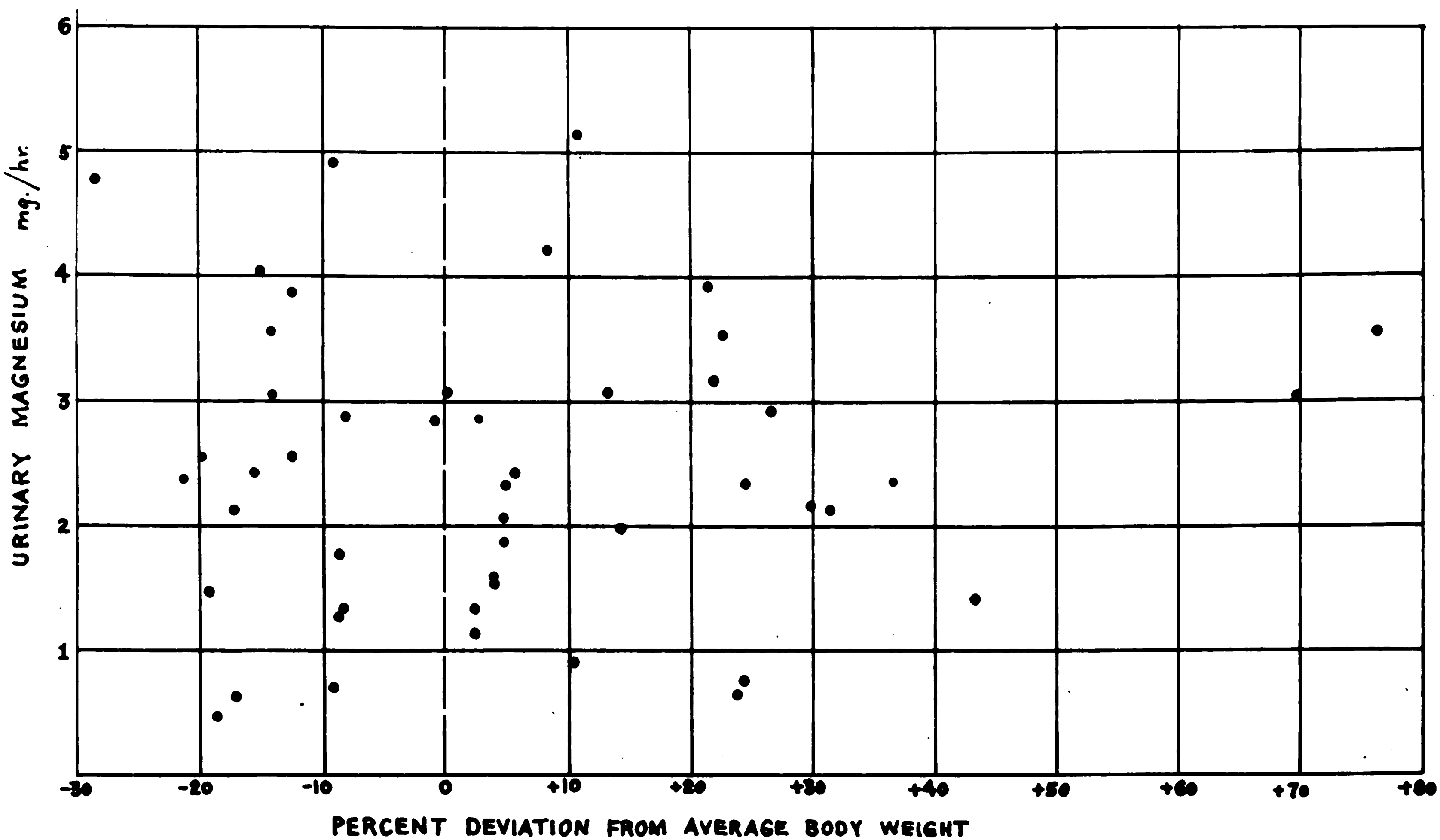

FIGURE 3. GRAPH SHOWING RELATIONSHIP OF MAGNESIUM CONTENT OF URINE AND THE PERCENT DEVIATION FROM AVERAGE BODY WEIGHT FOR 48 WOMEN

correlation coefficient obtained for urinary magnesium of the subjects and the percent deviation of body weight from average was +0.069. This indicated that there was not a significant relationship between urinary magnesium and body weight. The relationship of urinary magnesium and the percent deviation of body weight from standard weight also was investigated in the three groups of women. There was not a significant relationship between these two factors in the overweight individuals, subjects of average body weight and underweight subjects.

Possible differences in urinary magnesium of the overweight subjects, subjects of average body weight and underweight subjects were investigated. According to the Fisher "t" test there was no significant difference in the urinary magnesium excretions of these three groups. These results are in agreement with the results obtained by Brown and Beerstecher (1951) who reported that they found no significant relationship in the fasting urinary excretion of magnesium in 10 overweight and in 10 underweight adult men.

A correlation coefficient of only +0.190 was obtained in the comparison of serum magnesium and urinary magnesium for the total group. This indicated that the relationship between urinary magnesium and serum magnesium was not significant. The relationship of urinary magnesium and serum magnesium for the three groups of overweight, average weight and underweight subjects also was investigated. Figure 4

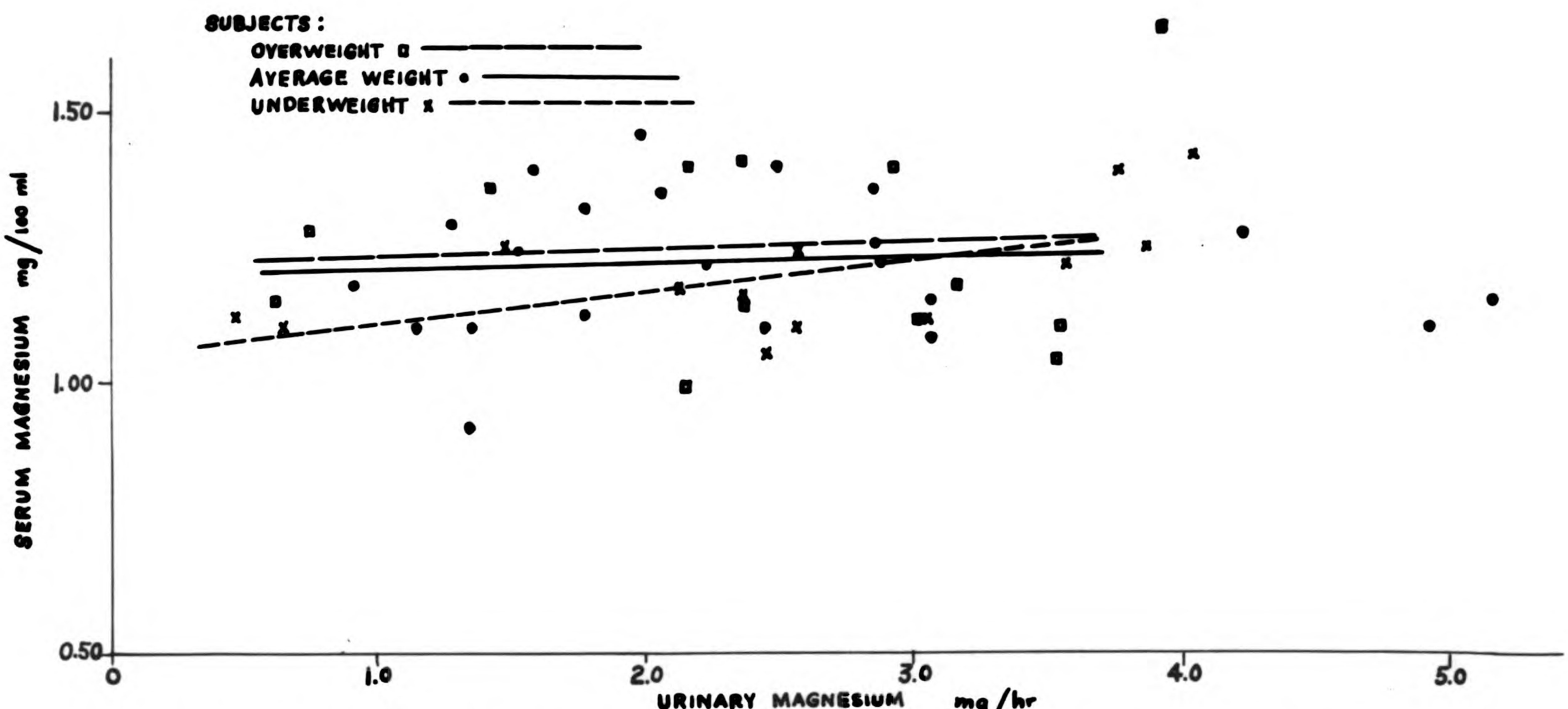

FIGURE 4. THE RELATIONSHIP OF URINARY MAGNESIUM AND SERUM MAGNESIUM FOR OVERWEIGHT, UNDERWEIGHT, AND AVERAGE WEIGHT SUBJECTS

shows the regression of serum magnesium upon urinary magnesium for the three groups. A correlation coefficient of +0.660 (P=0.05) was obtained for the underweight subjects for serum magnesium and urinary magnesium. This indicated that there was a significant relationship between serum magnesium and urinary magnesium in the underweight subjects. A correlation coefficient of +0.083 and +0.050 was obtained for the overweight subjects and the subjects of average body weight respectively between these two factors. Thus there was not a significant relationship between serum magnesium and urinary magnesium in the overweight subjects and in the subjects of average body weight. The latter results tend to support the studies of Berstein and Simkins (1940-41) who found no relationship between blood magnesium and urinary magnesium in normal healthy individuals.

It is of interest that a relationship of serum magnesium and urinary magnesium was observed among the underweight subjects but not among the subjects of average or above average weight. This may be a chance observation; however, it also presents the possibility that the metabolic relationship of serum and urinary magnesium may differ for the underweight individual from that of the individual of average weight or the obese person.

Relationship of dietary magnesium to serum and urinary magnesium. The calculated magnesium content of the diets of overweight women is reported in Table X. The average intake of magnesium was 212 milligrams per day with a range from 57 to 342 milligrams per day. The daily intakes of magnesium of subjects of average body weight are presented in Table XI. The range was from 147 to 494 milligrams magnesium per day with an average intake of 264 milligrams of magnesium per day. Table XII records the magnesium content of the dietaries of the underweight individuals. The average intake of magnesium was 273 milligrams per day with a range from 157 to 434 milligrams per day. The average magnesium intake for the total group was 253 milligrams per day.

Table VI presents the daily magnesium intake of seven individuals of average body weight for three successive weeks. For the first day, there was an average intake of 229 milligrams magnesium. In the estimation of dietary magnesium for one day in the sedond week, an average intake of 263 milligrams per day was obtained, and for one day of the third week, an average intake of 250 milligrams magnesium per day was calculated. Individual variations in dietary intake of magnesium for the three weeks ranged from 36 to 149 milligrams magnesium per day.

There was not a significant relationship between dietary magnesium and serum magnesium for the total group or for

the three groups of overweight subjects, subjects of average body weight and for the underweight subjects. This indicates that serum magnesium concentrations do not vary with the dietary intakes of magnesium.

Daniels and Everson (1936) in a retention study had suggested that urinary magnesium might show a relationship to magnesium intake. However the urine samples of this study were collected over a period of one hour after the subject had been in a fasting condition for at least eight hours. Therefore magnesium intake in this case does not represent the utilization of the daily magnesium intake by the body. There was not a significant relationship between fasting urinary magnesium excretion and dietary magnesium intake (correlation coefficient, +0.016.)

The studies of serum and urinary magnesium which have been presented here have indicated that the magnesium concentration in blood serum is relatively constant. Although variations in serum magnesium from 0.35 to 0.73 milligrams per 100 milliliters of serum were observed for three subjects at different times of the day, these variations are relatively small; moreover, very little variation was observed in fasting serum magnesium for seven subjects for three successive weeks. The range of serum magnesium concentration for the subjects of different body weights was small and no correlation was found between fasting serum magnesium and the estimated dietary intake of magnesium.

These observations suggest that serum magnesium may be maintained at a relatively constant concentration by certain metabolic factors.

Relatively little is known concerning metabolic factors which influence serum magnesium. Cantarow and Trumper (1949) reviewed factors affecting the regulation of serum magnesium and reported that serum magnesium was not greatly affected by the administration of phosphate, protein and vitamin D. The administration of the parathyroid hormone caused a slight increase of serum magnesium. In oxalic acid poisoning, a decrease in serum calcium was associated with an increase in serum magnesium, and in the injection of magnesium salts, an increase in serum magnesium was accompanied by a decrease in serum calcium. It is apparent that there is need of further investigations on the metabolic factors which are involved in magnesium metabolism.

SUMMARY AND CONCLUSIONS

The magnesium content of blood serum and urine of 48 women was studied in relation to body weight. The age range was from 18 to 53 years. All of the subjects were apparently healthy at the time in which they participated in this study.

Fasting blood serum was determined by the titan yellow method of Orange and Rhein (1951.) Urinary magnesium of a one hour urinary excretion, collected by subjects in the fasting state, was analyzed by the method of Garner (1946.) The magnesium content of the diet for the day previous to the collection of blood and urine samples was estimated. The percent deviation of body weight from the average weight was calculated from standard weight, height and age tables.

Of the 48 individuals studied, 13 were 20 percent or more overweight; 13 were 10 percent or more underweight and 22 were within a -10 to +15 percent of their average body weights. The average serum magnesium value for the group was 1.21 milligrams per 100 milliliters. The overweight subjects had an average serum magnesium value of 1.25 ± 0.19 milligrams per 100 milliliters, and the underweight subjects 1.20±0.11 milligrams per 100 milliliters. Statistical analysis by the Fisher "t" test indicated that there were no differences in serum magnesium for the three groups.

The average urinary magnesium excretion for the total group was 2.44 milligrams per hour. The overweight subjects excreted an average of 2.45±1.13 milligrams magnesium per hour; the underweight subjects, 2.61±1.28 milligrams magnesium per hour and the subjects of average body weight, 2.32±1.23 milligrams magnesium per hour. There was not a significant difference in urinary magnesium for the three groups.

No significant relationship was found between serum magnesium and the percent deviation of body weight from the standard weight or between urinary magnesium and the percent deviation of body weight from standard weight for the subjects. A correlation coefficient of 0.660 (P=0.05) indicated that there was a significant relationship between serum and urinary magnesium for the underweight subjects. The relationship of these factors in the individuals of average body weight or for the underweight subjects was not significant. There was not a significant relationship between serum magnesium or urinary magnesium and dietary magnesium for all subjects.

A comparison of the magnesium content of serum of venous and capillary bloods showed no marked differences. A study of the weekly variations of fasting serum magnesium and urinary magnesium for seven subjects demonstrated that there were no significant changes in serum magnesium values or urinary magnesium concentrations for three successive weeks. An investigation of the daily variations of serum magnesium showed that the individual variations of serum magnesium was 0.36, 0.58 and 0.73 milligrams per 100 milliliters.

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