COMPARISON OF TWO DIFFERENT METHODS USED IN PERFORMING FOUR HOUSEHOLD TASKS IN TERMS OF OXYGEN CONSUMPTION

By

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I. INTRODUCTION

Research in human energy metabolism started with the discovery of the gases, oxygen and carbondioxide. Whedon (1959)[1] reports that the significance of respiration in the utilisation of food energy was first demonstrated by Lavoisier. It was Lavoisier who first understood the importance of the chemical identity between the oxidative process happening in a guinea pig, and in the burning of carbon in a candle flame. Lavoisier extended his studies to human beings and in 1789, determined their oxygen consumption at rest, and work. He noted the increases in energy consumption from the ingestion of food and work.

Sherman (1940)[2] points out, "Every act and movement of life involves in terms of physics, a transformation of energy." Cooper et al (1957)[3] states that energy is expended whenever work is performed by the body; regardless of the nature of work whether 'voluntary' such as walking or sitting, or 'involuntary' such as circulation of blood or respiration.

Energy has been defined in numerous ways. Bratton (1959)[4] defines energy as, "Internal or inherent power; capacity of acting, operating or producing an effect whether exerted or not; power efficiently and forcibly exerted; rigorous or effectual operation." Thus any type of action whether performed consciously or unconsciously needs energy.

The energy expenditure of thebody appears in the form of heat. Energy measurements are therefore conveniently expressed in terms of heat, the unit 'calorie'. Sherman (1946)[5] defines the nutritional Calorie as "The amount of heat which raises the temperature of one kilogram of water through one degree centigrade". Energy is also measured in terms of cubic centimeters of oxygen per minute. Bratton (1950)[6] has shown that oxygen consumed is directly proportional to energy expenditure.

Interest in the study of energy expenditure in various activities began to increase sharply during the World War II when nutritional requirement of individuals and energy costs of various industrial and household activities were determined for the British Workers (1959)[1]. The innovation of new techniques to measure energy in terms of oxygen units, solved many of the problems of energy metabolism. They have facilitated studies on energy expenditure, making them versatile and flexible.

Knowles and Elliot (1961)[7] expounds, "the concept of human energy as a resource in management, is the broader concept of energy and not the one of calorie expenditure. Attitudes, interests, skills and physiological conditions of the circulatory and nervous system are the other factors, not covered in the laboratory measurement of energy metabolism". Therefore, while studying the energy cost of household activities, the concept of human energy is always given importance. The energy cost of an activity depends more on how a task is done and not just on the nature of the task performed. In a home, where the homemaker is pressed for time, it is essential for her to have a clear idea of her own limitations of energy.

Devadas (1959)[8] claims, "No profession is so diversified as that of a homemaker." She describes her role as a doctor, nurse, psychologist, banker, tailor, cook, nutritionist, caterer, gardener, governor, educationist, economist, home-manager, companion and social worker. All these jobs make a heavy demand upon her time andenergy. Therefore, she needs to know the methods for effective use and conservation of energy. Goodyear and Khlor (1954)[9] state that conservation of energy means a saving of time and vice versa. Conservation of energy is possible if the homemaker recognizes the demands on her time and energy and organizes her activities accordingly. Simplifying work methods, and evaluating their results will help in conserving energy.

Conservation of energy is one of the goals of the homemakers. Techniques of work simplification help to conserve energy and time.

Research in energy expenditure has been of interest to individuals having many demands on their time and other resources. Knowles and Elliot (1961)[7] point out that this sudden interest has been aroused due to three reasons; household mechanism, increasing number of home-makers taking up outside careers, and the realization of the need to rehabilitate women with physical handicaps such as arthritis and cardiac diseases.

The duties and responsibilities of the home-maker in the present day world have increased tremendously. Besides attending to the normal household chores, they are expected to fulfil many social and normal obligations. The national emergency situation demands that the home-makers do their best for the protection of soldiers in addition to looking after their homes. Home-makers who are members of organisations such as the Mahila Mandals, the Bharat Sevak Samaj and Red Cross and the Panchayats need to manage their energy efficiently.

The energy cost of many of the household activities, show that even heavy tasks demanding considerable energy expenditure can be lightened by employing better techniques and equipment, so that the home-maker can have more time and energy at her disposal to discharge her many responsibilities. Knowledge of the energy costs of the common household tasks will be of great use in planning work and simplifying the monotonous household tasks. Such knowledge is not available in India.

The aim of present study is to find out the oxygen consumption involved in performing four selected household tasks, using the Kofranyi Michaelis Respirometer and Beckman Oxygen Analyser. The study is a comparison of the 'conventional method' of work with an 'improved method' of work for each task. The four common household tasks selected are: (1) cutting a green plantain (2) grinding soaked rice (3) sweeping the floor and (4) rinsing a napkin.

It is hoped that the findings of this study will start a series of investigations into all aspects of energy metabolism in relation to different types of tasks.

II. REVIEW OF LITERATURE

Since the purpose of this study is to compare the energy and time management involved in the performance of selected household tasks by the conventional and the improved method, relevant literature pertaining to the different aspects of home management are reviewed here.

A. Area of home management in home Science:

Devadas (1959)[8] defines Home Science as "education for home living," that science, which correlates scientific facts with the activities in the home. Home Science, touches all aspects of home life. Devadas (1959)[8] states that Home Science imparts, necessary knowledge, about food and nutrition, clothing, housing, household finance, health, child-care, home decoration and community service. Home management is one of the very important and integral parts of home science which embraces the above aspects. According to Malone and Malone (1958)[10] the concept of home management centres its attention on family life as a whole. Gross and Crandall (1947)[11] state that "management takes place in every home, but the quality differs."

B. The Meaning of Management:

Mc Farland (1958)[12] defines management as "the basic integrating process of the business, activity that surrounds daily life". He has also reported that management has existed ever since human beings have united for economic and social purposes, it is only since 1900 that management has evolved as a special field of study and as an explicitly identified area of human behaviour. Riebel (1960)[13] considers that management is not a thing apart but is basic and applicable to all area of family life. According to Mc Forland (1958)[12] management principles were discovered and not invented. Though the management principles have existed all along, the awareness came later. He further stresses that management is the keynote of all business activities, and one of the avenues of social progress. Management is dynamic and sensitive to the currents of inevitable social change.

The principles of management can be applied everywhere. In a home where a home-maker has to work from dawn to dusk, a consciousness to apply management principles is essential. Gross and Crandall (1954)[14] assert that conscious home management is an art. Stressing the importance of home management in the home, Gross and Crandall (1954)[14] declare that "home management to a greater extent than many other fields of subject matter, cuts across different areas of living, for it is concerned with the way in which a family uses all its resources". According to Devadas (1959)[8] home management consists of making the best use of the available resources both human and material. Management in the home includes management of money, materials, energy, skill and abilities. Hoyt (1949)[15] considers that "one buys the quality of one's life with one's time, energy and money". Good Year and Khlor (1954)[9] have emphasized the important relationship of resources to the process of realizing values and goals, through the effective use of human and material resources. Managing means having control over resources, to organize, guide and direct their use and be responsible for the results that follow.

C. <u>Family Resources</u>:

According to Malone (1958)[10], the need for management arises whenever there are resources to be used and choices to be made on how to use them. Gross and Crandall (1954)[14] classify resources available to a family, under two categories: human and non-human. The human resources include time, energy, interests, abilities, skills, knowledge and attitudes; and non-human resources include money, material goods and community facilities. They further claim that these resources become important in proportion to the extent they are limited. The inevitability of these limitations must be accepted. Riebel (1960)[13] clarifies that resources are interrelated but limited; for example: the relationship between energy and time. Malone (1958)[10] states that home management requires more human resources than any other type of management. The home-maker is the guiding spirit in the home. She carries out all her duties and responsibilities for the alround development of the family. Hence, the manner in which she combines her human resources, namely, money and materials, go a long way in making the family happy.

1. Relationship Between Energy and Time:

Energy and time are interdependent. They go together in any task performed. However, the limitations of energy is different from those on time. The amount of energy or the capacity to work, differs from person to person, while the time available to all is the same, that is, 24 hours in a day. Nickell and Dorsey (1960)[16] report that the amount of energy each person has for use, depends on his physical heritage, mental and physical health. Besides - these, physical fatigue and the mental approach of the home-maker towards a certain job also affects the use of energy. Energy and time are required simultaneously in a task performed. By conserving the energy which is frequently wasted through inefficient practices, opportunities for achieving personal family and social goals, can be increased and the monotony in repetitive tasks eliminated.

In order to make working hours more productive, creative and pleasant, the home-maker should have an idea of the energy cost of the household activities which she performs daily. The energy costs, in terms of calorie expended, show the lightness or severity of a task. Nickell and Dorsey (1960)[16] are of the view that better management of energy will be accomplished if the relationship between energy -

expenditure to the stages of family life cycle, the energy expenditure on the various activities, the importance of rest periods, the role of planning, controlling and evaluating in energy management are understood.

2. Relationship Between Work and Energy:

Pasemore (1956)[17] states that the major components of energy expenditure can be classified under two categories; namely, "Energy at Rest" and "Energy at Work".

Energy at Rest:- The energy needed by the body when it is at complete rest is known as the basal energy requirement or energy at rest. The energy needed for the maintenance and promotion of internal activities is known as the basal metabolic rate. According to Sherman and Landford (1957)[18] "Basal Metabolism is a term often applied to the rate of expenditure of energy by a person awake, lying still at a comfortable temperature and who has taken little of any food during the past twelve or fourteen hours so that little digestion or absorption of food material is taking place at the time of observation (that is, in the 'post-absorptive' state)".

Kilander (1951)[19] defines "Basal Metabolism" as "that amount of energy required to maintain the body functions which continued in operation when the body is at complete rest but not asleep." The internal functions of the body include circulation, breathing, digestion, the maintenance of the normal temperature of the body and the activity of the glands. Sherman (1952)[20] says that the Basal energy metabolism, for a given age and size is used as the starting point for the calculations of the total energy requirement of individuals of different muscular activities, and also as a basis of comparison in Pathological disturbances, or in studies of the influence of age, sex, race or of disturbances or immediate environment. The greater part of the basal heat production is thought to be due to oxidation in the resting tissues, principally in maintaining the tone of the skeletal musceles. In the healthy adult, the basal metabolism depends chiefly upon the intensity of these internal processes, the size, shape and composition of the body.

Benedict (1952)[20] has concluded that basal metabolism of an individual may be considered as quantitatively determined by the total mass of active protoplasm tissue, and the total stimulus to cellular activity existing at the time of the measurement of the metabolism. He says that the factors causing variations in the stimulas to cellular activity are age, sleep, prolonged resting, character of the diet and often the effect of several muscular work.

Factors Affecting Basal Metabolic Rate.

There is a vast literature on the effect of age, sex, body size, growth, nutritional status and race on the basal metabolic rate. Many thousands of individual data have been subjected to statistical analysis and a diversity of conclusions drawn as to the effects of these variables. A brief description of some of these variables in relation to the basal metabolic rate is given below:

Influence of Size, Shape and Body Composition:- Dakshayani et al (1962)[21] has studied the body composition of normal women using Benedict Roth Apparatus. They have enumerated the effects of body composition of the basal metabolic rate of women. Taylor and Macleod (1956)[22] states that due to the great seat of energy exchange in the muscle the individuals of exactly the same weight and height and consequently of the same surface area may still differ in basal metabolic rate.

Influence of Internal Activities:- The work of maintaining the respiration and circulation obviously involves a continuous expenditure of energy. Murlin and Greer (1952)[23] emphasize the close relationship of the heat to energy required for the tissues. For the production of heat the supply of oxygen is needed. A large factor is basal metabolism is the maintenance of muscular tension or tone (Sherman 1952)[20].

Influence of Age and Growth:- Benedict and Talbot(1957)[24] concluded that the basal metabolic rate was greatest between the ages of one and two when expressed in calories per unit of weight or size. Krogh (1952)[25] attributes the regular increase in basal metabolism in infancy to "the development of the muscular system as such and perhaps simply the gradual development of muscle tone." Krishnan (1932)[2] has determined basal metabolic rate for 15 women of two different age-groups, viz., 19 years and 20-21 years. He found that basal metabolic rate was about 5 per cent lower for the women, belonging to the older age group.

<u>Influence of Internal Secretions</u>:- Some internal secretions influence the basal metabolism notably that of thyroid gland, thyroxine, which is quite specifically a regulator of the rate of oxidation in the body, Sherman (1952)[20] Taylor (1956)[22] state, one of the very fascinating fields of modern physiology is that embracing the endocrine glands which deliver internal secretions containing hormones to the blood.

These hormones are very important for the harmonious functioning of the body. The basal metabolic rate is affected by hypo or hyper activity of any of the endocrine glands. For instance, if the thyroid gland becomes over-active, the basal metabolic rate increases and vice versa. Over-activity of the pituitary gland tends to result in a rise of the basal rate (Sherman 1952)[20]. These changes are not usually of very great magnitude and are not nearly as characteristics as those due to abnormal functioning of the thyroid gland and the adrenals. According to Rose (1938)[27] the basal metabolic rate ofhuman beings, has been found to be somewhat low in many cases of subnormal functioning of the pituitary gland or hypophysics.

Specific Dynamic Action of Food:- Atwater, Benedict and Rubner (1952)[28] studied the effects of specific dynamic action of food over basal metabolic rate by means of a respiration calorimeter. They found that the food intake of the individuals affected the basal metabolic rate. Rubner found that each type of food exerted more or less specific influence upon the energy metabolism, so that when the foodstuffs were fed separately, somewhat different energy values were required for the maintenance of body equilibrium. Lusk and his co-workers (1952)[29] investigated the influence of the foodstuffs upon metabolism and called it "specific dynamic action of food".

Influence of Sex:- Benedict and Talbot (1952)[30] have found no difference in the basal metabolic rate of boys and girls of the same age, until they reached a weight of 11 kilograms or a surface area of 0.48 squaremeter. Beyond a weight per kilogram, the body maintains a persistently higher rate which is not apparently due at the early age to greater muscular developments. Taylor (1956)[22] has clearly said that there is not significant difference in basal metabolic rate due to sex hormones. Menstruation has little influence on basal metabolic rate. Other factors affecting the basal metabolic rate are the climatic conditions, and the nutrition status of the subject. Mukherjee and Gupta (1937)[31] after determining the basal metabolic rate of 18 Bengali young men, concludes that low metabolism of Bengali is perhaps due to climatic conditions and nutritional causes. A similar study by Ramanamurthi (1962)[32] has shown that the basal metabolic rate of children was lower when undernourished, than when their nutritional status was improved.

Energy at Work:- The daily activities of life involve muscular work, which necessitates energy expenditure. The energy expended, while maintaining the body in a sitting or standing position, is smaller than while performing more active work such as walking, climbing stairs, or lifting objects.

Langworthy and Barott (1920)[33] studied the energy-expenditure of a subject, while performing some of the household tasks; namely, knitting, darning, sewing, ironing, - dressing an infant, washing towels and sweeping the floor. They found that sweeping and washing were the most strenous activities. Swartz (1933)[34] worked with the selected tasks; paring potatoes sitting and standing and kneeding dough at different heights, and under different conditions thus designating the tasks as "light", "moderate", or "heavy", according to the energy expenditure involved. According to Swartz (1929)[35] running a vacuum cleaner at a speed of 1/2 foot per second required 55.5 calories per squaremeter of the body while running it at a speed of 4 feet per second required 146.3 calories. Gross and Crandall (1954)[14] show that work speedily done, involves higher energy costs than the same work done slowly.

D. Determination of Energy Expenditure:

Nickell and Dorsey (1960)[16] point out that the human body requires certain amount of energy for the maintenance of muscular tension and involuntary body processes such as respiration, circulation, secretion and excretion. This energy, when the body is at rest, is known as resting metabolism. The amount of energy used in performing any task is this resting metabolic rate plus the energy requirement for the task. The difference between the energy output at rest and at work gives the energy expended in the performance of the task. In some studies on energy expenditure with regard to sitting, standing, walking and other tasks, is measured by determining how much oxygen is consumed per minute. The data on oxygen consumption may either be converted to calories per squaremeter of the body area per hour or per kilogram or per pound of body weight per hour.

E. Relationship between Energy Output and Fatigue:

An understanding of the nature and causes of fatigue, its influence on the mental and physical efficiency is essential in handling problems connected with time and energy management. Nickell and Dorsey (1960)[16] state that research in recent years in the fields of physiology and industrial management has given much information on the causes and control of fatigue.

Fatigue manifests itself in two different but closely related forms; i. Physiological fatigue and ii. Psychological fatigue. Physiological fatigue results from feeling of tiredness or feeling of weariness, and decreased capacity of work. Burt (1954)[36] reports that 'feeling tired is a very common experience after strenuous or monotonous work.' - Tiredness is a general feeling of weakness which comes after physical exertion, and exercise, of a wide range of muscles. They indicate that tiredness is the physiological changes resulting from work. Therefore, such feeling of fatigue gives little or no indication of the energy expenditure. Haggard and Greenberg (1954)[37] define physiological fatigue as "incapacity for exertion induced by previous exertion". Physiological fatigue results in bodily changes such as incomplete oxidation of glucose which can be measured through laboratory methods, for determining the lactic content of muscles. Knowles (1946)[38] found that women, who ironed at the standard 31" height, described their feelings as tired or very weary after three hours of ironing and located pains, aches and strains on the back, feet and legs. The same - women, ironing at preferred height described the feelings, as somewhat or rather tired or very weary without many complaints about aches, excepting for two times only.

Much of the fatigue experienced in daily activities is of psychological nature. Bartley (1954)[39] defines such fatigue as, "Fatigue or tiredness is but one of the many reactions of a person as a whole to a situation as he consciously or unconsciously interprets and evaluates it. Fatigue is simply one form of inadequacy to meet the demands the person recognizes." It is expressed in both bodily feelings and aversion to work.

F. Rest Periods in Between Household Work:

Barnes (1954)[40] points out that rest periods are desirable in many types of work, both heavy and light. Nickell and Dorsey (1960)[16] indicate that rest, pauses and wisely spaced periods of work, help to prevent excess fatigue and inefficiency. The reasons are, that rest periods help to increase the amount of work done a day, decrease the variability in the rate of working, and tend to encourage the operated to maintain a level of performance nearer to its maximum. Rest period need not be complete cessation of work. If rest is maximum, the worker lies down and relaxes completely, because reclining requires less expenditure of energy than any other body position. Studies in industries have shown the benefits of including rest periods in the increasing capacity to produce more. Since the home-maker performs a variety of tasks in a single day without any record of her energy output, her needs for rest cannot be visualized. Wisely distributed working hours, interspersed with short rest periods, will increase highly the productivity and maintain the work pleasant, througnout the day.

G. <u>The Managerial Process as Applied to Energy Expenditure</u>:

According to Gross and Crandall (1954)[14], three important elements of energy management are, namely, planning, controlling and evaluating. Planning energy is not as concrete as planning other material resources. Planning energy is blended with planning time, because both are simultaneously needed to do a job. Knowledge of energy costs of the household tasks helps in planning energy so that home-makers can alternate heavy and light tasks avoiding exertion. Bratton (1951)[41] considers "Your own body constitutes your most important item of household equipment." She considers that developing skills in using the body effectively, based on an understanding of how the body functions, will help in controlling energy. Nickell and Dorsey (1960)[16] consider an awareness of one's feelings and attitudes towards fatigue, helps in controlling a work plan in action. Knowledge of the body mechanism is useful in controlling energy in action. They further explain that 'Body mechanics' is a term gradually replacing posture, because it includes the body in motion as well as in standing and sitting. The word mechanics suggests a relationship to the functioning of the body. The principles of body mechanics include keeping parts of the body in alignment considering its centre of gravity, and the object held. Keiser (1962)[42] declares that good posture during work of any kind results in less muscular effort, thus reducing the feeling of fatigue. According to Nickell and Dorsey (1960)[16], the most comfortable body position while working eases the body and relieves strain. They suggest that the leg muscles being - stronger than back muscles, should be used for lifting loads, through the use of "knee-bend" instead of "trunk-bend" or "back bend", and arm muscles instead of wrist and hand muscles.

Balanced rhythmic movements help to avoid strain. Gross and Crandall (1954)[14] state that "rhythmic performance may be defined as the repetition of movement at the same tempo." "What is called the dynamogenic effect is a further explanation of the pleasure of rhythm in reducing energy-cost." Burt (1959)[36] claims "There is fundamental economy in rhythmical performance; in that we get a repetition of the act without necessarily a repetition of the impulse."

H. Methods of Measuring Energy Expenditure:

The history of the measurement of energy-metabolism can be traced to the eighteenth century. Lavoisier, Rubner, Douglas, Pattenkofer, Atwater and Benedict were the outstanding - exponents in the field of energy-metabolism, (Douglas 1956)[43].

Edward Smith (1956)[44] in 1869 designed a portable open-circuit apparatus for experiments on man in which the subject fitted with a valve face piece inspired air through a dry gas meter. The expired air was directed through a bottle containing pumice soaked in strong sulphuric acid to remove water vapour and through a canister where it came into contact with potassium hydroxide solution to absorb carbondioxide. The amount of carbondioxide was ascertained from the gain in weight of the canister. Taylor (1956)[22] refers to Pattenkofer, who in 1859 designed a respiration apparatus, which could accommodate fairly large animal. In 1862, he built a metal lined respiration chamber, in which a man could live with comfort. He - thought that a mask or a mouthpiece and respiratory valve might interfere with the natural breathing of the subject. The chamber was ventilated by fresh air pumped through it, its valve could be varied between 15 and 75 m^3 per hour, and was measured by gas meter. A sample of the air leaving the chamber was passed through sulphuric acid, to remove water vapour, barium hydroxide absorption tubes to remove carbondioxide and a small gas meter to measure the actual volume of the air. The carbondioxide production could thus be determined. Viot in 1875, - used an apparatus designed on similar lines for small animals. Hopper Seyler (1956)[45] in 1894 designed a respiration chamber for man on the same principles as those applied by Regnault and Reiset. The capacity of the chamber was 4.8 m^3 (170 gt)^3 to determine the oxygen consumption as well as the carbondioxide production.

Jaquet in 1903 used an open circuit method in which pure air was drawn by a pump through a chamber of 1.4 m^3 (50 ft) - capacity in which the subjects could sit or lie down. Through a wet gas meter, a small sample of air leaving the chamber at a rate governed by rotating the drum of the meter. The carbon-dioxide and oxygen content could be determined by a Patterson type of apparatus. In 1910 Grafe built a chamber, the sides being fitted into a material in the floor eliminating the door since the whole chamber could be lifted to admit the subject. The main ventilating current was ensured by the mechanical rotation of a wet gas meter. Krough and Linghand constructed in 1920, an open circuit chamber of 2.27 m^3 (80 ft)^3 capacity, which allowed work to be done on a bicycle ergometer.

Rubner in 1894 used the differential principle of Lavoisier and Laplace in his apparatus for classical comparison of the heat given out by a dog, with the heat calculated from the carbondioxide, water output andthe nitrogen excretion of the same dog, thus proving the principle of conservation of energy. This marked the beginning of indirect calculation of the energy output. The respiration chamber of Atwater and Benedict was suitable for experiments of long duration, but information about human energy output could very often be satisfactorily obtained in experiments of short duration. Rose (1938)[27] outlined - briefly the work of Zuntz in the year 1887, on the respiration chamber. He introduced an open circuit apparatus in which the subject breathed through a mouth piece and respiration valves, the expired air being directed through a wet gas meter. As the drum of the gas meter rotated, a gearing on its shaft lowered the outlet tube of a gas burette which had been filled at the beginning with liquid. The original form of this apparatus was suitable only for the laboratory. For field observations, the wet gas meter was replaced by a dry meter which could be carried on the back. This form was used in an extensive series of observations during rest and exercise by Zuntz, Loewy, Muller and Gaspari in the year 1906.

Sherman and Landford (1951)[46] describes the "man in the copper box" in the respiration calorimeter by Atwater, Rose and Benedict, that is, experiments with human subjects which had been developed and brought into successful use. The respiration calorimeter as the name implies, is both for the chemical determination of the oxygen consumed, the carbondioxide expired and water produced in the respiratory exchange. The calorimeter was the direct measurement of the heat given off by the body. The recently developed outfits for measuring energy are portable, adaptable to people of widely varied ages and occupations and less expensive than those that are previously available.

1. Direct Calorimetry: There are two distinctive methods for measuring energy expenditure. One direct, through the use of calorimeter; the other is through indirect calorimetry.

Passmore (1956)[17] points out that the direct calorimetry is easy in theory, although difficult and costly in practice. Direct calorimetry consists of measuring the total energy -

expenditure of the body as heat, and mechanical work by confining the subject to a chamber. Direct calorimetry consists of an air tight copper chamber, large enough for a man to live in without discomfort surrounded by zinc and wooden walls with air spaces between. The chamber is about 7 feet long, and 7 feet wide and 6½ feet high. An opening in front of the apparatus sealed with a glass pane, admits sufficient light for reading and writing. Another small opening is used for passing food and drink, excreta, into and out of the chamber. The chamber is furnished with folding chair and table and ventilated by means of air currents. The carbondioxide and water given off by the subject are removed by circulation.

2. Indirect Calorimetry: Indirect calorimetry is computing the calories through measurement of oxygen consumption. Davidson et al (1959)[47] considers that indirect calorimetry is technically a far simple procedure than the measurement of heat through direct calorimetry. In human physiology, indirect calorimetry has completely replaced direct calorimetry, in the study of energy expenditure. Davidson et al (1959)[47] describes - three types of apparatus that are in general use; Benedict Roth Spirometer, Douglas Bag and Kofranyi Michaelis Respirometer.

The Benedict Roth Spirometer is a closed circuit system in which the subject breathes in oxygen from a metal cylinder about six litres capacity; the expired air passes back through a sodalime canister to absorb the carbondioxide. The cylinder floats in water inside a second cylinder. As the oxygen is consumed, the inner cylinder falls. The rate of the fall of cylinder is recorded on a rotating drum. The Benedict Roth apparatus is widely used in hospital for measuring the "basal metabolism". It is very simple to use and the direct reading of oxygen consumption avoids the need to use a gas analyser. However, the Benedict Roth Spirometer is not portable and can only be used when the subject is at rest either lying or sitting.

Douglas (1956)[43] claims that Douglas bag is simple to operate, readily adaptable to a great variety of conditions with the advantage of portability. The expired air collected is for a period of three to ten minutes. The air in the bag is then passed through a gas meter for analysis of the carbon-dioxide and oxygen contents. Passmore (1956)[17] considers that the Douglas bag is cumbersome and clumsy to use for experiments in the fields and industries, while he regards the Douglas bag method as the simplest and most reliable means of measuring.

Passmore et al (1952)[48] considers that the development by Kofranyi and Michaelis in 1940 of a compact, light, portable calorimeter is a great technical advance. Davidson et al (1959)[47] says - that the Kofranyi Michaelis respirometer being an improved method over the Douglas bag, has facilitated energy management.

The instrument is essentially a dry gas meter, weighing only 4 kilograms, and easily carried on the back of the subject. It measures directly the volume of expired air and at the same time collects small samples of the expired air in constant fractions, namely, 0.3 per cent and 0.6 per cent, available for subsequent analysis.

III. EXPERIMENTAL PROCEDURE

The aim of the study is to compare the oxygen consumed, while performing four selected household tasks by the 'Conventional method' and an 'Improved method'. The Conventional methods meant the methods commonly followed in performing the household tasks. They were arrived at after interviewing and observing a group of home-makers in the Municipal Colony of Coimbatore city. The Improved methods desired for performing the same household tasks were based on the principles of energy, management; keeping the body parts in alignment using muscles in economical ways and taking advantage of gravity (Cross and Crandall 1954)[14] and were expected to be less energy consuming. The selected tasks were: cutting a green plantain, grinding soaked rice, sweeping the floor and rinsing a napkin.

The experimental procedure consisted of:-

A. Selection of the sample.

B. Selection and description of the household tasks.

C. Selection of equipment and tools.

D. Standardization of methods.

E. Conducting the experiments.

A. Selection of the sample:-

The sample selected consisted of sixteen college students of Sri Avinashilingam Home Science College, Coimbatore. They

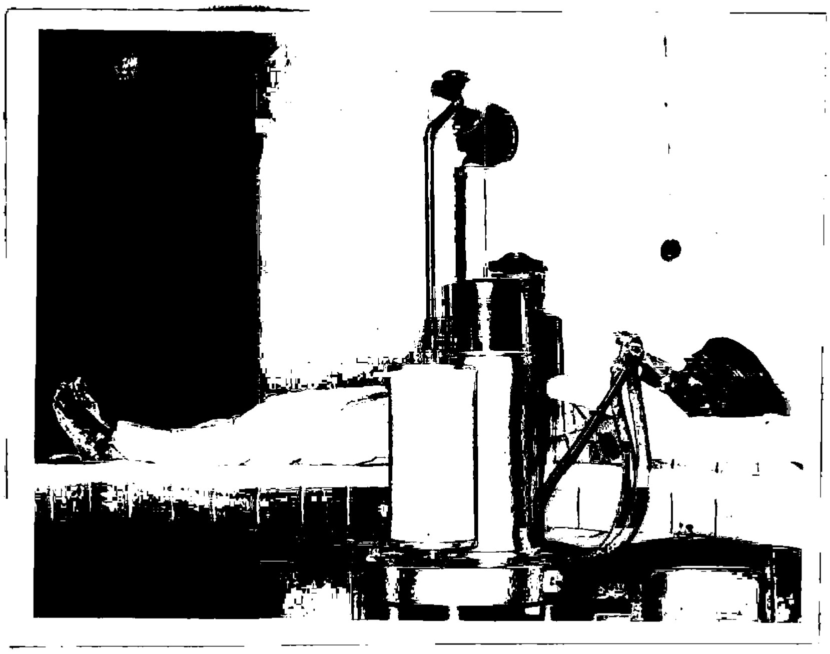

FIGURE 1

BENEDICT ROTH APPARATUS

were normal and healthy individuals, with no tension. Out of the sixteen subjects, three were post-graduates and the rest under-graduates. The age range of the students varied from 17 to 20 years. The height of the subjects varied from 4'9" to 5'4" and their weights from 86 lbs. to 125 lbs. as shown in Appendix I. The "Basal Metabolic Rate" was determined for each subject using the Benedict Roth Apparatus, as in Figure 1. The individual Basal Metabolic Rate data of the sixteen subjects are given in Appendix I. The Basal Metabolic Rate of the subjects ranged from 25.3 to 43.5 square-meter of body surface area per hour according to Aub Dubois Standards.

B. <u>Selection and description of the household tasks</u>:-

The four tasks chosen for the study were (1) Cutting a green plantain, (2) Grinding soaked rice, (3) Sweeping the floor, and (4) Rinsing a napkin, the most commonly performed in all the households interviewed.

Given below is the description of each task:

1. <u>Cutting a Green Plantain</u>:- The vegetable chosen for the cutting experiment was raw green plantain. The plantains for the whole series of experiments were obtained from the same garden in order to eliminate variation. The length and circumference of the plantains were noted before their use for the experiment. The basic cutting procedure in both the methods

consisted of peeling with a sharp knife and slicing the plantains for chips on a wooden board of one inch height. In the process of peeling the skin was removed off the plantain from one end to another, lengthwise. The thickness of the slices was measured using a vernier calipers. The average thickness of the slices was 0.2 cm and the average length and the circumference of the plantain were 6.5" and 2.5" respectively.

a. Conventional method of cutting plantain:

The subject squatted on the floor with a wooden board in front crossing the legs, with the forearms extended as in Figure 2A1. The mean angles formed at the elbow joint were 160° and 130° for the right and left hands respectively as illustrated in Figure 2 A_2.

b. Improved method of cutting plantain:

The subject stood on the floor with no stoop and cut the plantain on a wooden board at a working height of 31.5" as in Figure 3 A_1. The arms were placed over the cutting board. The mean angles formed at the elbow joint, were 160° and 130° for the right and the left arm respectively as illustrated in Figure 3 A_2. With this posture the subject made use of gravity, i.e., the flow of work in the same direction. Nickell and Dorsey (1960)[16] claim that tasks could be made easier by utilizing gravity such as in cutting vegetables down on a board with a knife.

2. Grinding Soaked Rice: The common stone device, named 'Kall-ural' was used for the experiment on grinding. The quality, quantity and the soaking time of rice were maintained constant throughout the grinding experiments. For one experiment on grinding, a cup of rice was soaked in 1½ cups of water for seven hours. The soaked rice was placed around the grinder which was rotated with one hand while the other hand fed the rice into the depression of the 'Kall-ural'. Water was sprinkled from time to time to facilitate grinding and also to get the desired consistancy. Here the principle of rhythm, "As the repetition of movements at the same tempo" was applied. Bratton (1961)[49] reports that the rhythmatic work was less tiring than the non-rhythmic. With this basic procedure for grinding, the 'Conventional' and the 'Improved' methods were employed as described below:

a. Conventional Method of grinding soaked rice:

The subject squatted on the floor, crossing the legs with the right hand extended for feeding the rice into the depression, and the left hand holding the grinder to make rotations as in Figure 4 A_1. The mean angles formed at the elbow joints were 120° and 135° for the right and the left arms respectively as illustrated in Figure 4 A_2.

b. Improved method of grinding soaked rice:

The subject stood on the floor 2" away from the working surface which was at a height of 33.8". Both the hands were extended for grinding as in Figure 5 A_1. The mean angles formed at the elbow joints were 135° and 145° for the right and left arms respectively as illustrated in Figure 5 A_2.

3. Sweeping the Floor:- The sweeping involved the removal of 3/4 cup of sand, spread over a floor area of 76" x 120". A short broom was used for the 'Conventional' method of sweeping, and a broom with a long handle was used for the 'Improved' method of sweeping. Following is the basic procedure, sweeping was done employing the Conventional and the Improved methods as described below:

a. Conventional method of sweeping the floor:

The subject swept the floor using a short broom with trunk bend. The broom was held in the right hand with the left arm extended and resting along the side as in Figure 6 A_1. The mean angles formed at the trunk bend was 90° as illustrated in Figure 6 A_2.

b. Improved method of sweeping the floor:

The subject swept the floor in a standing posture using a broom with a long handle. The broom was held with both the hands, the right hand being at a higher level than the left as in Figure 7 A_1. The right arm formed an angle of 90° at the elbow joint, as illustrated in Figure 7 A_2. There was no trunk bend at all in this method.

4. Rinsing a Napkin:- The process of rinsing consisted of kneading a napkin of 43" x 21" between the palms and dipping in and out of soapy water contained in a wide-mouthed basin. The soap solution was prepared with five cups of water and a teaspoonful of soap powder. The rinsing was done for one minute. Following this basic procedure the Conventional and Improved methods were employed as described below:

a. Conventional method of rinsing a napkin:

The subject sat with a knee-bend with her feet on the floor as in Figure 8 A_1. Angles of 90° were formed at the elbow joints for both the arms, while taking out the napkin from the water in the basin, as illustrated in Figure 8 A_2.

b. Improved method of rinsing a napkin:

The subject rinsed the napkin in a standing posture at a working height of 25.8" as in Figure 9 A_1. The mean angles formed at the elbow joint in both the arms were 90° as illustrated in Figure 9 A_2. According to Bratton (1961)[49], the force can be exerted downwards by the hands more easily and effectively from a right angle bend at elbow than in any other direction.

C. Selection of equipment and tools:-

The equipment and tools needed for performing the four selected tasks, measuring angles, time, room temperature, room pressure and oxygen consumption are described below:

1. Cutting Green Plantain:- The following equipment were selected for cutting Green Plantain.

a. A wooden board of 10" x 8.11" x 1".

b. A stainless steel knife of 7.5" length, 0.11" width with a blade of 4" length, and

c. A pan of 6" diameter and 4" height.

2. Grinding Soaked Rice:- A grinding stone otherwise called 'Kall-ural' with an enamel bowl were the equipment selected for grinding soaked rice. The dimensions of the 'Kall-ural' are given in Table I. The 'Kall-ural' consisted of two parts the upper part the grinder and the lower part the base with the depression into which the grinder fitted.

TABLE I

DIMENSIONS OF THE GRINDING STONE.

Part	Length	Width	Depth	Diameter	Height
1. Base (Square)	21"	16.5"			15"
2. Depression			2.5"	4"	
3. Grinder	13"			3.5"-4.1" (Upper)(Lower)	

3. Sweeping the Floor:- The equipments selected for sweeping the floor were:

A short broom of 28" length, 16" thickness, 385 grams in weight; a long handled broom of 51" length, 19.5" thickness and 705 grams in weight.

Two identical brooms of 28" length were taken and one kept as it was to be used as the short broom for the Conventional method and the other made longer by tying the handle to a slender cylindrical bamboo stock to be used as the long broom for the Improved method.

4. Rinsing a Napkin:- A basin of 18" diameter and 3.8" height was used.

5. Measuring Angle:- An improvised device as described below was used for measuring angles of the arms at the elbow joints. Two thin card-board strips one and-a-half inch broad and one foot long each, were nailed together on one end so that they rotated smoothly in all directions with the nail as fulcrum. While measuring the angle of the arm lift, the moveable device was placed over the arm with the fulcrum over the elbow joint with its two free ends placed along the upper and lower arms of the subject. The angle of the elbow joint was then measured directly on a protractor. Larsen (1961)[50] had used a similar device made of clear plastic protractor to which was fastened a moveable arm for measuring angles formed by the arm lift.

6. Measuring Time:- A stop watch was used to note the time.

7. Measuring Room Temperature:- For measuring the room temperature, a centigrade thermometer was used.

8. Measuring Room Pressure:- For measuring room pressure a Fortin's barometer was used.

9. Measuring Oxygen Consumption:- For determining the oxygen consumption Kofranyi Michaelis Respirometer and Beckman Oxygen Analyser as in Figure 10 used. The various parts of the Respirometer and Analyser are given below:

A. Parts of the Respirometer (Figure 11):-

1. Entry port.
2. Corrugated rubber hose.
3. Exit port.
4. Rubber belt.
5. Valve.
6. Mouth piece.
7. Nose clip.

B. Parts of the Analyser (Figure 12):-

1. Absorbent cotton packing.
2. Drying tube cap.
3. Drying tube.
4. Silica gel desiccant.
5. Aspirator bulb.
6. Aspirator tubing.
7. Aspirator check valve.
8. Instrument case.
9. Shock absorbing packing.
10. Lamp switch.

11. Sample inlet.
12. Sample outlet.
13. Light beam mirrors.
14. Batteries.
15. Protective rubber bulb.
16. Adapter.
17. Sample tubing.

Detailed descriptions of the mechanism and operation of the Kofranyi Michaelis Respirometer and Beckman Oxygen Analyser are given below:

A. Mechanism of Kofranyi Michaelis Respirometer:-

The respirometer consists of two chambers, each chamber is divided into two half-chambers by a moveable partition of leather so that when one chamber is filled, the other is emptied. These partitions transfer their movement over a lever system to a crankshaft 'A' which turns a counting mechanism and controls the sliding valves in that way that the half chambers fill and empty themselves alternately.

The sliding valves are pressed on the valves lids by metal springs "F 1" and "F 2", to remain closed in any position of the meter. The expired air enters by the entry port "AS". In Figure 13, the mechanism for extraction of a sample has been made clear by removing the top cover. It consists of double-membrane pump and 2 air valve sheets. The double-membrane pump "DMP" consists of a metal piece. It shows on both sides basin-shaped cavities, which are covered with membrane rubber. The rubber membranes are tightened to the pump bars "P1", "P2". These again are connected to each other by a metal ring, which is moved by the eccentric piece 'E' on the crankshaft 'A'. The pump can easily be removed by loosening its screw joints. This will be quite useful when replacing new rubber membranes.

The air valve sheets "V V" are made of a self greasing synthetic product. They will be adjusted against each other in the out-phase of the membrane pump by one of the two sliding valves with the help of a push rod in that way, that the membrane pump alternatively sucks air from the entry port and then pumps it into the rubber bladder.

The connecting tubes 'R O 5' between membrane pump and air valve sheets consists of copper tubing and small rubber tubes. These rubber tubes have to be renewed as well as the rubber membrane of the double membrane pump when the rubber, due to deterioration, is worn off.

The direction of air flow from the membrane pump to the rubber bladder is regulated by 2 three-way taps. In the level position of the 'Hal', the route to the exit port 'St' is closed. The air flows through the third way of the tap to the outside. In the vertical position of the tap, the expired air passes into the exit port "St" and fills the rubber bladder. In the level position of the tap "Ha 2" both halves of the -

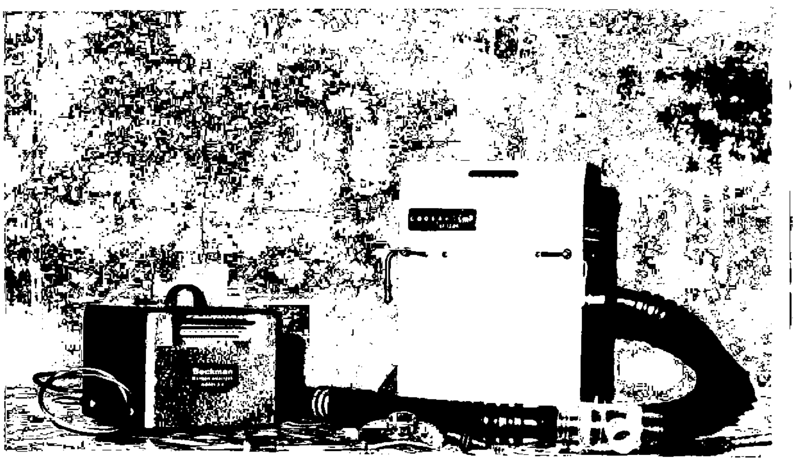

FIGURE-10
KOFRANYI MICHAELIS RESPIROMETER
AND
BECKMAN OXYGEN ANALYSER

double membrane pump fill the rubber bladder (0, 6% take-off) which, having turned the tap in vertical position, only one half is filling the bladder (0, 3% take-off).

Through the transmission of the crankshaft rotation over the toothed wheel 'Z2' on toothed wheel 'Z1' of the counting mechanism, continuous registration of the expired air is made. The counting mechanism with toothed wheel 'Z1' in its position to the crankshaft can be moved into level position.

At the level position of the already mentioned 3 way tap 'Ha 1' the indicator will be moved to the left by a spring pressure of spring 'F 3'. The cog wheel 'Z 1' and 'Z 2' are ~~are~~ unmeshed and no further measurement of expired air takes place. In this position a strip of spring 'F 4' enters the cog wheel 'Z 1' and thus prevent the movement of the counting mechanism. At the level into the vertical position, the cog wheels are again meshed and measurement of expired air starts simultaneously.

This possibility of enmeshing and unmeshing the counting mechanism simultaneously with the opening or closing of the exit port 'St' enables an exact reading of the counter either before or after a respiration test.

The counting mechanism is externally protected by a glass window embedded into the top cover. The misting of this glass window can be avoided by spreading a glycerine

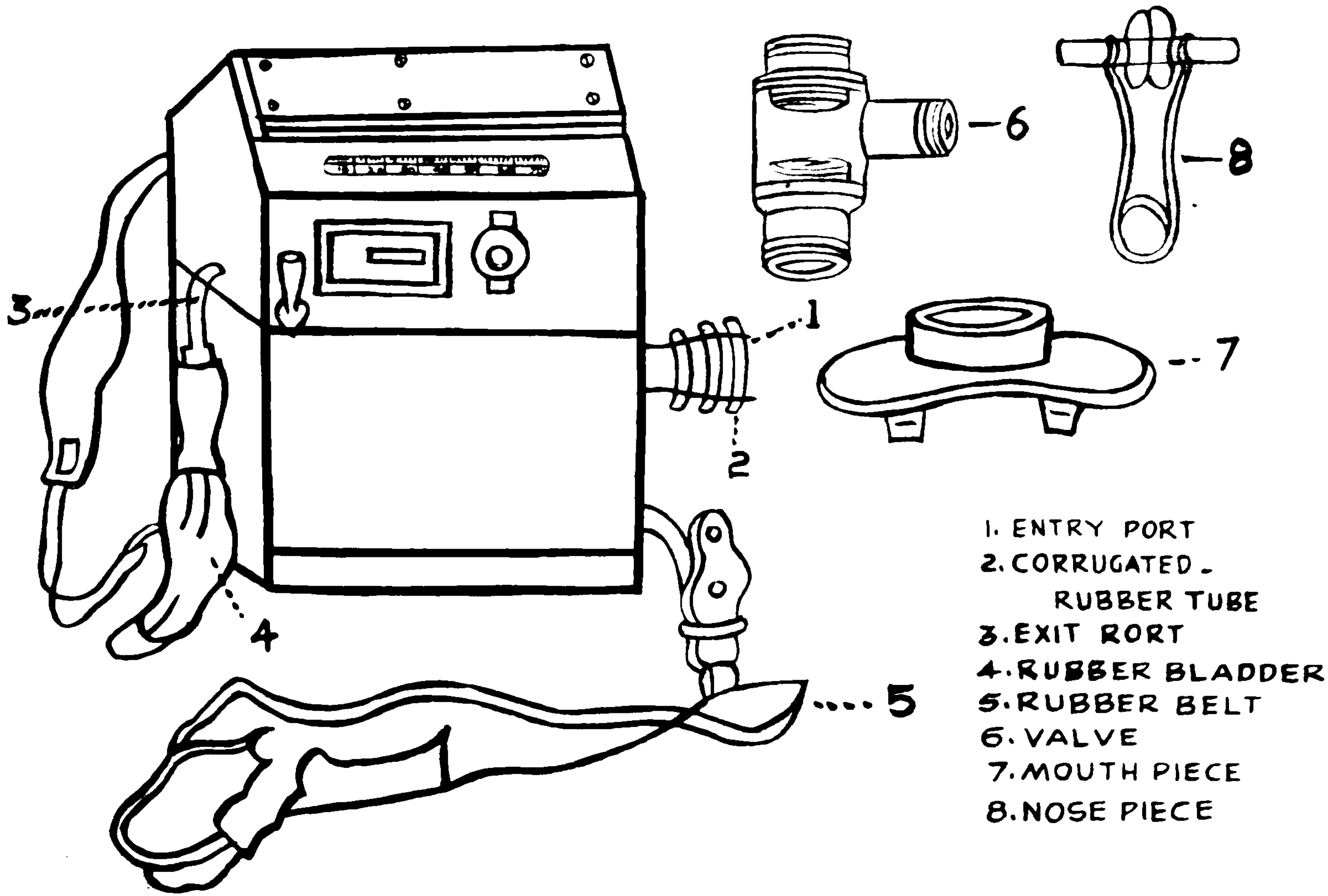

FIGURE - 11

PARTS OF THE RESPIROMETER

vaseline mixture over it. The window can also be removed without affecting the function of the gas meter. Condensed vapour in the gas meter can be poured out of the ports at the end of a test. For the actual meter temperature checking, a thermometer has been built into the top cover of the gas meter.

A plate which is placed on the top cover shows the function of the taps.

The shoulder straps permit a rucksact-like carrying of the gas meter. On account of its position near the centre of gravity and its light weight it will hardly affect the experimenter.

For experiments of long duration in conditions of physical strength especially in hot conditions, it would be advantageous to place a sponge rubber cushion on the back of the meter for better padding.

B. Operation of the Respirometer:-

The operation of the Respirometer involves the following steps:-

1. Saturating the rubber bladder with the expired air for 2 to 3 hours in order to fill in the air spaces of the - bladder, thus preventing diffusion of air.

2. Placing the Respirometer on the back of the subject.

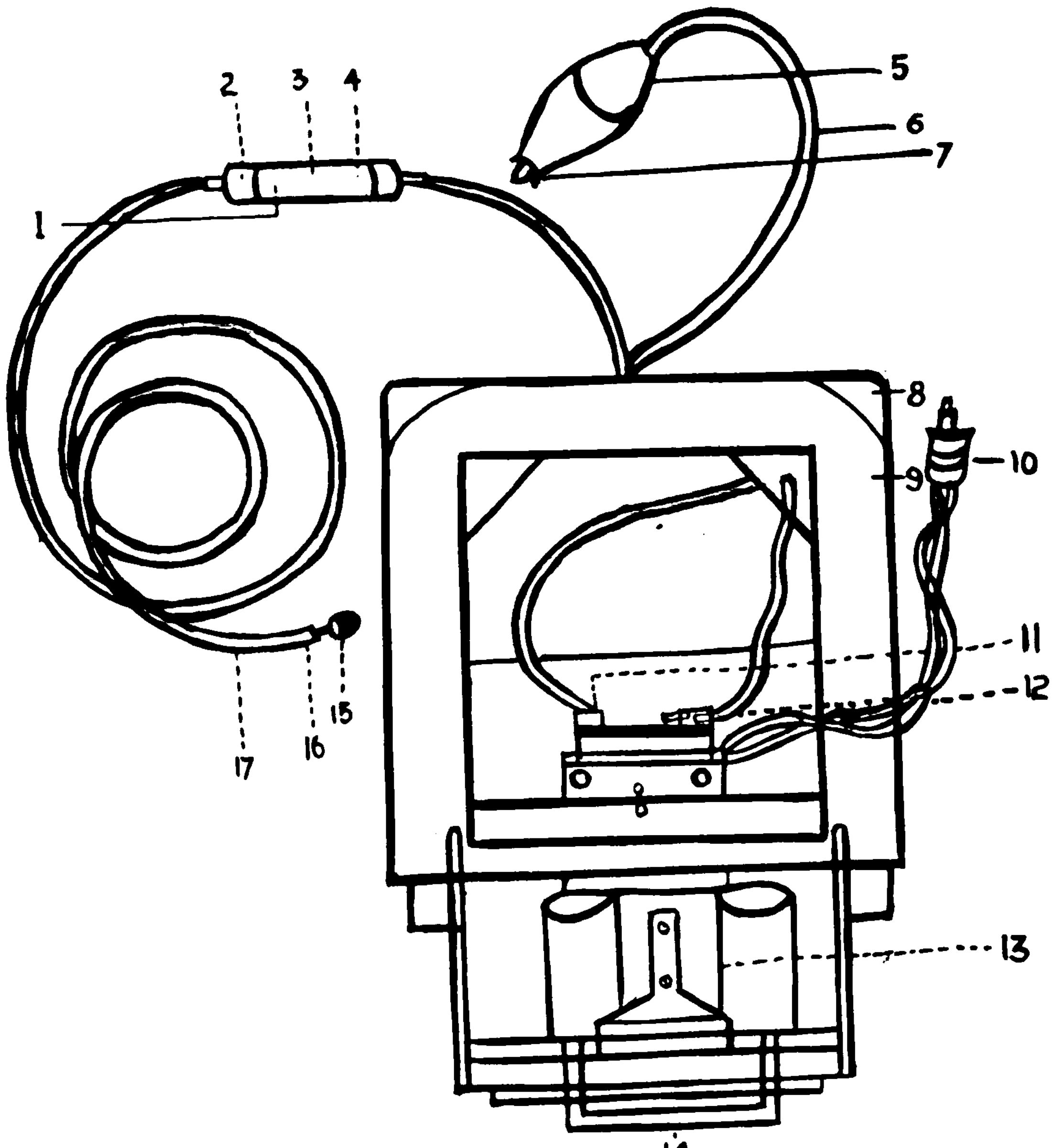

FIGURE - 12

PARTS OF THE BECKMAN OXYZEN ANALYZER

1. ABSORBENT COTTON PACKING
2. DRYING - TUBE CAP
3. DRYING TUBE
4. SILICA GEL DESICCANT
5. ASPIRATOR BULB
6. ASPIRATOR TUBING
7. ASPIRATOR CHECK VALVE
8. INSTRUMENT CASE
9. SHOCK-ABSORBING PACKING
10. LAMP SWITCH
11. SAMPLE INLET
12. SAMPLE OUTLET
13. LIGHT BEAM MIRRORS
14. BATTERIES
15. PROFECTIVE RUBBER BULB
16. ADAPTER
17. SAMPLE. TUBING

3. Attaching the rubber bladder after emptying, to the exit port of the respirometer, with a screw clip on.

4. Fixing the nose clip and mouth piece.

5. Turning the tap on the respirometer (right hand side of the subject) to the position required to extract either 0.6 or 0.3% of the total expired air passing through the meter.

6. Noting down the reading on the meter scale of the respirometer.

7. Turning the tap on the respirometer (left hand side of the subject) to the vertical position.

8. Noting down the time, room temperature and the barometric pressure.

9. Turning the tap to the horizontal position at the end of each test period.

10. Noting down the reading on the meter dial of the respirometer.

11. Removing the nose clip and mouth piece.

12. Removing the rubber bladder after closing it tight with the screw clip.

13. Analysis of the gas contents in the rubber bladder.

14. Removing the respirometer.

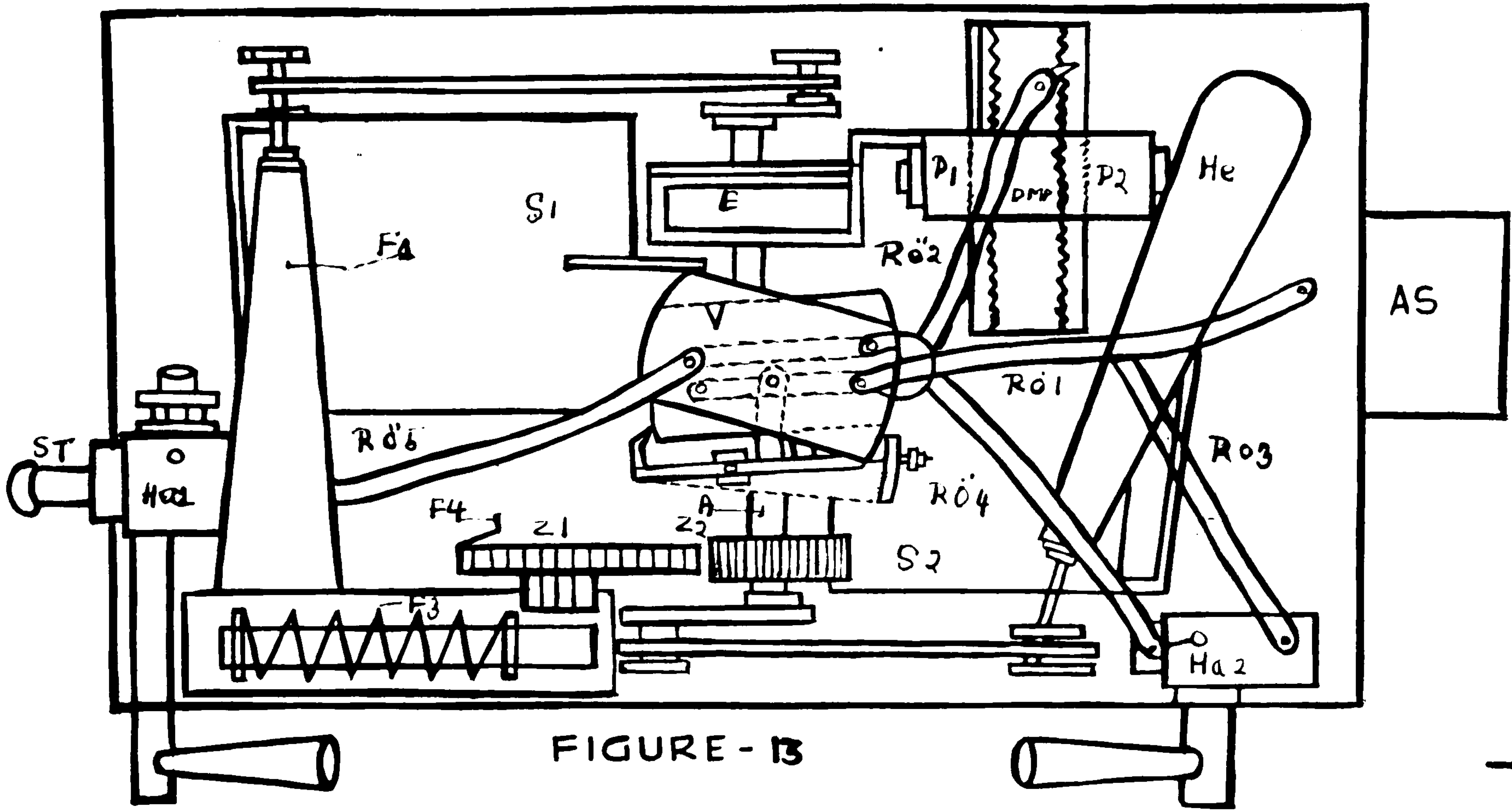

FIGURE - 13

KOFRANYI MICHAELIS RESPIROMETER

15. Cleaning the mouth piece and the nose clip.

A. Mechanism of the Beckman Oxygen Analyser:

Beckman Oxygen Analysers are based on a simple phenomenon - the magnetic susceptibility of oxygen. The susceptibility of oxygen can be thought of as a measure of the propensity of an oxygen molecule to become a temporary magnet when placed in a magnetic field; this is analogous to the effects of a magnetic field of soft iron. The Figure 14 shows the Measuring System of the movement of test body suspended in a magnetic field causes light beam to indicate values on the scale. The heart of the oxygen measuring system is a small glass dumbbell suspended on a taut, durable, quartz fibre in a non-uniform magnetic field as in Figure 15. At the equillibrium the magnetic force on the dumbbell is balanced by the torque of the quartz fiber. When a gas sample containing oxygen is drawn into the test chamber surrounding the dumbbell, the magnetic force is altered. This change in force allows the dumbbell to rotate. The degree of rotation is proportional to the change in force; the change in force is proportional to the partial pressure of oxygen in the sample. A small mirror attached to and rotating with the dumbbell throws a beam of light on the instrument's translucent scale. The position of the light beam on the scale indicates the partial pressure of the oxygen.

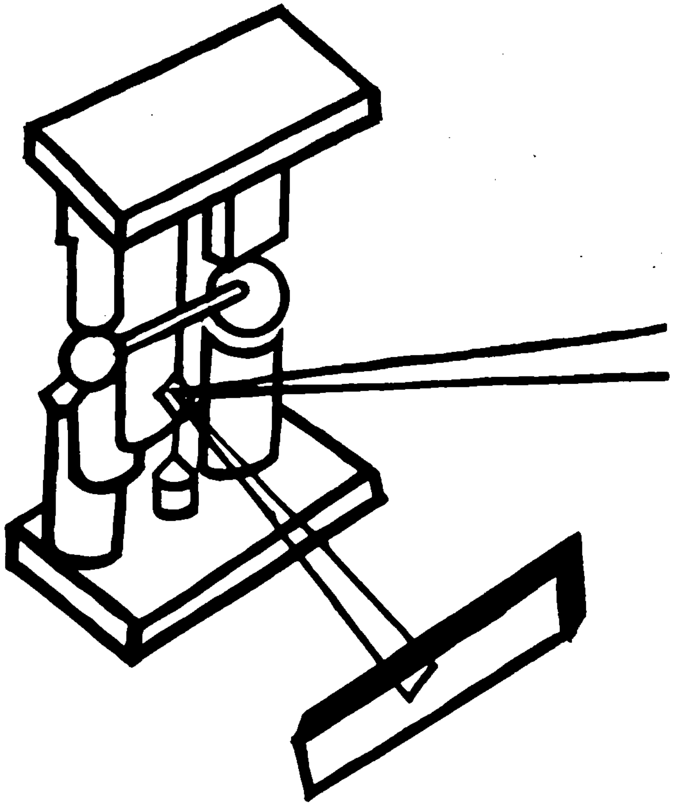

FIGURE 14
MEASURING SYSTEM OF THE ANALYSER

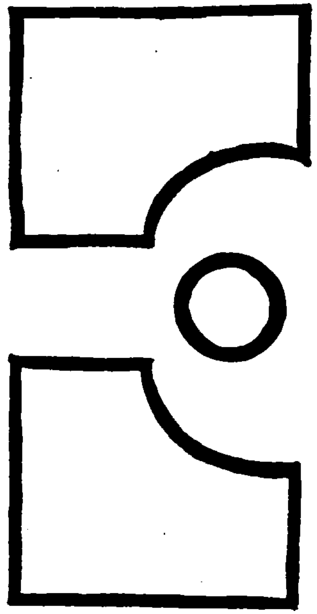

FIGURE 15
VECTOR DIAGRAM OF A SMALL SPHEPR IN A NON-HOMOGENEOUS MAGNETIC FILED

B. Operation of the Beckman Oxygen Analyser:

1. Connecting the rubber bladder to the sampling tube after removing the protective rubber bulb.

2. Loosening the screw clip on the rubber bladder.

3. Pressing and releasing the aspirator bulb till all the air in the bladder enters the analyser.

4. Noting down the percentage reading on the meter scale of the analyser at once.

D. Standardisation of the methods:-

The factors which were common in the Conventional and the Improved methods for cutting green plantain, grinding soaked rice, sweeping the floor and rinsing a napkin were standardised as given below.

1. Cutting a Green Plantain:

a. Holding the plantain in position over the wooden board.

b. Removal of the outer green skin off the plantain from the stem end lengthwise.

c. Slicing the plantain crosswise to give pieces of the same dimensions.

d. Removal of the peels from the board.

e. Leaving the slices in a pan to the right side of the subject.

2. Grinding Soaked Rice:

a. Placing the soaked rice in the grinding stone.

b. Holding the grinder, with the left hand.

c. Rotating clockwise with the left hand and the right hand continuously feeding the rice into the depression.

d. Lifting the grinder and taking out the rice from inside.

e. Sprinkling water once with the right hand during the experiment.

3. Sweeping the Floor:

a. The standing position of the subject.

b. Method of sweeping, ie., the type of swing made by the broom in one direction.

4. Rinsing a Napkin:

a. Holding the napkin.

b. Dipping in and taking out.

c. Kneading the napkin between the palms.

d. Alternating the process of dipping and kneading.

E. Conducting the Experiments:-

The following were the steps in conducting the experiments:-

1. Preparation of the work area.
2. Preparation of the subject.
3. Operation of the respirometer.
4. Performance of the tasks.
5. Analysis of the gas contents in the rubber bladder.
6. Conversion of the data to oxygen units.

1. Preparation of the work area:-

Preparation of the work area meant the placement of the tools needed for a particular task ready for the work.

2. Preparation of the subject:-

Preparation of the subject involved the placement of the respirometer on the back of the subject with the necessary connections; and maintaining the standardised position of the subject for work.

3. Operation of the respirometer:-

The respirometer was operated as described on pages 50 and 52.

4. Performance of the tasks:-

The selected tasks were performed by the subject as described below.

a. Cutting a green vegetable:- For cutting a green plantain the standardised basic procedure as given on page 56 was followed for the Conventional and the Improved methods.

Since a plantain was taken as the standard, six plantains were needed, three for each method. The time taken in cutting a plantain was noted down.

b. Grinding soaked rice:- For grinding the soaked rice the standardised basic procedure as given on page 57 was followed for the Conventional and the Improved methods. The grinding was carried out for one minute and the time was noted. Here, the time was the constant factor.

c. Sweeping the floor:- For sweeping the floor the standardised basic procedure as given on page 57 was followed for the Conventional and the Improved methods. The time taken to sweep the marked floor area was noted down.

d. Rinsing a napkin:- For rinsing a napkin the standardised basic procedure as given on page 57 was followed for both the Conventional and the Improved methods. Since rinsing was done for one minute the time was noted. Here the time was the constant factor.

The above four tasks performed by the Conventional and the Improved methods were repeated three times by each subject and for each method.

5. Analysis of the gas contents in the rubber bladder:-

The gas contents of the rubber bladder were analysed as per procedure given on page 56.

6. Conversion of the data to oxygen units:-

The data were converted to the amounts of oxygen consumed in terms of cubic centimeters per minute using the following formula:

1. Corrected volume of air =

Gas meter reading x Correction factor. (in litres)

2. Corrected volume of air at N.T.P. =

$$\text{Corrected volume of air} \times \frac{273}{760} \times \frac{\text{Atm. pressure in mm.}}{273 + \text{Observed temp.}}$$

3. Correction for oxygen consumption (K) =

$$\frac{\text{No. of mts. the expired air was kept in the rubber bladder} \times 0.04}{\text{Corrected volume of air at N.T.P.} \times \text{Rate at at which the expired air was collected}}$$

4. Corrected volume of oxygen =

Percentage of oxygen in the expired air - K

5. Volume of oxygen consumed =

Percentage of oxygen in the atmospheric air - Corrected volume of oxygen

6. Total oxygen used per minute =

$$\frac{\text{Corrected volume of air at N.T.P.} \times \text{Volume of oxygen used}}{\text{No. of mts. the expired air was kept in the rubber bladder} \times 100}$$

7. Cubic centimeters of oxygen =

Total oxygen used per minute x 1000

The correction factor for the readings of the respirometer was 1.024. The rate at which the expired air was collected in the rubber bladder was 0.6 per cent of the total air. The percentage of oxygen in the expired air ranged between 15 to 17 on the meter scale of the oxygen analyser. The percentage of oxygen in the atmospheric air was taken as 20.97.

IV. RESULTS AND DISCUSSION

The data obtained in the experiment on oxygen consumption for the household tasks performed by the Conventional and Improved methods were compared in relation to (A) Oxygen Consumption (B) Time Management (C) Convenience and Ease of work.

A. Oxygen Consumption

The oxygen consumption for the four selected household tasks is given below:-

1. Oxygen Consumed for Cutting a Green Plantain:- Table II gives the mean oxygen consumption for cutting a green plantain by the Conventional and Improved methods in cubic centimeters per minute.

TABLE II

MEAN OXYGEN CONSUMPTION IN CUTTING A GREEN PLANTAIN BY THE CONVENTIONAL AND IMPROVED METHODS.

Replications	Cubic centimeters per minute			Percentage saving in oxygen consumed.
	Conventional method	Improved method	Difference	
1	398.6	367.6	31.0	7.7
2	378.0	385.0	- 7.0	- 1.8
3	358.4	375.0	- 16.6	- 4.4
Average	381.6	375.8	5.8	1.5

As indicated in Table II, the average amount of oxygen consumed for cutting a green plantain by the Conventional and Improved methods were 381.6 and 375.8 cubic centimeters per minute respectively, with a saving of 1.5 percentage of oxygen consumed in favour of the Improved method although this difference was not statistically significant as presented in Appendix II.

2. Oxygen Consumed for Grinding Soaked Rice:- Table III gives the oxygen consumption for grinding soaked rice by the Conventional and Improved methods in cubic centimeters per minute.

TABLE III

MEAN OXYGEN CONSUMPTION IN GRINDING SOAKED RICE BY THE CONVENTIONAL AND IMPROVED METHODS

Replications	Cubic centimeters per minute			Percentage saving in oxygen consumed.
	Conventional method	Improved method	Difference	
1	473.3	458.5	14.8	3.1
2	471.2	452.4	20.9	4.8
3	481.3	463.9	17.4	4.3
Average	475.2	458.2	17.0	3.6

As indicated in Table III, the average amount of oxygen consumed for grinding by the Conventional and the Improved - methods were 475.2 and 458.2 cubic centimeters per minute -

respectively, resulting in a difference of 17.0 cubic centimeters of oxygen, which was found to be statistically significant beyond one per cent level, as presented in Appendix III. A saving of 3.6 percentage has resulted in favour of the Improved method. Hence, it can be said that the Improved method of standing and grinding over a working height is superior to the Conventional method of sitting on the floor and grinding. It was observed that while grinding in a standing posture, the arms of the subject made use of the principles of gravity without additional strain on the muscles of the arms. Sitting on the floor and grinding caused greater friction and strain on the muscles of the arms as the hands were not able to fall naturally.

3. Oxygen Consumed for Sweeping the Floor:- Table IV gives the mean oxygen consumption for sweeping the floor by the Conventional and Improved methods in cubic centimeters per minute.

TABLE IV

MEAN OXYGEN CONSUMPTION IN SWEEPING THE FLOOR BY THE CONVENTIONAL AND IMPROVED METHODS

Replications	Cubic centimeters per minute			Percentage saving in oxygen consumed.
	Conventional method	Improved method	Difference	
1	605.5	538.9	66.6	10.9
2	588.1	528.6	59.5	10.1
3	614.3	525.3	89.0	14.4
Average	601.1	530.9	70.2	11.6

As indicated in Table IV, an average amount of oxygen consumed for sweeping the floor by the Conventional and Improved methods were 601.1 and 530.9 cubic centimeters per minute respectively, resulting in a difference of 70.2 cubic centimeters of oxygen which was found to be statistically significant beyond one per cent level as presented in Appendix IV. A saving of 11.6 per centage of oxygen consumed has resulted in favour of the Improved method. Hence, it can be said that the Improved method of using the long handled broom is superior to the Conventional method of using a short broom.

4. Oxygen Consumed for Rinsing a Napkin:- Table V gives the mean oxygen consumption for rinsing a napkin by the Conventional and the Improved methods in cubic centimeters of oxygen per minute.

TABLE V

MEAN OXYGEN CONSUMED IN RINSING A NAPKIN BY THE CONVENTIONAL AND IMPROVED METHODS

Replications	Cubic centimeters per minute			Percentage saving in oxygen consumed.
	Conventional method	Improved method	Difference	
1	537.2	448.9	88.3	16.4
2	520.2	429.9	90.3	17.3
3	498.6	465.4	33.2	6.4
Average	518.6	448.6	72.0	13.8

As indicated in Table V, an average amount of oxygen consumed for rinsing by the Conventional and Improved methods were 518.6 and 446.6 cubic centimeters per minute respectively, resulting in a difference of 72 cubic centimeters of oxygen which was found to be statistically significant beyond one per cent level as presented in Appendix V. A saving of 13.8 percentage of oxygen consumed has resulted in favour of the Improved method. Hence, it can be said that the Improved method of standing and rinsing is superior to the Conventional method of sitting on the floor and rinsing.

B. Time Management

The time taken to cut one whole green plantain and to sweep a definite floor area as in the previous chapter were determined for the Conventional and the Improved methods and compared.

1. Time Management in Cutting a Green Plantain:- Table VI gives the mean time taken to cut a green plantain by the Conventional and the Improved methods.

TABLE VI

MEAN TIME TAKEN IN CUTTING A GREEN PLANTAIN BY THE CONVENTIONAL AND IMPROVED METHODS

Replications	Seconds			Percentage saving in time taken
	Conventional method	Improved method	Difference	
1	112.4	120.6	- 8.2	- 6.7
2	114.3	123.6	- 9.3	- 7.5
3	119.3	123.4	- 4.1	- 3.3
Average	115.3	122.5	- 7.2	- 6.2

As indicated in Table VI, the average time taken for cutting a green plantain by the Conventional and Improved methods were 115.3 and 122.5 seconds respectively, resulting in a difference of 7.2 which was found to be statistically not significant even at five per cent level as presented in Appendix VI. A saving of 6.2 percentage of time taken has resulted in favour of the Conventional method of sitting on the floor and cutting.

2. Time Management in Sweeping the Floor:- Table VII gives the mean time taken for sweeping a definite floor area by the Conventional and the Improved methods as given in the previous chapter.

TABLE VII

MEAN TIME TAKEN IN SWEEPING THE FLOOR BY THE CONVENTIONAL AND IMPROVED METHODS

Replica-tions	Seconds			Percentage saving in time taken
	Conventional method	Improved method	Difference	
1	65	43.6	21.4	32.9
2	70	42.6	27.4	39.1
3	75	42.6	32.4	43.2
Average	70	42.9	27.1	38.7

As indicated in Table VII, the average time taken for sweeping a definite floor area by the Conventional and the Improved methods were 70 and 42.9 seconds respectively, resulting in difference of 27.2 seconds which was found to be statistically significant beyond one per cent level as shown in Appendix VII. A saving of 38.7 percentage in the time taken has resulted in favour of the Improved method of using a long handled broom. Hence, the Improved method of sweeping using a long handled broom was superior to the Conventional method of using a short broom.

C. Convenience and Ease of Work

Convenience and ease of work in performing the selected tasks were studied with regard to the Conventional and Improved methods. The subjects were requested to give their opinion regarding the methods followed in order to know whether or not the Improved method meant real improvement for the worker, whose comfort and convenience counted most. The subjects' comments about convenience in the methods of work and the different positions during the experiment were recorded daily.

Table VIII gives the preferences of sixteen subjects for the Improved method over the Conventional method used for performing the selected tasks.

TABLE VIII

PREFERENCE FOR THE IMPROVED METHOD

Task	No. of subjects	Reasons
Cutting a green plantain	15	Convenience and ease of work, large work area for work.
Grinding soaked rice	16	Convenience and ease of work.
Sweeping the floor	12	Absence of physical fatigue due to bending and novelty of the method.
Rinsing a napkin	16	Convenience and ease of work.

As indicated in Table VIII, all the sixteen subjects preferred the Improved method for grinding and rinsing. Out of sixteen subjects, fifteen and twelve preferred the Improved method of cutting and sweeping the floor respectively. For the same activities, one and four subjects respectively preferred the Conventional method for no specific reason.

V. SUMMARY AND CONCLUSION

The purpose of the study was to compare the oxygen consumed for the Conventional and Improved methods used for performing four selected household tasks. The tasks chosen were: cutting green plantain, grinding soaked rice, sweeping the floor and rinsing a napkin. Sixteen college students between 16-20 years of age were selected for the experiment. Kofranyi Michaelis Respirometer and Beckman Oxygen Analyser were used for the measurement of oxygen consumption.

The Conventional and Improved methods of cutting plantain and grinding rice, consisted of squatting on the floor; standing on the floor and working over a height respectively. The working height for cutting and grinding were 31.5" and 33.5" respectively. The Conventional and Improved methods of sweeping the floor consisted of using a short broom and a broom with a long handle respectively. The Conventional method of rinsing consisted of sitting on the floor for work with a knee bend. The Improved method of rinsing consisted of standing on the floor and working over a height of 28.5". The experiments on each activity were repeated thrice for each method and by each subject. The experiments were conducted during evenings after light refreshment.

A summary of the results obtained from the analysed data is given below:

The mean difference in the oxygen consumption between the Conventional and Improved methods for_

i. cutting a green plantain was found to be statistically insignificant even at five per cent level.

ii. grinding soaked rice was found to be statistically significant beyond one per cent level. The Improved method saved 3.6 percentage of the oxygen consumed for grinding.

iii. sweeping the floor was found to be statistically significant beyond one per cent level. The Improved method saved 11.6 percentage of the oxygen consumed for sweeping.

iv. rinsing a napkin was to be statistically significant beyond one per cent level. The Improved method saved 13.8 percentage of the oxygen consumed for rinsing.

Thus from the results summarised above, it is evident that excepting in the case of cutting, the Improved method has proved better than the Conventional method with regard to time utilisation and energy expenditure which is directly proportional to the oxygen consumption in cubic centimeters per minute.

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A P P E N D I C E S

APPENDIX I

INDIVIDUAL DATA OF SIXTEEN SUBJECTS.

No. of Subjects	Age Yrs.	mths.	Height ft.	inches.	Weight lbs.	ozs.	B.M.R. Calories per metre per hour
1	19		5	1½	104	6	38.8
2	16	4	5	4	113		32.2
3	19	1	5	4	102		43.5
4	20		5	2	125		31.04
5	20		5	1	113		31.6
6	19	6	5	½	86		34.65
7	17	1	4	11½	88		35.98
8	17		5	2½	99	11	31.3
9	16	11	4	9	86	5	31.6
10	20		5	1	98	09	29.43
11	17	10	5	2	102	6	32.79
12	19	9	5		102	3	25.3
13	19		5	3	94	11	34.1
14	20		5	1	101	7	31.6
15	19	1	5	1	109		33.2
16	20		5	1	98	6	34.88

TABLE - II

[illegible] OF VARIANCE, COMPARISON OF OXYGEN CONTENT IN [illegible] BY THE [illegible]

[illegible]

Source of variation	Sum of squares	d.f.*	Mean square
Total	6,81,389	95	
Between methods	4,000	1	4,000
Within replicates	62,54,411	64	99,956

F = 0.4018 F_0 0.05 = 3.98 P 0.05

*d.f. means degrees of freedom.

APPENDIX III

ANALYSIS OF VARIANCE, COMPARISON OF OXYGEN CONSUMED IN GRINDING SOAKED RICE BY THE CONVENTIONAL AND IMPROVED METHOD

Sources of variation	Sum of squares	d.f.	Mean square
Total	9,02,731	95	
Between methods	56,250	1	56,250
Within replicates	4,21,344	64	6,583

$F = 8.5$ F_o 0.01 = 7.01 P 0.01

$t = 2.858$ t_o 0.01 = 2.65 P 0.01

APPENDIX IV

ANALYSIS OF VARIANCE, COMPARISON OF OXYGEN CONSUMED IN SWEEPING THE FLOOR BY THE CONVENTIONAL AND IMPROVED METHODS

Source of variation	Sum of squares	d.f.	Mean square
Total	10,55,083	95	
Between methods	5,72,983	1	5,72,983
Within replicates	26,52,000	64	40,430

$F = 14.17$ F_o 0.01 = 7.01   F 0.01

$t = 3.75$ t_o 0.01 = 2.65   P 0.01

APPENDIX V

ANALYSIS OF VARIANCE, COMPARISON OF OXYGEN IN RINSING A NAPKIN BY THE CONVENTIONAL AND IM-PROVED METHODS

Source of variation	Sum of squares	d.f.	Mean square
Total	8,11,800	95	
Between methods	95,833	1	95,833
Within replicates	1,53,334	64	2,395.8

$F = 40$ $\quad F_o$ 0.01 = 7.01 $\quad$ P 0.01

$t = 633$ $\quad t_o$ 0.01 = 2.65 $\quad$ P 0.01

APPENDIX VI

ANALYSIS OF VARIANCE, COMPARISON OF THE TIME TAKEN IN CUTTING A GREEN PLANTAIN BY THE CONVENTIONAL AND IMPROVED METHODS

Source of variation	Sum of squares	d.f.	Mean square
Total	14,142	95	
Between methods	200	1	200
Within replicates	3,251	64	50.7

$F = 3.94$ F_o $0.05 = 3.99$ P 0.05

[illegible]

[illegible]
[illegible]
[illegible]

Source of variation	Sum of squares	d.f.	Mean square
Total	1,[illegible],050	95	
Between methods	7,800	1	7,800
Within replicates	35,050	64	547.6

F = 14.2 F_o 0.01 = 7.01 [illegible] 0.01

t = 3.75 t_c 0.01 = 2.65 [illegible] 0.01