THE ENERGY EQUATIONS:
DEVELOPMENT OF EQUATIONS FOR ESTIMATING ENERGY EXPENDITURE IN HOSPITALIZED PATIENTS

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BY

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To the Provost of the Graduate School:

I am submitting herewith a dissertation written by Carol S. Ireton-Jones entitled "The Energy Equations: Development of Equations for Estimating Energy Expenditure in Hospitalized Patients". I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Nutrition.

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This work is dedicated to my family without whom I could never have come this far. CIJ/88

ABSTRACT

THE ENERGY EQUATIONS:
DEVELOPMENT OF EQUATIONS FOR ESTIMATING
ENERGY EXPENDITURE IN HOSPITALIZED PATIENTS

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AUGUST, 1988

Commonly accepted formulae for estimating energy expenditures are based on data generated from normal volunteers. The applicability of such formulae to hospitalized patients is problematic. A recent advancement in the nutritional care of hospitalized patients has been the clinical application of indirect calorimetry for measurement of energy expenditure. The purpose of this study was to relate easily measured variables to measured energy expenditure (MEE) values of hospitalized patients in an attempt to derive an equation/equations for estimating energy expenditure. Height, age, sex, weight, obesity, ventilatory status, and diagnosis were correlated with the MEE's of 200 adult patients, using stepwise, multiple regression analysis. Two equations were derived:

$$EEE(v) = 1925 - 10(A) + 5(W) + 281(S) + 292(T) + 851(B)$$

$$EEE(s) = 629 - 11(A) + 25(W) - 609(O)$$

Multiple R2 values for the two equations are 0.43 and 0.50, respectively. (EEE = kcal/day, v = ventilator-dependent, s = spontaneously breathing, A= age (years), W = body

weight (kg), S = sex (male=1, female=0), diagnosis of T = trauma, B = burn, O = obesity (present=1, absent=0)}. The equations were tested prospectively on 100 patients. MEE's were not significantly different from EEE(s) or EEE(v) (paired t-tests, $p > 0.25$). Energy expenditures can be accurately estimated in patients using easily obtained data and the above mentioned equations.

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CHAPTER I

INTRODUCTION

Nutritional care of hospitalized patients begins with the determination of calorie requirements. This is important to prevent overfeeding and underfeeding, both of which may have deleterious effects on recovery. There have been several formulae developed for estimating caloric requirements. Foster, et al. (1), has identified 191 different published formulae for predicting energy expenditures. Only a few are consistently used for calculating the calorie requirements of hospitalized patients. The most widely used formulae are those that were developed by Harris and Benedict for estimating the caloric requirements of normal subjects (2). These formulae are usually adjusted using a mathematical factor to provide an estimation of a hospitalized patient's calorie requirements (3,4). Some formulae have been developed for use with specific diseases. The Curreri formula is used for burned patients (5). Other formulae are used for patients with head-injuries (6), obesity (7), bone marrow transplants (8), or various types of cancer (9). These formulae estimate energy expenditures by utilizing pre-established factors to approximate the energy requirements of hospitalized patients. The predictive equations of Harris and Benedict, Fleish, Klieber, Cunningham, and others have been shown to be generally good predictors for normal populations but are unpredictably inaccurate for individuals whose metabolic functions are compromised by illness or injury (10).

Patients requiring intensive nutritional support are often administered calories based on "basal energy expenditures" (BEE's) which are calculated by using the Harris-Benedict equations (2). These equations, which employ age, height, sex, and weight as variables, were derived by performing a regression analysis on measured energy expenditure (MEE) data obtained using normal volunteers. The principle of applying easily measured variables to the calculation of energy expenditure which is embodied in the Harris-Benedict equations, may be suitable for use with hospitalized patients.

Utilization of indirect calorimetry to measure energy expenditures in hospitalized patients is efficacious (3). Bedside indirect calorimetry provides nutritional support clinicians with precise, individualized determinations of energy expenditure (11).

The purpose of this study was to relate easily measured variables (height, weight, age, sex, ventilatory status, and diagnosis) to measured energy expenditure values of hospitalized patients by utilizing multiple regression analysis. This was done to derive an energy equation(s) which would provide an accurate assessment of patient energy needs. A list of the description of terms used in this study is found in Appendix I. The derived equation(s) will provide the clinician with a valuable and accurate tool for assessing the energy needs of hospitalized patients.

CHAPTER II

REVIEW OF LITERATURE

The caloric needs of hospitalized patients have been estimated using several methods, including the Harris-Benedict equations (2). These formulae are used to estimate energy expenditures of hospitalized patients by applying pre-established factors to approximate the various levels of stress or injury (3).

A recent advancement in the nutritional care of hospitalized patients has been the clinical application of indirect calorimetry to the assessment of energy expenditure (11). Indirect calorimetry involves the quantification of energy nutrient requirements by measurements of oxygen consumption and carbon dioxide production (12). Traditionally, the methodology of indirect calorimetry has been cumbersome, however, with the advent of reliable, automated, portable indirect calorimeters, called metabolic measurement carts, rapid and easy measurements can be obtained (11). Indirect calorimetry can be used for an initial nutritional assessment as well as for serial monitoring of energy requirements.

PHYSIOLOGY OF ENERGY EXPENDITURE

The maintenance of body functions is dependent on a constant amount of voluntary and involuntary energy expenditure. This energy is expended for microprocesses such as active transport, the synthesis of macromolecules, and contraction of muscles. The total daily energy expenditure of humans consists of several components, the extent of each varying among individuals. These components include: Basal energy expenditure ("basal metabolic rate"), resting energy expenditure, diet-induced thermogenesis (the "thermic effect of food"), shivering and non-shivering thermogenesis, and energy expenditure used for physical activity (11).

Basal metabolism is defined as the minimal heat production of an individual which is determined twelve to fourteen hours after the ingestion of food and with the individual at complete rest (13). The basal metabolic rate (BMR) is the approximate energy cost of maintaining basic physiologic activities including heartbeat, respiration, kidney function, osmotic balance, brain activity, and body temperature (14). The BMR varies with the size of an individual. Resting energy expenditure (REE) includes the BMR and any increases that occur following awakening and with minimal activity.

The "thermic effect of food" is said to account for from five to ten percent of daily energy expenditure (11).

Diet-induced thermogenesis includes an obligatory process due to the inevitable energy costs of digestion, absorption, and processing or storage of substrates and a component which involves stimulation of the sympathetic nervous system (15). Nicotine and caffeine are the most active thermogenic agents contributing to an increase in energy expenditure (16).

Shivering or "cold-induced thermogenesis" plays a minor role in everyday life. Non-shivering thermogenesis is difficult to demonstrate in adult individuals and therefore is considered to be of little or no consequence in overall daily energy expenditure (17).

Physical activity is the most difficult component of energy expenditure to predict; however, it must be considered (18). The energy costs of many activities have been measured; Girandola and Katch (19) found that the amount of energy expended is proportionate to the rate of sustained muscle contraction.

Energy expenditure is also proportionate to the body surface area and to the percentage of lean body mass (20). Males typically have higher metabolic rates than do females. Energy expenditure is generally depressed during starvation and in chronic dieters and anorexics (21). It is normally increased in people residing in cold climates as compared to those in warmer climates, in the obese, in smokers, and under conditions of stress and disease (3,6,22).

THE HARRIS-BENEDICT EQUATIONS

Patients requiring intensive nutritional support are often administered calories based on "basal energy expenditures" (BEE's) calculated by using the Harris-Benedict equations (2). These equations employ age, height, sex, and weight as variables (Appendix II). The equations were derived using indirect calorimetric measurements of energy expenditures in normal volunteers. A regression analysis was performed relating the subject population's measured energy expenditure, obtained using indirect calorimetry, to their age, height, weight, and sex in order to develop an equation for estimating basal metabolic rate.

The Harris-Benedict equations are appropriate for use with normal populations but their applicability to hospitalized patients is questionable. These equations are not designed for use with children since only adults participated in the original study to develop the equations. The equations also do not take into account the effects that disease, therapeutic intervention, and clinical and nutritional status may have on a hospitalized patient. Often the equations are modified by using a variety of multipliers to account for various levels of stress or injury in order to make them more applicable to hospitalized patients (Table I) (3,23). Multipliers developed to predict the effect of injury or illness on energy expenditure are variable and should only be used as general guidelines.

Table I

Multipliers to Use for Energy Expenditure Calculations

Activity Level*	Factor	Degree of Injury*	Factor
Confined to bed	1.2	a) minor operation	1.20
Out of bed	1.3	b) skeletal trauma	1.35
		c) major sepsis	1.60
		d) severe thermal burn	2.10

*The activity and injury factors are multiplied by the Harris-Benedict equations to determine daily energy expenditure (3).

Studies have shown that the use of these factors as applied to the BEE is not accurate when compared to energy expenditures measured by indirect calorimetry (7,22).

Daly and colleagues (24) studied the accuracy of the Harris-Benedict equations in predicting energy expenditure in healthy adults. Energy requirements were measured using both direct and indirect calorimetry and calculated using the Harris-Benedict equations. Their data showed that there was a mean difference between direct and indirect measures of energy expenditure of 3% and that the Harris-Benedict equations over-estimated measured energy expenditures by an average of 12%. A recent informal study was conducted to determine the clinician's view of the clinical value of the Harris-Benedict equations for estimating energy expenditures in hospitalized patients (25). In general, the Harris-Benedict equations were found to be used in larger institutions, however, such use was often tempered with the clinical judgement of the practitioner.

DETERMINATION OF ENERGY EXPENDITURE EQUATIONS USING NORMAL POPULATIONS AND APPLICATION TO HOSPITALIZED PATIENTS

Standard formulae for estimating energy expenditure including the Harris-Benedict equations, the Klieber formula, and the Mayo Foundation nomogram were developed using normal population groups (26, 27). The multiple correlation coefficients for the Harris-Benedict equations are 0.587 for males and 0.275 for females (28). These statistical representations indicate that 59% of the total variance in energy expenditure can be attributed to the combined variance due to height, weight, and age in healthy males. Only 28% of the total variance in measured resting energy expenditure can be attributed to the combined variance of the same variables in females. These equations were developed using measurements taken from 136 males and 103 females who were healthy normal weight subjects and consequently are most applicable to the population from which they were developed. In a study by Feurer and colleagues (28), both the Harris-Benedict equations and the Klieber formula were found to be inaccurate in predicting energy expenditures of clinically stable hospitalized patients and healthy control subjects. These inaccuracies included both under- and over-estimation of calorie needs in the two populations.

CALORIMETRY

Energy expenditure can be quantified in humans using either direct or indirect calorimetry. These two methods do not measure energy expenditure in the same fashion. Direct calorimetry is the measurement of energy expenditure in the form of heat lost by the body, whereas, indirect calorimetry allows for the assessment of energy expenditure by measuring respiratory gas exchange.

The theory behind calorimetry has been discussed for many years. A review of the history of calorimetry by Feurer and Mullen (11) showed that in the late 1700's Black and Lavoisier used calorimeters to relate oxygen consumption to heat production in animal studies. By the middle of the nineteenth century, BMR was being measured using gas exchange and a respiration chamber for human studies was designed. Rubner (13) performed calorimetric measurements on dogs using both indirect and direct methods and showed the correlation between the two methods. Atwater, Rosa, and Benedict (11) developed a respiration chamber large enough for adults, therefore, initiating some of the landmark studies on the use of indirect calorimetry for the assessment of human energy expenditure. In 1903, they demonstrated the correlation between direct and indirect calorimetry in humans. It was during this same time period that the classic equations of Harris and Benedict were published (2). The work done by these pioneering researchers in metabolism remains useful and standard today.

Direct Calorimetry

Direct calorimetry is used to measure heat production or the total rate of heat loss by the body. Since all types of energy in the body are converted to heat, this can be measured to determine energy expenditure. Direct calorimetry can be used to measure metabolic rate provided that body thermal equilibrium is maintained and no external work is done (29). To determine energy expenditure by direct calorimetry, the subject is placed in a sealed insulated chamber with an oxygen supply. A known volume of water is circulated through a series of pipes located at the top of the chamber. Because the entire chamber is well insulated, the heat produced and radiated by the individual is absorbed by the circulating water. The change in water temperature reflects the individual's metabolic energy release (18). Human energy expenditure was determined by direct calorimetry in classic studies conducted in the early twentieth century (30) using young men who rested or worked in a sealed, insulated chamber. These studies demonstrated that energy expenditure was almost directly related to the consumption of oxygen.

Bradham (31) utilized direct calorimetry to measure the energy expenditure of a burned patient. This was done to determine the quantity and individual variation of energy required during an illness and allowed him to predict the course of his patient's physical condition. Bradham's direct calorimetry technique is difficult to utilize in most burn unit settings because it requires the use of non-mobile, large laboratory equipment. Since direct calorimetry requires the use of a chamber or cumbersome equipment in which the subject is placed for the duration of the study, it is difficult if not impossible to achieve these measurements in a clinical setting where continuous patient care is required. Therefore, this technique is of little use in the routine clinical care of hospitalized patients.

Indirect Calorimetry

Because the first law of thermodynamics can be applied to the human body, the energy released by oxidative processes and by anaerobic glycolysis is ultimately transformed into heat or external work (32). Indirect calorimetry is based on the premise that all energy is derived from the oxidation of protein, carbohydrate and fat and that the amount of oxygen consumed and carbon dioxide produced are characteristic and constant for each fuel. When using indirect calorimetry, heat production (energy expenditure) is determined by measuring oxygen consumption and carbon dioxide production during respiratory gas exchange (12). From those values, energy expenditure can be calculated with the use of the Weir equation (33) or similar equations. Indirect calorimetry is simpler to perform than direct calorimetry and permits individualized determination of energy expenditure (34). A method for performing indirect calorimetry was described by Douglas (12) in 1911 and is still used presently in some clinical settings (35).

Indirect calorimetry may be performed using either of two methods (36). In the open-circuit method, the subject is permitted to breathe air from the environment, while his expired air is collected for volumetric measurement. This gas volume is then corrected for standard conditions and is analyzed for its oxygen and carbon dioxide content, with a subsequent calculation being done to determine oxygen consumption and carbon dioxide production. The closed-circuit method isolates the subject from outside air during the measurement by having him breathing entirely through a closed system. In the closed-circuit system, the subject often breathes from a reservoir containing pure oxygen and as the gas is expired from the subject, carbon dioxide is constantly removed by a material such as soda lime. The decrease in the gas volume in the closed system is related to the rate of the oxygen consumption, from which the metabolic rate is then calculated.

Although the methodology of indirect calorimetry has been cumbersome in the past, the advent of reliable, automated, portable indirect calorimeters, called metabolic measurement carts, now allow for rapid and easy measurement of energy expenditure (37). Some investigators have assembled an indirect calorimetry system from readily available components (38). Although accurate, a laboratory assembled system requires a research setting for validation of the system and for continuous maintenance. There are several instruments commercially available which allow the clinician or researcher to measure oxygen consumption and carbon dioxide production at the bedside. A typical portable indirect calorimeter is called the SensorMedics Horizon System Metabolic Measurement Cart (MMC) (Anaheim, Ca.). It utilizes an open system for measuring oxygen consumption and carbon dioxide production. The MMC is applicable to the clinical setting because it can be easily transported and used at the patient's bedside; both ventilator-dependent and spontaneously breathing patients can be measured; and measurements can be obtained in a minimal amount of time (34).

MEASUREMENT DATA

Measured Energy Expenditure

The measurement of oxygen consumption and carbon dioxide production provides data required for the calculation of energy expenditure. These data are used to calculate measured energy expenditure (MEE) by using the Weir equation. Some metabolic carts may use a modification of the Weir equation to determine energy expenditure from oxygen consumption and carbon dioxide production data (22). A steady state measurement of energy expenditure is determined by measuring three consecutive MEE's which are within ten percent of each other and which have corresponding respiratory quotients that are within five percent of each other. An average of the three values for both the MEE and respiratory quotient is obtained to provide what is considered to be the patient's daily MEE and respiratory quotient.

Respiratory Quotient

Metabolic measurement systems capable of measuring both oxygen consumption and carbon dioxide production also have the advantage of permitting calculation of the respiratory quotient (RQ). RQ has been used to determine the efficacy of nutritional support regimens for hospitalized patients (39). RQ is calculated from the ratio of carbon dioxide (VCO_2) produced to oxygen consumed (VO_2) and reflects net substrate utilization (VCO_2/VO_2) (39). Oxidation of each major nutrient class occurs at a known RQ. An RQ of 0.7 occurs when fat as the primary energy source being oxidized. The RQ's for protein and glucose oxidation are 0.80 and 1.0, respectively. Fat synthesis occurs at an RQ of 8.0 (39). If nitrogen excretion is measured, the nonprotein RQ may be calculated (11). Often urinary nitrogen excretions are not available from which to calculate the proportion of protein used in energy expenditure. Weir (33) analyzed this problem and showed that by employing a formula for calculating energy expenditure and taking into account estimated nitrogen excretion, the resulting error was no more than 2% in both energy expenditure and RQ.

Energy expenditure assessment using indirect calorimetry can be accurately determined under standard conditions. Indirect calorimetry is a useful and accurate technique, and it has been employed to measure energy expenditures in acutely ill patients (30).

APPLICATION OF INDIRECT CALORIMETRY

An understanding of the relationship between energy expenditure and energy requirements is fundamental in clinical nutritional assessment. A recent advancement in the nutritional care of hospitalized patients has been the clinical application of indirect calorimetry to the assessment of energy expenditure (37).

An indirect calorimetric measurement of energy expenditure (MEE) of the sick, hospitalized patient will contain the components of daily energy expenditure and include the BMR, thermic effect of food, and the effect of disease state, stress, and/or trauma (37). MEE should be done under specific conditions so that reliable results are obtained. Patients should be measured when they are awake and two hours after a meal unless they are being provided continuous nutritional support. Measurements should be made at least sixty minutes following strenuous activity such as a dressing change, chest physiotherapy, or physical therapy. When these conditions are met, MEE's may be considered to be reliable, useful assessments of a patients' energy expenditure (10, 22,37).

Indirect calorimetry currently can be an important component of an initial nutritional assessment and can also be used for serial monitoring of energy requirements. Energy requirements in hospitalized patients cannot be accurately predicted using equations developed from healthy individuals (40). Long and colleagues (3) used indirect calorimetry to estimate energy needs of patients suffering from various types of trauma. Patients who had undergone elective surgery, skeletal trauma, or who were suffering from sepsis or burns had their energy expenditures measured using indirect calorimetry and expressed as "percent increases in metabolic rate above normal". All patients' energy expenditures were greater than normal as would be expected. Measurements obtained using indirect calorimetry allowed for a more precise approximation of the patients' energy expenditures than did the Harris-Benedict equations. The authors developed modifications of the Harris-Benedict equations by applying activity and injury factors developed from the percentage increases in energy expenditure noted with varying disease states. In a study by Turner and colleagues (22), measured energy expenditures in burned patients were compared to those calculated using the Harris-Benedict equations and a standard burn formula. The study concluded that neither the Harris-Benedict equation nor the burn formula accurately predicted the measured energy expenditures in the severely burned patients.

The accurate assessment of energy expenditure in hospitalized patients is important, since overfeeding of patients may be as harmful as underfeeding. Glucose, when infused into surgical patients in amounts in excess of 7 mg/kg/min is not oxidized. Rather, it is synthesized into fat, which may lead to hepatic steatosis (41). Also, extra carbon dioxide and fluid loads produced as a result of excess nutrient intake exert deleterious effects in patients with impaired ventilatory function.

One way of assessing patient substrate utilization is by determining the patient's RQ. An RQ greater than 1.0 indicates net fat synthesis. RQ's greater than 1.0 can occur when carbohydrate (glucose) intake or total caloric intake is excessive. The effect is probably a function of high carbohydrate (glucose) intake. Excess caloric intake, especially in the form of carbohydrate, is thought to increase energy expenditure (39). A very low RQ is often seen under conditions of inadequate nutritional support such as hypocaloric feeding of low concentrations of dextrose or in patients who have had prolonged periods of inadequate nutrient intake.

RQ has been used to determine the efficacy of nutritional support regimens for hospitalized patients (39, 41). Intensive nutritional support of hospitalized patients is often administered intravenously, using glucose as the major energy source. In a study comparing RQ's of patients receiving glucose-based parenteral nutrition to those of patients receiving balanced proportions of carbohydrate, protein, and fat (either enterally or parenterally), RQ's greater than 1.0 were noted more frequently in those who received the glucose-based parenteral nutrition (39). This study suggested that fat added to nutritional support regimens containing carbohydrate and protein optimizes substrate utilization.

The use of indirect calorimetry to measure energy expenditures in hospitalized patients is efficacious (2,3,7,10,32,35,36). Bedside indirect calorimetry provides nutritional support clinicians with precise, individualized determinations of energy expenditures. Indirect calorimetry, however, may not be applicable in all patient care situations. Metabolic measurement carts are expensive and require the presence of an experienced technician with a thorough understanding of patient airway management. Other limitations of indirect calorimetry include the following: (a) Many institutions do not have access to a portable indirect calorimeter; (b) some patients cannot be measured using indirect calorimetry; and (c) indirect calorimetry may not be available at all times, necessitating an equation to use in the interim.

It is important that an equation(s) be developed which can be used for estimating energy expenditures in hospitalized patients for whom indirect calorimetry is not available. This could be done by using data obtained via indirect calorimetry and would provide the clinician with a valuable and accurate tool for assessing the energy needs of hospitalized patients. Utilization of easily measured variables, such as height, weight, age, sex, diagnosis, obesity, and ventilatory status would allow for the application of the equation(s) to many different types of hospitalized patients.

CHAPTER III

RESEARCH DESIGN

SUBJECTS

The subject population used for this study consisted of 300 adult male and female patients who were obtaining treatment at Parkland Memorial Hospital (Dallas, Texas). The study did not include children (less than 15 years old) due to the unavailability of equipment to measure their energy expenditures at the institution where the work was done. Subjects were 15 years of age or older and part of a population that was being monitored by the hospital's Nutritional Support Team. Permission to gather and utilize the data from these patients was granted by the director of the Nutritional Support Team (Appendix III, IV). In obtaining data from human subjects, it was necessary to comply with the Human Research Review Committee at Texas Woman's University (Appendix V). All patient data used in this study were referred to by initials only to maintain confidentiality. This study was conducted in accordance with the principles for human experimentation as defined in the Declaration of Helsinki.

PROCEDURES

The development of an energy expenditure equation(s) for use with hospitalized patients was accomplished by dividing the 300 subject population into two groups. Group I consisted of 200 patients and Group II consisted of 100 patients. Data gathered from Group I patients was used in the development of the energy expenditure equation(s), whereas, the Group II patients were used to test the validity of the equation(s) developed from Group I patient data. General data collected from each patient in both groups included the following: Height, weight, age, sex, diagnosis, ventilatory status, and presence or absence of obesity. Patient data were always collected from patients monitored by the Nutritional Support Team and were obtained from the Nutritional Assessment sheet in the medical record.

Obesity was determined to be a current body weight greater than 30% above ideal body weight assessed using the medium frame for reference in the Metropolitan Life Insurance Tables (1959) (Appendix VI). Ventilatory status was determined to be the patient's current mode of ventilation at the time of energy expenditure determination. Diagnoses were made by the primary physician and were obtained from the medical record. Patient diagnoses were considered to be in one of three categories: Burn, trauma, and non-burn, non-trauma. Trauma was defined as a complex injury such as a complicated gunshot wound, stab wound requiring exploratory laparotomy or a head-injury. Patients with all other diagnoses including pancreatitis, diabetes, or cancer were included in the non-burn, non-trauma group.

ENERGY EXPENDITURE METHODOLOGY

Measured and calculated energy expenditure data were collected from each patient in both groups. Energy expenditures were measured using indirect calorimetry. Measured energy expenditures (MEE's) and respiratory quotients (RQ's) were determined using a Metabolic Measurement Cart (MMC Horizon System, Sensor Medics, Anaheim, California). The MMC was used to measure oxygen consumption (VO_2) and carbon dioxide production (VCO_2) instantaneously (Appendix VII). Indirect calorimetry was performed by the researcher (CIJ).

The MMC used an infrared carbon dioxide analyzer and a paramagnetic oxygen sensor. A turbine volume transducer was used for volume measurement. Fully automated calibration procedures and computerized data management were employed for energy expenditure determinations (34). Measurement of gas exchange required that mixed expired air was directed past the gas analyzers and the concentrations of oxygen and carbon dioxide in the expired air were then compared to the concentrations of oxygen and carbon dioxide in the inspired gas. The exact composition of inspired air and the volume (or flow rate) of expired gas were assessed over the measurement period. The key variables measured during the open-circuit indirect calorimetry were: Total expired volume or minute ventilation, the fractional concentration of inspired oxygen (FIO_2) and carbon dioxide ($FICO_2$), the fractional concentration of mixed expired oxygen and carbon dioxide, barometric pressure, the temperature of the mixed expired gas and time. The equations utilized by the MMC for computation of energy expenditure from these values are listed in Appendix VIII. The volume measurement system, temperature sensor, and barometer were calibrated daily. The gas analyzers were calibrated at the bedside before each measurement. Both 100% nitrogen and a calibration gas mixture which approximated the patient's mixed expired air were used during the gas calibration procedures. In this study, patients receiving room air or an inspired air containing 21% oxygen (equivalent to that found in normal room air) were measured after the gas analyzers had been calibrated using a mixture of 16% oxygen, 4% carbon dioxide, and 80% or the balance as nitrogen. Patients receiving an inspired oxygen greater than 21% were usually ventilator-dependent and the calibration gas mixture used consisted of 40% oxygen, 4% carbon dioxide and 56% or the balance as nitrogen.

The MMC was placed in the patients' room at the bedside. The MMC was calibrated automatically prior to each energy expenditure measurement. Patient measurements were achieved using a noseclip and mouthpiece or a mask which covered the nose and mouth, if the patient was breathing spontaneously. Extreme care was taken to ensure a complete seal at the mask cuff throughout the measurement. This was accomplished by securing the mask firmly to a headpiece which holds it in place. Measurements made on patients supported by mechanical ventilators were accomplished by the use of a single-piloted exhalation valve. In both cases, inspired gas was collected to determine the percentage of oxygen in the inspired air. Inspired gas was collected from an inlet on the MMC for room air measurements of spontaneously breathing patients. For measurements of inspired gas in ventilator-dependent patients, an adapter with narrow sampling tubing was placed into the inspiratory limb of the ventilator system on the dry side of the humidifier. Exhaled gas was collected from tubing attached to either the mask or the exhalation limb of the ventilator system to determine expired oxygen and carbon dioxide. As the patient breathed the MMC was used to measure oxygen consumption and carbon dioxide production at one minute intervals. The abbreviated Weir formula was used to determine MEE from these data (34) (Appendix VII). The complete Weir formula was not utilized since no attempt was made to account for the incomplete oxidation of protein.

Measurements of energy expenditure were conducted using the following standard conditions (10):

1. Patients were resting in the supine position (in bed or in a recliner) before the measurement.

2. Patients were without oral dietary intake or intermittent enteral or parenteral feedings for 2 hours before the MEE was determined to avoid the thermic effect of food on the MEE.

3. All sources of supplemental oxygen (nasal cannulas, masks, or tracheostomy collars) were turned off when room air measurements were made.

4. No leaks were present in the system during the measurement period.

The measurement procedure was complete when a steady state was achieved. All data used to derive the MEE were taken during a period of equilibration or "steady state" that had been previously defined according to statistically generated guidelines (42). Equilibrium or a "steady state" was defined as a period of three or more consecutive one-minute measurements having a coefficient of variation for MEE of $\leq 5\%$ and an appropriate average minute ventilation for the patient's size and clinical condition. The measurements were then averaged to obtain the MEE used for estimating the patients' daily energy expenditure. The rate and composition of nutrients being infused on a continuous basis were noted.

Basal Energy Expenditure (BEE) was calculated using the Harris-Benedict Equations (Appendix II).

STATISTICAL ANALYSIS

The MEE was compared to the easily measured variables (height, weight, obesity, age, sex, diagnosis, and ventilatory status) in order to derive an equation(s) for estimating energy expenditure (EEE) in hospitalized patients. Statisticians at the University of Texas Southwestern Medical Center utilized the VAX computer system to generate the statistical analyses. Statistical analysis was done using stepwise multiple regression analysis with MEE as the dependent variable and the other measured data as independent variables (43). The equation(s) for estimating energy expenditure (EEE) which was derived using Group I patients was used prospectively to determine estimated energy expenditures (EEE) in Group II patients. The EEE's were compared to actual MEE's to determine the accuracy of the predictive equation(s) developed. Paired T-tests were used to determine statistical significance of the EEE(s) as compared to the MEE (44).

CHAPTER IV

RESULTS

PATIENT DATA

The goal of this research was to determine which variables (gender, age, height, weight, ventilatory status, and diagnosis) could be used for the development of an equation(s) to predict energy expenditure in hospitalized patients. Patient data related to these variables were collected between 1982 and 1985 and is shown in Appendix IX. When variable distributions were analyzed, no differences were found for gender, diagnosis or ventilatory status between Group I and Group II patients (Table II). Ranges for age, height, and weight were similar between Group I and II patients (Table III).

Group I and Group II patients in the various diagnostic groups were also similar in regards to type and degree of injury. Trauma diagnoses included: Gunshot wound to the femoral artery, spinal fracture with closed head injury, blunt trauma with ruptured spleen, multiple fractures following motor vehicle accidents, and stab wounds. Burn patients, on the average, had suffered burns covering 40% of their body surface areas. Patients who had suffered burns in Group I had an average of 40 $\pm$ 18.5 % of their body

Table II

A Comparison of Variable Distribution Between Group I and Group II Patients

	GROUP I PATIENTS		GROUP II PATIENTS	
	n	%	n	%
SEX				
Males	137	(68)	63	(63)
Females	63	(32)	37	(37)
DIAGNOSIS				
Trauma	47	(23)	23	(23)
Burn	66	(33)	33	(33)
Non-trauma, Non-Burn	87	(44)	44	(44)
Obesity	16	(8)	7	(7)
VENTILATORY STATUS				
Ventilator-dependent	65	(33)	36	(36)
Spontaneously breathing	135	(67)	64	(64)

Table III

Ranges for Age, Height, and Weight for

Group I and Group II Patients

	Group I Patients		Group II Patients	
Variable	Mean	Range	Mean	Range
Age(yrs)	43	(15-80)	41	(14-81)
Height (cm)	171	(141-193)	171	(152-196)
Weight (kg)	69.8	(32-171)	66.4	(32-120)

surfaces areas burned (% BSAB) (mean % BSAB ± SD) while those in Group II with burns had 41 ± 22.6 % BSAB (mean ± SD). Measured energy expenditure was obtained on approximately the eighteenth post burn day. The summary of "non-burn, non-trauma" diagnoses is listed in Table IV.

MEASURED ENERGY EXPENDITURE AND

RESPIRATORY QUOTIENT DATA

MEE'S and RQ's did not vary significantly among the two groups of patients. The mean MEE for Group I patients was 1955 ± 712 kcal/day (mean ± SD) while the mean MEE for Group II patients was 1928 ± 659 kcal/day (mean ± SD). The RQ for Group I patients was 0.89 ± 0.13 (mean ± SD) while the RQ for Group II patients was 0.89 ± 0.15 (mean ± SD).

NUTRITIONAL SUPPORT DATA

Most patients were receiving either enteral nutrition (tube feeding or oral diet), parenteral nutrition (intravenous nutrient intake provided solely as dextrose, amino acids and fat emulsion), or a combination of both. Some patients, however, were not receiving nutritional support at the time of energy expenditure measurement. In Group I, 50% of the patients were receiving enteral nutrition, 37% were receiving parenteral nutrition, 6% were receiving both parenteral and enteral nutrition and 7% were not receiving nutritional support at the time of the energy expenditure measurement. In Group II, 41% of the patients were receiving enteral nutrition, 45% were receiving

Table IV

Distribution of Non-Burn, Non-Trauma Diagnoses
in Group I and Group II Patients

DIAGNOSIS	GROUP I n*	GROUP II n^
unknown	3	10
abdominal dehiscence	1	0
intracranial hemorrhage	6	1
chronic renal failure	4	1
pancreatic pseudocyst or pancreatitis	12	1
COPD	1	0
thigh abscess	1	0
hepatic abscess	1	0
malnutrition, weight loss	2	2
peripheral vascular disease	7	0
alcoholic liver disease	2	0
Crohns disease	1	0
cancer	11	6
multiple decubiti	1	2
pneumonia	1	0
ileus	3	0
home total parenteral nutrition	2	1
bowel resection	1	1
GI bleed, gastric ulcer, perforated duodenal ulcer, or gastrectomy	8	2
extremity amputation	3	1
esophageal varices	1	0
TAH	1	0
hernia repair	1	0
diabetes	1	3
bone flap	1	0
bowel obstruction	4	4
biliary disease	2	0
fistula, colostomy	3	7
appendectomy	1	1
gun shot wound	1	0
congestive heart failure	0	1

* n = 87 ^ n = 44

parenteral nutrition, 7% were receiving both and 6% were not receiving nutritional support at the time of the measurement of energy expenditure.

Caloric intake data were available for 68% of the patients in Group I and 71 % of the patients in Group II. The caloric intake of the patients for whom intake data were available was significantly different between patients in Group I (2216 ± 643 kcal/day (mean ± SD)) and in Group II (1828 ± 912 kcal/day (mean ± SD)).

EQUATION DEVELOPMENT

During the first phase of the determination of the energy expenditure equation, regression analysis was used to: Analyze each variable present in the model, estimate the coefficients, and use the coefficients to predict energy expenditure. The equation to be determined from this research was an empirical model in that there was no theoretical relationship between all of the variables chosen and energy expenditure. The variables: height, weight, age, sex, diagnosis, ventilatory status and presence or absence of obesity were chosen for expediency on the assumption that if all were used then a significant estimate of energy expenditure would be obtained. The equation developed using all of the variables was not adequate to predict energy expenditure reliably in hospitalized patients.

During the second phase of equation development, stepwise multiple regression analysis was used since it was unknown which variables would be important predictors. When Group I patient data were analyzed using MEE values as the dependent variable, a single equation was revealed in which age, weight, obesity, ventilatory status, and presence or absence of burn were the independent variables. However, an inspection of the residuals, from this analysis showed that the proposed "one equation" model would not meet the necessary mathematical assumptions of least squares regression analysis to provide a significant correlation between predicted energy expenditure and estimated energy expenditure. The pattern of the residuals, the amount of over- or under-prediction of energy expenditure by the equation, indicated that the analysis should be done using two equations: One equation being developed for burn patients and another for all others or one equation being developed for ventilator dependent patients and another for all others. An examination of the residuals of the new equations indicated that the mathematical assumptions were tenable only when ventilator dependent patients were separated from all others.

Two equations for estimating energy expenditure (EEE) in hospitalized patients were developed using stepwise multiple regression analysis from Group I patient data. One equation can be applied specifically to ventilator dependent (v) patients and the other can be applied to spontaneously breathing (s)patients. These formulae are summarized as follows:

VENTILATOR-DEPENDENT PATIENTS EQUATION:

$$EEE(v) = 1925 - 10(A) + 5(W) + 281(S) + 292(T) + 851(B)$$

SPONTANEOUSLY BREATHING PATIENTS EQUATION:

$$EEE(s) = 629 - 11(A) + 25(W) - 609(O)$$

WHERE:

EEE = kcal/day

A = age (years)

W = body weight (kg)

S = sex (male=1, female=0)

T = diagnosis of trauma (present=1, absent=0)

B = diagnosis of burn (present=1, absent=0)

O = obesity (body weight greater than 30% above ideal body weight-1959 Metropolitan Life Insurance tables) (present=1, absent=0)

The multiple R-squared values for the two equations are 0.43 and 0.50, respectively, indicating that there is adequate prediction of energy expenditure in a biological system where other non-quantifiable variables may produce effects that cannot be accounted for in a predictive equation.

The energy equations (EEE(v) and EEE(s)) were developed using 200 patients in Group I and validated using a separate, independent set of data determined using 100 patients in Group II. Validation showed no significant difference between Group II patients' observed (MEE) and predicted energy expenditures using the equations for EEE(v) and EEE(s) (paired t-test, $p > 0.25$). The mean differences (MEE minus EEE) were -49 ± 55 kcal/day (mean ± SE) for spontaneously breathing patients and -160 ± 138 kcal/day (mean ± SE) for ventilator-dependent patients.

MEE's for ventilator-dependent and spontaneously breathing patients were compared. Patients who were ventilator dependent were found to have significantly higher ($p<0.001$) MEE's (2349 ± 764 kcal/day) than those of spontaneously breathing patients (1747 ± 564 kcal/day). These results illustrated the usefulness of equations for patients who are divided according to ventilatory status since ventilator-dependent patients tend to have higher measured energy expenditures than do spontaneously breathing patients.

CHAPTER V

DISCUSSION

VENTILATORY STATUS AS A VARIABLE

Differences between the ventilator-dependent patients and spontaneously breathing patients might be expected since mechanical ventilation has been shown to correlate with increased energy expenditures in hospitalized patients (45, 46). Patients dependent on mechanical ventilation have been identified as particularly susceptible to malnutrition (47). These are the individuals who have suffered the most severe injuries (polytrauma, major surgery, etc.) (45). This increased energy expenditure may partially explain why it was necessary to derive a special equation in this study for ventilator-dependent patients.

AGE AS A VARIABLE

In analyzing the variables involved in the prediction of energy expenditure, age is a factor in both EEE(v) and EEE(s). This finding was not surprising since metabolic rate decreases with age (48). Aging has also been associated with the loss of cells by organ systems and a reduction of the cellular metabolism of tissues (49). Data from the Harris-Benedict equations have shown that body cell mass, as a fraction of body weight, decreases significantly with age in both males and females (48). Formulae have been derived for establishing "reference standards" for the calorie requirements of groups utilizing age, weight, and sex (50, 51). In these formulae, older men and women have reduced calorie allowances to account for the decrease in body cell mass and activity that accompanies the aging process (52).

BODY WEIGHT AS A VARIABLE

Body weight was the single best predictor of energy requirements in a study of healthy lean and overweight women (53). However, if the assessment of an individual's energy requirement is based solely on body weight, a considerable error is likely to be introduced because of the effects of other factors (54). This may explain the presence of age and weight as factors in both of the energy equations.

Obesity, in this study, was defined as body weight greater than 30% above ideal body weight as determined using the 1959 Metropolitan Life Insurance tables (55). The 1959 Metropolitan Life Insurance Company standards were used in order to permit comparisons between data gathered in the present study and published data. Furthermore, newer ideal weight standards from Metropolitan have been criticized and consequently were not used. According to a 1985 NIH consensus study on the health implications of obesity, the average weights listed in the 1983 Metropolitan Life Insurance tables could be considered too high for desirable weights (56). While both of the equations developed include a factor for current body weight, the presence of obesity is significant only in the equation for spontaneously breathing patients. The work of breathing is increased if additional weight is carried on the chest wall. It may also be postulated that ventilator-dependent patients are "sicker" than other patients and the metabolic activity of all cells is increased to maintain body functions since EEE(v) does not factor out the presence of obesity.

GENDER AS A VARIABLE

Sex of the patient was a factor in the energy equations only if the patient was a ventilator-dependent male. A possible reason for this gender related difference is that metabolic rate tends to be greater in males than in females (57, 58). Roza and colleagues (48) have re-examined the data gathered in earlier studies, however, and have found no significant differences between men and women when energy expenditure was correlated with body cell mass. In women, body fat occupies a larger proportion of the body weight, while the body cell mass makes up a smaller fraction of body weight. Energy expenditure, therefore, is lower per kilogram of body weight in women than in men. This finding would also relate to the lack of correlation between sex and energy expenditure in spontaneously breathing patients. Therefore body weight especially in regard to the distribution of lean and fat mass may be more correlated with energy requirements than gender.

DIAGNOSIS AS A VARIABLE

Diagnosis groups were labeled empirically as either trauma, burn, or non-burn, non-trauma. Trauma would be expected to increase energy expenditure as was shown in this study because the multiple organ systems are often effected (59, 60). The presence of trauma was associated with an increase in energy expenditure when the patient was ventilator-dependent. Burn injury, which has been identified as the injury that causes the greatest increase in metabolic rate among all disease states (61, 62), was also only associated with an increase in caloric requirement when ventilator-dependent patients were analyzed. The finding that energy expenditures in burned patients may not be as great as was once estimated is similar to previously published data (22, 34, 63). Saffle, et al, (63) and Turner, et al, (22) demonstrated that energy expenditures in burn patients are lower than would be expected when compared to standard burn formulae. In these previous studies, a differentiation between spontaneously breathing and ventilator-dependent patients was not made.

The non-trauma, non-burn diagnoses did not become a factor in either equation. Energy expenditure has been studied in patients with specific diagnoses similar to those found collectively in the non-burn, non-trauma group. These studies have indicated that energy expenditure is not significantly increased due to a specific disease state such as cancer, bowel disease, or spinal cord injury (64-68). Energy expenditures of cancer patients may be increased due to increased protein breakdown, however, this is not a consistent finding (69).

EFFECTS OF NUTRIENTS ON ENERGY EXPENDITURE

An excessive intake of calories has been shown to increase energy expenditure (70). This is usually accompanied by an RQ greater than 1.0 (39). Since the mean RQ's of patients in both groups was less than 1.0, it can be assumed that patients were not being overfed and this did not have an effect on the MEE. Also, caloric intakes were not excessive when compared to MEE's for either group.

EFFECTS OF OTHER FACTORS ON ENERGY EXPENDITURE

Pulse rate and heart rate were not assessed in this study. Pulse rate has been examined previously to determine its applicability in determination of energy expenditure. Dennis and colleagues (71) found no practical clinical use for determining pulse rates of surgical or trauma patients when trying to establish daily resting energy expenditures. Another study examined the relationship between heart rate and energy expenditure in pregnant and lactating women (72). Prediction of energy expenditure from heart rate was unreliable other than in the resting state. Therefore, it would seem that the application of heart rate to the prediction of energy expenditure for a hospitalized patient, especially an intensive care patient who is rarely in a "resting " state, is inadequate.

One study indicated that the energy cost of standardized activities may be higher in Europeans and Americans as compared to Asians and Africans (73). These differences may be due to body build and muscle mass and although not considered by standard predictive formulae, they would be accounted for by indirect calorimetry. Asians, Afro-Americans, Latin Americans, and Caucasian Americans were included in this study population, however, no attempt to account for racial differences was made in this study.

OTHER METHODS OF DETERMINING ENERGY EXPENDITURE

Although most previous attempts to estimate energy expenditure in hospitalized patients have utilized factors which were developed from studies using normal individuals, other more applicable equations have been proposed. Ligget and colleagues (74) predicted energy expenditures in intensive care patients using thermodilution pulmonary artery catheters to determine oxygen consumption. Although accurate in their clinical setting, this technique is applicable to only a small number of patients who have indwelling pulmonary artery catheters. Twenty-four hour urinary creatinine has been correlated with resting energy expenditure measured in normal and clinically stable patients (75). A linear regression was determined relating

24-hour urinary creatinine excretion to measured energy expenditure with a statistically significant correlation. When the equation was tested in compromised patients with increased measured energy expenditures, however, the predictive equation was not accurate (75). The urinary creatinine coefficients used in the study were developed using a nutritionally sound, healthy population and their use in the development of a predictive equation for hospitalized patients is highly questionable. Also, an accurate urine collection is necessary for the efficacy of the equation and that is difficult to obtain even in intensive care patients who are monitored very closely.

INTERPRETATION AND APPLICATION OF THE ENERGY EQUATIONS DEVELOPED IN THIS STUDY

An understanding of the relationship between energy expenditure and energy requirements is fundamental in order to provide an accurate clinical nutritional assessment. Energy expenditure equations are interpreted using guidelines developed following intensive review of indirect calorimetry and energy expenditure, and from clinical expertise gained from experience with the methodology (43).

Guidelines for use of the energy equations have been developed and successfully implemented at Parkland Memorial Hospital. These guidelines are presented as an example and must be assessed for their usefulness within each institution. The energy equations EEE(v) or EEE(s) are used to determine a patient's Recommended Energy Intake (REI). The REI provides for energy expenditure plus any additional energy required to replete body cell mass in adults such as with a repletion regimen. A maintenance regimen is utilized for the nonstressed, inactive outpatient who is in normal nutritional status. Any adjustments upward will be computed for activity only. The BEE (2) may be used in place of the EEE. A maintenance regimen which provides the number of calories predicted by the EEE's is applied for a stressed, inpatient who has a normal nutritional status and a normal or mildly catabolic level as determined by urinary urea nitrogen excretion. A repletion regimen is indicated to provide the energy required for anabolism. A repletion regimen is employed for a stressed, inpatient deemed to be malnourished or who has a severe catabolic level. The REI will be fifty percent above the calculated EEE(s) or EEE(v) (4). Occasionally, a patient will have mixed criteria such as an abnormal nutritional status but a normal catabolic level. In this case, clinical judgement must be used in deciding to increase the EEE by fifty percent.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Two equations were developed which can be used to predict the energy expenditure of hospitalized patients with statistical accuracy. The equation for ventilator-dependent patients includes age, current weight, sex, diagnosis of trauma and diagnosis of burn as variables for prediction of energy expenditure. The equation developed for ventilator-dependent patients showed that 43% of the variance in measured energy expenditure could be explained by the combined variance of the previously mentioned variables. The equation determined for spontaneously breathing patients includes age, current weight, and presence of obesity as the pertinent variables for predicting energy expenditure. Fifty percent of the variance in this equation could be explained using these variables.

Many factors affect energy expenditure. Some of these factors can be accounted for in a predictive equation and some cannot. Indirect calorimetry can be used to develop equations for estimating energy expenditures using easily measured variables (76). The energy equations provide a statistically accurate and practically useful solution to the problem of predicting energy expenditure in hospitalized patients when indirect calorimetry is not available.

MAJOR FINDINGS OF THE STUDY

1) Accurate energy expenditure equations can be developed using indirect calorimetric measurements and easily measured patient data.
2) Energy expenditure can be accurately predicted using these "new" energy equations.
3) Energy expenditures of a wide variety of hospitalized patients can be predicted using the energy equations.

RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the findings of this study, continuing research in the area of the energy expenditures of hospitalized patients is important. Since these equations are the only ones of their kind, future research should include obtaining new patient data for more cross validation of the new equations developed in this study.

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APPENDICES

APPENDIX I

Definition of Terms

DEFINITION OF TERMS

Basal Energy Expenditure (BEE) - the daily amount of energy required to maintain metabolic processes in a resting, fasting, non-stressed, conscious state (kcal/day).

Energy Expenditure - the daily amount of energy required to maintain metabolic processes (kcal/day).

"Ideal" Body Weight (IBW) - optimal weight for a patient based on the Metropolitan Life Insurance Standards, 1959; used to define obesity.

Indirect Calorimetry - determination of measured energy expenditure (MEE) via measurement of oxygen consumption and carbon dioxide production; performed using a metabolic cart.

Intensive Nutritional Support - provision of nutritional requirements by enteral or parenteral infusion.

Metabolic Measurement Cart (MMC) - a portable machine which performs indirect calorimetry and is used to measure energy expenditure (MEE) and respiratory quotient (RQ).

Obesity - body weight greater than 130% of "ideal" body weight (adult).

Ventilator Dependent - breathing assisted or controlled by a mechanical ventilator continuously or intermittently.

For the purposes of this study, the following measurement units will be used:

- Age - expressed in years
- Height - expressed in centimeters
- Weight - expressed in kilograms
- Sex - male or female
- Diagnosis - The patients' primary diagnosis obtained from the medical record entered as one of three categories:
  - Trauma-non-burn injury
  - Burn-percentage of the body surface area with a burn
  - Non-Trauma, Non-Burn-all other non-trauma, non-burn diagnoses, including cancer, diabetes, pancreatitis, etc.

APPENDIX II

The Harris-Benedict Equations

HARRIS-BENEDICT EQUATIONS

Male: $BEE = 66 + (13.8 \times W) + (5 \times H) - (6.8 \times A)$

Female: $BEE = 655 + (9.6 \times W) + (1.8 \times H) - (4.7 \times A)$

Where: BEE = basal energy expenditure (kcal/day)
W = weight (kg)
H = height (cm)
A = age (years)

APPENDIX III

Institution Approval Request

August 3, 1987

Dr. William W. Turner, Jr.
Director, Nutritional Support Service
Parkland Memorial Hospital
Department of Surgery
University of Texas Health Science Center
5323 Harry Hines Boulevard
Dallas, Texas 75235

Dear Dr. Turner,

This letter is to request your authorization to allow me to utilize data obtained from patients monitored by the Nutritional Support Team at Parkland Memorial Hospital in the completion of my doctoral dissertation. The study I am proposing is entitled "The Energy Equation: Development of an Equation for Estimating Energy Expenditures in Hospitalized Patients". The objective of this study is to derive an equation for estimating energy expenditure in hospitalized patients using measured energy expenditure data obtained by indirect calorimetry associated with the following easily measured variables: height, weight, age, sex, diagnosis, obesity, and ventilatory status. Data collected from patients entered into the study will be that mentioned above which is routinely collected on all patients followed by the Nutritional Support Team at Parkland Memorial Hospital. Regression analysis will be used to derive an equation which correlates the measured variables to the indirect calorimetric data using two hundred patients inititally. The derived equation will be tested hypothetically on one hundred patients prospectively. During interpretation and presentation of data, the patients will not be discussed by name, only by I.D. number. Professional conduct will be exemplified at all times to protect the rights of the patients.

We have discussed this study thoroughly and I hope that the information provided in this letter outlines the proposed study. If you have any questions please do not hesitate to contact me.

Sincerely,

Carol S. Ireton-Jones

Carol S. Ireton-Jones, M.S.,R.D./L.D.

3010 Scott Mill Road
Carrollton, Texas 75007
(214) 242-7283

APPENDIX IV

Institution Approval Letter

The University of Texas
Health Science Center
at Dallas

William W. Turner, Jr., M.D.
Associate Professor
Department of Surgery

Southwestern Medical School

August 5, 1987

Carol Ireton-Jones, M.S., R.D./L.D.

Dear Carol:

You have my authorization to utilize data obtained from patients monitored by the Nutritional Support Team at Parkland Memorial Hospital in the completion of your doctoral dissertation, "The Energy Equation: Development of an Equation for Estimating Energy Expenditures in Hospitalized Patients". I have been involved in numerous studies on patients followed by the Nutritional Support Team in collaboration with you. I anticipate that the study will be conducted in much the same way as previous studies.

Yours sincerely,

William W. Turner, Jr., M.D.
Associate Professor
Department of Surgery

WWT/sw

5323 Harry Hines Boulevard Dallas, Texas 75235 (214) 688-3509

APPENDIX V

Human Research Review Approval

TEXAS WOMAN'S UNIVERSITY
Box 22939, TWU Station
RESEARCH AND GRANTS ADMINISTRATION
DENTON, TEXAS 76204

HUMAN SUBJECTS REVIEW COMMITTEE

Name of Investigator: Carol Ireton-Jones Center: Denton

Address: 3010 Scott Mill Rd. Date: 10-16-87

Carrollton, Texas 75007

Dear Carol Ireton-Jones

Your study entitled Development of an Equation For Estimating Energy Expenditures in Hospitalized Patients

has been reviewed by a committee of the Human Subjects Review Committee and it appears to meet our requirements in regard to protection of the individual's rights.

Please be reminded that both the University and the Department of Health, Education, and Welfare regulations typically require that signatures indicating informed consent be obtained from all human subjects in your studies. These are to be filed with the Human Subjects Review Committee. Any exception to this requirement is noted below. Furthermore, according to DHEW regulations, another review by the Committee is required if your project changes.

Any special provisions pertaining to your study are noted below:

_____ Add to informed consent form: No medical service or compensation is provided to subjects by the University as a result of injury from participation in research.

_____ Add to informed consent form: I UNDERSTAND THAT THE RETURN OF MY QUESTIONNAIRE CONSTITUTES MY INFORMED CONSENT TO ACT AS A SUBJECT IN THIS RESEARCH.

_____ The filing of signatures of subjects with the Human Subjects Review Committee is not required.

_____ Other:

XX No special provisions apply.

cc: Graduate School
Project Director
Director of School or
Chairman of Department

Sincerely,

Chairman, Human Subjects
Review Committee

APPENDIX VI

Metropolitan Life Insurance Tables

Ideal Body Weight
Metropolitan Life Insurance Tables

Ideal body weight standards (by height) for adults. The figures are modified from the 1959 Metropolitan Life Insurance Company Standards to height without shoe heels and medium frames.

Height(cm)	Men Weight (kg)	Women Weight (kg)
142	---	49
145	---	50
147	---	51
150	---	53
152	---	54
155	59	56
158	60	57
160	62	59
163	63	61
165	65	63
168	67	65
170	69	67
173	71	69
175	73	70
178	75	72
180	77	---
183	80	---
185	82	---
188	84	---
191	86	---

APPENDIX VII

Metabolic Measurement Cart Protocol

METABOLIC MEASUREMENT CART (MMC) PROTOCOL
MMC Horizon System, Sensor Medics,
Anaheim, California

METHODOLOGY: SPONTANEOUSLY BREATHING PATIENTS are connected to the MMC using a mask and non-rebreathing valve. VENTILATOR-DEPENDENT PATIENTS are connected to the MMC using a single-piloted exhalation valve to collect expired gas. Inspired gas is sampled on the "dry side" of the ventilator humidifier.

INTERPRETATION: Measurements of oxygen consumption, carbon dioxide production and ventilatory volume are made in one-minute intervals until a steady-state is achieved. Measured Energy Expenditure (MEE) and respiratory quotient (RQ) are calculated. A steady-state is achieved when three consecutive one minute measurements of MEE are within 10% of each other and the corresponding RQ's are within 5% of each other. Indirect calorimetry measurements include: VO_2 (oxygen consumption L/minute), VCO_2 (carbon dioxide production L/minute), RQ (respiratory quotient), VT (tidal volume), VE (minute ventilation), fr (frequency of ventilation-breaths), and $VEqO_2$ (ventilatory equivalent of oxygen). These data are used to determine the energy expenditure and RQ as well as checks to validate the methodology.

EQUATION: The modified Weir Equation, used to calculate energy expenditure from oxygen consumption (VO_2) and carbon dioxide production (VCO_2), is written as follows:

$$MEE = ([VO_2 \times 3.796] + [VCO_2 \times 1.214]) \times 1440$$

Where:

MEE=measured energy expenditure (kcal/day)

VO_2=oxygen consumption (L/min)

VCO_2=carbon dioxide production (L/min)

APPENDIX VIII

Metabolic Measurement Cart Equations

Metabolic Measurement Cart Equations

The following equations are used in the Horizon system Metabolic Measurement Cart to perform the calculation necessary to provide energy expenditure data from indirect calorimetric measurements. Symbols and abbreviations used in the following equations are:

- Pb - barometric pressure in mmHg
- VE - minute volume in liters per minute (BTPS)
- t - test time elapsed (minutes)
- T - temperature at turbine (degrees Centigrade)
- VT - tidal volume in liters per breath (BTPS)
- vol - expired volume in liters
- FIO_2 - fraction of inspired oxygen
- $FICO_2$ - fraction of inspired carbon dioxide
- FEO_2 - mixed expired oxygen (fractional concentration)
- $FECO_2$ - mixed expired carbon dioxide (fractional concentration)
- VO_2 - oxygen consumption in liters per minute
- VCO_2 - carbon dioxide production in liters per minute
- RQ - respiratory quotient
- f - breath rate in breaths per minute
- REE - resting energy expenditure in kcal per day (equivalent to MEE in this study)

Equations

$$VE(BTPS) = [vol(60)/t][(Pb-29)(Pb-47)][310/(273+T)]$$

$$VE(STPD) = (VE)(Pb-47)/863$$

$$VT(BTPS) = VE/f$$

$$VO_2(STPD) = [(FIO_2)(1-FEO_2-FECO_2)/(1-FIO_2-FICO_2)-FEO_2]VE(STPD)$$

$$VCO_2 = (FECO_2-FICO_2)VE(STPD)$$

$$RQ = VCO_2/VO_2$$

REE = (without urinary urea nitrogen consideration)

$$1.44[(3.796)(VO_2)+(1.214)(VCO_2)]$$

APPENDIX IX

All Patient Data By Group

ALL PATIENT DATA BY GROUP

GROUPI

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
1	RB	1128	1265	1.03	42	177	44	M	O	N	N
2	TB	1750	1459	0.90	51	180	61	M	O	N	N
3	MB	2034	1474	0.84	29	173	54	M	O	N	N
4	DC	1802	1402	0.85	32	168	61	F	T	N	N
5	SF	1781	1315	0.81	30	163	52	F	T	N	N
6	MG	1980	1414	0.79	48	163	71	F	O	N	N
7	TF	1828	1519	0.83	20	165	56	M	T	N	N
8	AH	1549	1097	0.97	48	160	39	F	O	N	N
9	PJ	2649	1438	0.74	46	170	61	M	T	N	N
10	JF	2710	1730	0.92	39	183	74	M	T	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
11	WH	1186	1304	0.73	39	173	46	M	O	N	N
12	GW	2040	1570	0.88	62	168	79	M	T	N	N
13	JB	1196	1346	0.80	54	170	58	M	O	N	N
14	RS	1760	1442	0.79	38	173	56	M	T	N	N
15	DY	2440	1446	0.90	55	178	63	M	O	N	N
16	PC	1157	1529	0.76	28	165	60	M	O	N	N
17	SG	1554	1303	0.81	17	158	46	F	O	N	N
18	NL	1429	1203	0.80	62	165	53	M	O	N	N
19	AM	1205	1201	0.92	67	156	60	F	O	N	N
20	BH	1422	1155	1.02	49	155	46	F	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
21	BL	1165	1252	0.87	75	165	67	F	O	N	N
22	RC	1614	1449	0.89	48	173	61	M	O	N	N
23	BF	1442	1462	0.73	42	170	60	M	O	N	N
24	RR	1917	1343	0.98	39	168	58	F	O	N	N
25	MR	1463	1371	0.91	57	173	60	M	O	N	N
26	RB	1216	1196	0.96	73	168	57	M	O	N	N
27	GK	2077	1568	0.76	42	178	65	M	T	N	N
28	GH	1750	1803	0.81	43	174	84	M	O	N	N
29	JM	2119	1524	0.96	30	183	54	M	O	N	N
30	JZ	2039	1634	1.02	46	193	66	M	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
31	ET	1311	1497	0.83	15	163	52	M	T	N	N
32	JV	2060	1654	0.89	26	168	67	M	T	N	N
33	DA	2246	2081	0.77	50	170	109	M	T	N	Y
34	TK	1898	1547	0.79	57	172	73	M	O	N	N
35	AR	2097	1377	0.96	26	168	56	F	T	N	N
36	WW	2739	1829	0.86	29	185	75	M	T	N	N
37	RN	2371	1618	0.81	28	163	68	M	T	N	N
38	JM	1395	1503	0.82	27	166	70	F	T	N	N
39	LN	1181	1349	0.72	41	169	52	M	T	N	N
40	BJ	1599	1229	0.89	43	160	50	F	O	N	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
41	AB	1515	1257	0.90	80	168	73	F	O	N	N
42	DK	1078	1443	0.90	29	183	48	M	T	N	N
43	JR	1266	1544	0.89	64	180	73	M	O	N	N
44	EO	1095	1059	0.88	78	183	47	F	O	N	N
45	LB	1200	1200	0.83	68	165	58	F	O	N	N
46	MD	1157	1090	0.78	68	147	50	F	O	N	N
47	VH	1381	1216	0.99	47	167	50	F	O	N	N
48	RC	2518	2018	0.80	45	170	102	M	O	N	Y
49	FC	1195	1089	0.91	64	170	44	M	O	N	N
50	CA	1395	1469	0.84	45	165	75	F	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
51	PC	1082	1116	0.86	47	168	39	F	O	N	N
52	AH	1830	1145	0.78	61	165	49	F	O	N	N
53	SJ	1104	1028	1.02	46	152	32	F	O	N	N
54	MS	884	1160	0.80	68	148	57	F	O	N	N
55	RB	1230	1094	1.04	69	163	48	F	O	N	N
56	GT	2363	2050	0.80	28	191	88	M	T	N	N
57	HS	2002	1878	0.85	72	189	98	M	O	N	N
58	JS	2295	2471	0.83	25	189	118	M	T	N	Y
59	RO	1173	1303	0.77	63	165	68	F	O	N	N
60	BW	1137	1451	0.93	49	175	61	M	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
61	CR	1378	1182	0.97	41	160	44	F	O	N	N
62	LB	1712	1072	0.81	46	150	37	F	O	N	N
63	JM	2405	2024	0.90	45	188	96	M	O	N	N
64	HM	2092	1345	0.95	44	173	52	M	O	N	N
65	DM	1097	1123	0.97	59	158	47	F	O	N	N
66	JM	1987	1389	0.75	75	163	74	M	O	N	N
67	DR	1764	1412	0.86	78	166	76	M	O	N	N
68	BH	1416	1513	0.87	40	175	61	M	T	N	N
69	PM	1254	1611	1.03	32	185	61	M	T	N	N
70	GH	2068	1519	1.00	28	168	58	M	T	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
71	MR	1195	1231	0.91	33	141	49	F	O	N	N
72	LQ	1325	1133	0.89	49	163	42	M	O	N	N
73	MC	1132	1130	0.91	64	162	50	F	O	N	N
74	JL	1752	1535	0.84	57	160	77	M	T	N	N
75	IC	1558	1619	0.93	33	168	68	M	T	N	N
76	JN	1516	1588	1.01	61	183	74	M	O	N	N
77	LD	1376	1410	0.97	52	180	58	M	O	N	N
78	GM	2149	1592	1.02	29	179	60	M	O	N	N
79	JB	1391	1221	0.99	61	183	47	M	O	N	N
80	DA	1975	1834	0.99	20	175	75	M	T	N	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
81	MS	2034	1434	0.95	58	163	78	F	O	N	N
82	EL	1363	1060	1.04	68	163	44	F	O	N	N
83	LH	1589	1398	1.01	33	165	62	F	O	N	N
84	RG	1039	1392	0.90	33	165	53	M	O	N	N
85	LD	942	1455	0.85	43	176	58	M	O	N	N
86	EF	1825	1477	1.03	34	163	71	F	O	N	N
87	TB	1417	1308	0.92	50	175	51	M	O	N	N
88	DC	1608	1560	1.07	55	183	69	M	O	N	N
89	BR	1543	1170	1.07	51	158	48	F	O	N	N
90	SH	1386	1261	1.10	52	165	52	M	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
91	CF	1181	1096	1.09	45	150	42	M	O	N	N
92	JL	1323	1269	1.02	57	165	55	M	O	N	N
93	TF	1323	1330	1.16	55	183	52	M	O	N	N
94	JG	1348	1406	1.01	39	178	63	F	O	N	N
95	OB	1588	1230	1.12	47	160	52	F	O	N	N
96	PB	1447	1355	1.03	51	175	55	M	O	N	N
97	GG	1116	1242	1.21	49	178	45	M	O	N	N
98	JM	1991	1613	0.96	21	165	63	M	T	N	N
99	RS	1474	1338	0.82	69	165	73	F	O	N	N
100	LW	2132	1858	0.82	17	185	71	M	T	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
101	DB	3365	1831	0.89	24	185	73	M	B	N	N
102	MC	3136	2024	0.80	34	185	92	M	B	N	N
103	DD	2381	1854	0.86	21	175	76	M	B	N	N
104	JF	2620	1862	0.79	23	178	77	M	B	N	N
105	HF	2983	1832	1.03	47	183	85	M	B	N	N
106	GG	3181	2151	0.79	20	184	94	M	B	N	N
107	RO	1529	1679	0.89	19	178	62	M	B	N	N
108	WS	2375	1724	0.79	19	175	66	M	B	N	N
109	MU	1850	1523	1.02	20	163	69	F	B	N	N
110	CS	1282	1761	0.82	78	173	99	M	B	N	Y
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
111	TW	1936	1749	0.80	17	174	67	M	B	N	N
112	RF	2672	1871	0.85	37	175	86	M	B	N	N
113	GT	2300	1525	0.86	43	164	80	F	B	N	N
114	AB	1334	1392	0.90	15	152	55	F	B	N	N
115	FA	3410	2415	1.03	42	185	124	M	B	N	Y
116	SW	1790	1287	0.79	60	152	66	F	B	N	N
117	PW	1486	1429	0.74	26	158	63	F	B	N	N
118	JD	1997	1705	0.84	37	172	75	M	B	N	N
119	JP	1361	1683	0.77	37	185	69	M	B	N	N
120	JB	1482	1644	0.74	61	175	81	M	B	N	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
121	YJ	3137	1857	0.88	22	168	103	F	B	N	Y
122	LG	2200	1681	1.15	41	183	71	M	B	N	N
123	MG	1583	1533	0.79	31	168	75	F	B	N	N
124	RS	1669	1807	0.68	30	178	77	M	B	N	N
125	GT	2792	2050	0.86	48	182	101	M	B	N	N
126	LR	2230	1851	0.89	32	183	79	M	B	N	N
127	WJ	2166	1617	0.95	50	178	73	M	B	N	N
128	CY	1677	1373	0.80	38	165	62	F	B	N	N
129	JC	1275	1451	0.77	17	163	60	F	B	N	N
130	BF	1673	2198	1.17	24	180	101	M	B	N	Y
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
131	GF	2491	1902	0.88	56	182	95	M	B	N	N
132	BH	2630	2120	0.85	41	163	137	F	B	N	Y
133	SR	2866	1936	0.77	18	175	81	M	B	N	N
134	GT	1542	1712	0.97	33	180	70	M	B	N	N
135	RA	4924	2005	0.92	22	193	82	M	B	N	N
136	TM	2493	1485	0.94	57	175	67	M	B	Y	N
137	RH	2783	1793	1.05	65	183	91	M	B	Y	N
138	GR	1396	1379	1.26	61	170	64	M	T	Y	N
139	WA	1721	1825	0.82	53	183	87	M	T	Y	N
140	RB	3636	1839	0.87	22	180	74	M	B	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
141	JB	2632	1691	0.69	44	175	76	M	T	Y	N
142	BC	3482	1377	0.85	55	175	59	M	B	Y	N
143	MA	1876	2297	0.75	70	178	171	F	O	Y	Y
144	CP	1039	1417	1.03	44	175	67	F	O	Y	N
145	JM	2156	2076	1.14	50	183	104	M	B	Y	Y
146	PL	2824	2030	0.86	30	185	90	M	T	Y	N
147	RM	3670	1619	1.25	26	173	63	M	B	Y	N
148	HF	2535	1872	0.76	47	183	88	M	B	Y	N
149	BK	1572	1553	0.72	75	157	100	F	O	Y	Y
150	JR	2721	1363	0.51	46	165	57	M	T	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
151	JP	2708	1700	0.72	37	167	76	M	T	Y	N
152	FS	1507	1580	0.73	47	178	68	M	O	Y	N
153	RS	2619	2245	1.33	26	183	105	M	B	Y	Y
154	MW	1023	1356	1.20	47	152	67	F	O	Y	N
155	GW	2143	1700	0.83	56	172	84	M	T	Y	N
156	GA	2571	1689	0.98	28	173	69	M	B	Y	N
157	DH	2139	1887	0.79	32	180	83	M	B	Y	N
158	MW	1327	1374	0.66	36	165	53	M	O	Y	N
159	JJ	2013	1301	1.09	51	170	53	M	O	Y	N
160	WP	2233	1824	1.13	36	180	77	M	T	Y	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
161	IF	1535	1205	0.75	79	165	64	F	O	Y	N
162	MT	2195	1565	0.92	49	175	85	F	B	Y	N
163	MA	1685	1446	0.71	42	165	71	F	B	Y	N
164	TH	1207	1648	1.06	24	178	62	M	T	Y	N
165	DC	2754	2028	0.75	19	183	85	M	B	Y	N
166	DC	2565	1432	0.82	25	165	61	F	B	Y	N
167	LM	1916	1632	0.88	44	170	74	M	B	Y	N
168	DP	4358	1898	0.82	45	183	89	M	B	Y	N
169	MB	3233	1853	0.83	23	175	77	M	B	Y	N
170	TK	3148	1409	0.60	20	163	67	F	B	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
171	RY	3527	1637	1.04	59	180	78	M	B	Y	N
172	RM	2363	1953	0.79	32	180	87	M	B	Y	N
173	TC	2359	1856	0.65	34	163	111	F	B	Y	Y
174	SD	2194	1805	0.81	15	175	70	M	B	Y	N
175	JJ	1456	1633	0.74	68	185	83	M	O	Y	N
176	JV	2194	1815	0.82	51	175	88	M	O	Y	N
177	CW	1213	1519	0.87	55	175	69	M	T	Y	N
178	AR	2681	2030	0.85	53	170	137	F	O	Y	Y
179	CR	2093	1516	1.07	41	175	62	M	T	Y	N
180	JR	2036	1622	1.05	75	183	83	M	O	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
181	WM	1977	1851	0.62	21	180	75	M	T	Y	N
182	BL	1297	1248	1.15	76	165	67	F	O	Y	N
183	TH	2063	1393	0.85	24	165	48	M	T	Y	N
184	CH	1854	1722	0.90	19	175	66	M	T	Y	N
185	RF	1374	1502	0.83	56	168	71	M	T	Y	N
186	LC	2770	1360	0.77	61	165	64	M	T	Y	N
187	ED	999	1130	0.99	87	168	59	M	O	Y	N
188	JB	2227	1956	1.15	22	180	83	M	T	Y	N
189	CM	3056	1538	0.81	24	168	71	F	B	Y	N
190	KM	2259	1761	0.88	46	172	83	M	B	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
191	LM	1916	1632	0.88	44	170	74	M	B	Y	N
192	AM	3204	2120	0.93	52	178	110	M	B	Y	Y
193	DC	2888	1916	0.76	22	178	80	M	B	Y	N
194	KJ	3091	1238	0.99	19	164	57	M	T	Y	N
195	ND	2952	1468	0.83	35	165	70	F	B	Y	N
196	HM	2284	1803	0.89	31	180	76	M	T	Y	N
197	LL	1001	1569	0.75	80	152	105	F	B	Y	Y
198	SW	2475	1335	1.10	17	156	49	F	T	Y	N
199	JM	2958	1732	0.72	40	183	74	M	B	Y	N
200	DC	4022	1811	0.90	30	170	80	M	B	Y	N

GROUP II

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
1	TD	2114	1417	0.74	43	178	55	M	B	N	N
2	MO	1289	1449	0.76	43	163	72	F	B	N	N
3	RR	2116	1615	0.89	27	180	60	M	B	N	N
4	DC	2680	1445	0.91	30	170	53	M	B	N	N
5	SD	2167	1805	0.79	15	175	76	M	B	N	N
6	JS	2250	1640	0.75	32	173	67	M	B	N	N
7	SW	2012	1492	0.76	14	165	62	F	B	N	N
8	RN	2131	1478	0.91	30	160	59	M	B	N	N
9	DT	1985	1278	0.88	85	160	76	F	B	N	N
10	KF	2032	1293	0.89	35	163	52	F	B	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
11	KA	1958	1229	0.69	33	160	45	F	O	Y	N
12	MB	2866	1670	0.92	21	178	62	M	T	Y	N
13	LK	1838	1589	1.08	40	168	85	F	B	Y	Y
14	RB	4283	1915	0.66	37	180	87	M	T	Y	N
15	LD	3477	1950	0.57	55	183	98	M	T	Y	N
16	BH	2216	1653	0.68	50	172	95	F	O	Y	Y
17	LM	2520	1498	0.95	27	165	69	F	B	Y	N
18	KP	1873	1358	0.97	28	165	55	F	B	Y	N
19	MH	1611	1321	0.67	28	157	53	F	T	Y	N
20	DJ	3952	2036	0.88	21	183	87	M	B	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
21	DP	2913	2117	0.86	25	180	96	M	T	Y	N
22	TL	1100	1337	0.83	65	183	58	M	T	Y	N
23	EH	2871	1983	0.96	56	178	102	M	B	Y	Y
24	HS	2155	1182	1.13	55	161	51	F	T	Y	N
25	TR	2756	1861	0.69	19	185	72	M	T	Y	N
26	JC	2498	1692	0.77	19	183	61	M	B	Y	N
27	FB	1689	1769	1.10	37	170	80	M	B	Y	N
28	SB	1228	1374	1.50	73	167	78	F	B	Y	N
29	KF	2055	1351	0.91	35	163	58	F	B	Y	N
30	JB	2575	2463	0.93	35	196	120	M	B	Y	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
31	EC	2201	1515	0.87	35	175	59	M	T	Y	N
32	PC	2384	1575	1.08	51	178	70	M	T	Y	N
33	GL	3015	2095	0.82	23	183	103	M	B	Y	N
34	DP	3078	1602	0.69	24	170	61	M	B	Y	N
35	LP	1519	1051	0.85	65	165	44	F	B	Y	N
36	MB	2482	2163	0.92	25	175	101	M	B	Y	Y
37	BC	1659	1507	0.86	43	168	77	F	B	Y	N
38	TD	1958	1370	0.65	43	178	51	M	B	Y	N
39	FP	1716	1363	0.91	82	175	71	M	B	Y	N
40	MO	3642	1541	0.57	43	163	82	M	B	Y	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
41	SN	3656	1873	0.81	18	180	75	M	B	Y	N
42	JS	2640	1693	0.98	32	173	71	M	B	Y	N
43	MS	2049	1353	0.65	45	163	56	M	T	Y	N
44	VS	1942	1445	0.73	58	155	81	F	O	Y	N
45	MV	1744	1511	0.96	25	168	56	M	O	N	N
46	AA	1888	1251	0.83	65	152	64	F	O	N	N
47	FB	1311	1295	0.91	52	192	45	M	O	N	N
48	SD	1596	1473	0.96	30	165	68	F	O	N	N
49	DD	2000	1594	0.77	26	163	64	M	T	N	N
50	EH	2310	1500	0.99	32	166	81	F	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
51	JJ	1211	1094	0.91	51	166	39	F	O	N	N
52	PJ	1119	1645	0.88	23	185	59	M	O	N	N
53	MM	1097	1149	0.81	60	165	49	F	O	N	N
54	MP	1309	1328	0.81	66	163	71	F	O	N	N
55	LR	1463	1509	0.81	67	163	90	F	O	N	Y
56	PS	1781	1383	0.99	17	157	54	F	O	N	N
57	CS	1637	1122	0.87	75	165	53	M	T	N	N
58	SW	2037	1295	0.90	17	156	45	F	T	N	N
59	EE	1734	1541	1.13	35	162	62	M	O	N	N
60	AB	1766	1734	1.05	26	165	74	M	O	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
61	JB	1798	1686	0.91	23	175	65	M	T	N	N
62	JG	1558	1334	1.20	34	168	48	M	O	N	N
63	GH	1658	1163	0.75	62	159	52	F	O	N	N
64	LH	1131	1257	1.06	75	157	69	F	O	N	N
65	JH	1768	1623	1.14	33	193	59	M	O	N	N
66	EJ	1837	1743	0.83	37	160	101	F	T	N	Y
67	PJ	2649	1438	0.74	46	170	60	M	T	N	N
68	WL	1197	1390	0.93	47	178	54	M	O	N	N
69	MM	943	1645	0.86	25	188	59	M	T	N	N
70	RO	1173	1303	0.77	63	165	67	F	T	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
71	FS	1618	1443	0.92	62	170	69	M	O	N	N
72	FT	1198	1651	1.12	33	188	63	M	O	N	N
73	VW	1799	1385	1.24	65	173	64	M	T	N	N
74	BH	1570	1736	0.77	45	180	78	M	O	N	N
75	JH	2129	1371	0.72	40	165	62	F	O	N	N
76	MJ	1586	1310	0.90	81	178	73	F	O	N	N
77	MO	1540	1680	1.10	34	184	67	M	O	N	N
78	JR	2146	1677	0.82	25	168	68	M	O	N	N
79	BR	1010	1004	0.91	53	157	32	F	O	N	N
80	JM	1033	1514	0.98	27	185	51	M	O	N	N

No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
81	DN	1654	1649	1.25	20	180	59	M	O	N	N
82	AP	1255	1037	0.87	50	157	38	M	O	N	N
83	DC	1971	1808	0.80	18	175	72	M	T	N	N
84	LB	1856	1389	0.82	70	168	70	F	O	N	N
85	GG	1538	1387	0.81	23	157	50	M	O	N	N
86	ME	1436	1040	0.97	56	155	38	F	O	N	N
87	JS	1064	1239	0.82	71	178	55	M	O	N	N
88	MG	1427	1693	0.85	27	180	66	M	O	N	N
89	JP	1335	1755	0.99	30	171	75	M	O	N	N
90	LT	2103	1432	0.89	35	163	57	M	B	N	N
No.	PT	MEE	HBEE	RQ	AGE	HT	WT	SEX	DX	VENT	OBESE
91	MP	1660	1275	0.96	81	152	75	F	B	N	N
92	TO	2446	1665	0.98	21	183	60	M	O	N	N
93	AM	2075	1443	0.80	37	168	57	M	O	N	N
94	AJ	1583	1259	0.81	63	166	62	F	O	N	Y
95	OF	1953	1712	0.94	22	170	88	F	B	N	N
96	TY	1124	1650	0.86	24	193	57	M	O	N	N
97	BS	2011	1970	0.96	23	183	83	M	O	N	N
98	RP	1091	1468	0.82	67	185	67	M	O	N	N
99	JP	1420	1741	0.93	30	171	74	M	O	N	N
100	JL	1333	1296	0.82	57	165	57	M	T	N	N

MEE (measured energy expenditure)=kcal/day, HBEE (basal energy expenditure-Harris-Benedict equations)=kcal/day, AGE=years, HT(height)=cm, WT(weight)=kg, DX (diagnosis - T=trauma, B=burn, O=non-trauma, non-burn), OBESE = greater than 30% above ideal body weight (medium frame, Metropolitan Life Ins. tables)