ASSESSMENT OF BODY WATER BALANCE BY ANALYSIS OF THE DIFFERENCE BETWEEN MEASURED INTAKE AND OUTPUT AND CHANGE IN DAILY WEIGHT

by

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CHAPTER I

INTRODUCTION

Many patients in the hospital setting develop fluid imbalances. Fluid imbalance in an acute or chronically ill individual may cause severe complications. There are two kinds of fluid imbalance, fluid excess and fluid deficit. Fluid excess (volume overload) can produce pulmonary and/or systemic edema, hypervolemia, heart failure and/or electrolyte disturbances. Fluid deficits (volume depletion/dehydration) occasionally lead to decreased cardiac output, hypovolemia and/or related electrolyte disturbances.

Water is the primary component of all body fluids. Water comprises 50 to 60% of a normal adult's total body weight. This body water is distributed into several different compartments. These include the intracellular compartment which comprises 40% of the total body weight and the extracellular compartment comprising 20% of the total body weight. The extracellular compartment is further subdivided into interstitial and plasma compartments. Interstitial fluid makes up approximately 16% and plasma 4% of total body weight (Valtin, 1973). Another less definitive compartment called the transcellular space, comprises 1 to 2% of body weight. Transcellular fluid includes cerebrospinal fluid, intraocular, pleural, peritoneal and synovial fluid (Valtin, 1973). Figure 1 illustrates these relationships.

The body has several pathways by which water enters and leaves. The healthy adult normally gains body water by ingestion of food and fluids and by producing water in the cells during metabolism. Normal water losses occur as urine, feces, sweat and insensibly via skin and

TOTAL BODY WATER

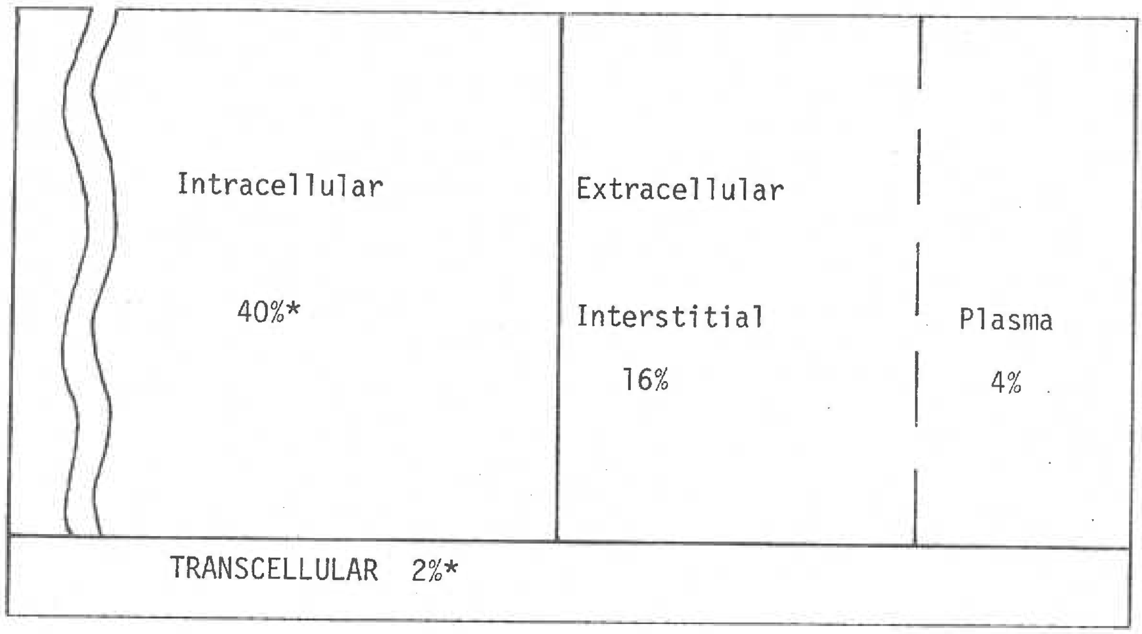


Figure 1. Distribution of Total Body Water in the Adult

* Approximate percent of total body weight.

lungs. Insensible loss is that water excreted via the lungs during exhalation and through the skin by diffusion. The normal volumes of water intake and output are shown in Table 1.

Table 1. Normal volumes of water gained and lost in adults (adapted from Vander, 1980).

	Milliliters per 24 Hours
Intake	
Fluids	1200
Food	1000
Metabolism Production	200
	2400
Output	
Urine	1500
Feces	100
Sweat	50
Insensible water loss	750
	2400

Disease states frequently change the normal patterns of water intake and output. For instance, food and fluids may not be obtained via oral ingestion and needed water is replaced with intravenous infusions. Fever can increase body metabolism which may increase water production. Fever may also increase the volume of water lost through sweating.

Output routes may be altered by disease, accidents or surgical intervention. For example, increased amounts of water can be lost through excessive urine production, burns, nasogastric suction, frequent emesis or surgical stoma sites. Figure 2 depicts routes for intake and output of water in illness.

Healthy adults usually maintain a balance of body water. Valtin (1979) uses two terms, internal and external, to express balance of body water. First, internal balance, is that which reflects the maintenance of water volumes distributed among compartments. The second term, external balance, is used clinically to represent the maintenance of total body water at its normal volumes. Assessment of internal or external balance requires very different procedures.

To evaluate the volume of water within each compartment special laboratory techniques are required. Total body water can be measured by deuterium (D_2O) or tritium (^3H_2O) dilution (Moore, 1980). Measurement of fluid volumes in other compartments requires special markers. For example, radioactive $SO_4^=$ may be used to determine extracellular fluid volume and Evans blue to determine plasma volume (Guyton, 1976). Each of these assessments is currently beyond the scope of nursing.

External balance is a nursing assessment and depends on the measurements of all water intake and output volumes. External balance may be

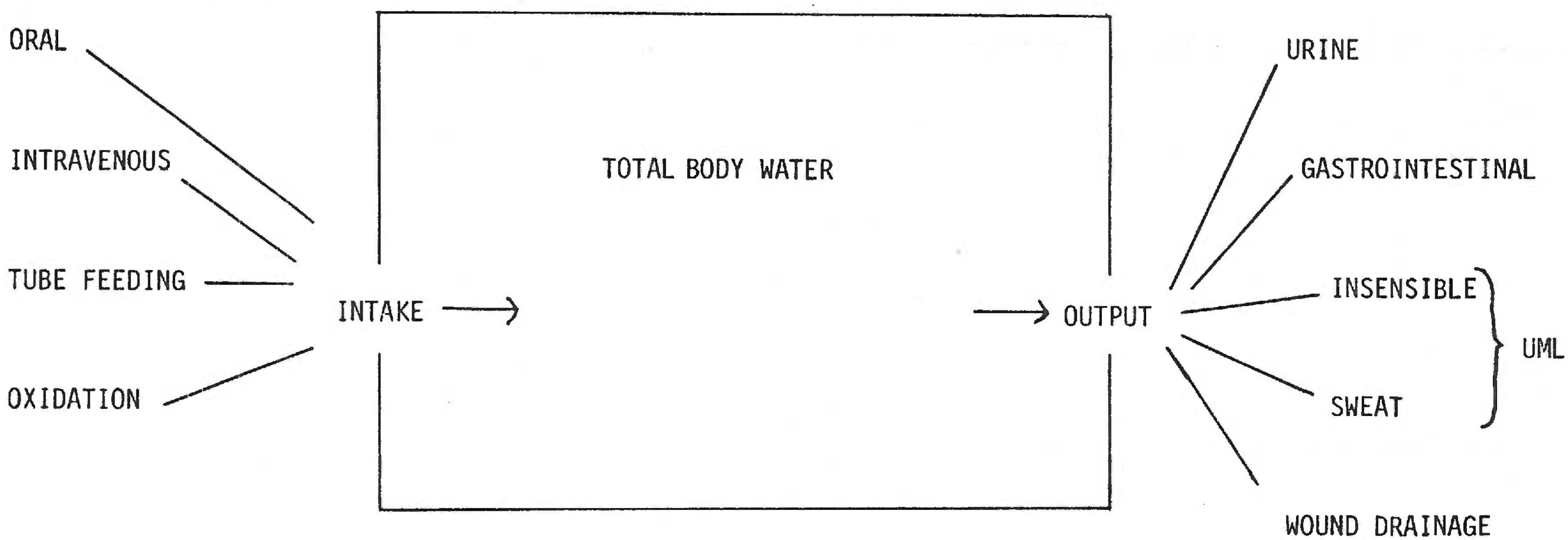


Figure 2. Routes for Intake and Output

UML represents unmeasured water loss. Insensible and sweat are routes of water loss that are difficult to measure at this time. When sweating is minimal and wound drainage is zero, the unmeasured water loss should closely represent insensible water loss.

evaluated by two different methods, fluid balance or total body water balance (water balance). Murray, Schaffel, Geiger, Long and Blakemore (1979), state that fluid balance and water balance are different from each other. Fluid balance is the assessment of the difference between all measurable intake and output water volumes. Insensible water loss as well as the water produced through oxidation reactions in cells are not included. Sensible (measurable) water intake and output are related to fluid balance in the following equation.

$$I - O = \emptyset \qquad (1)$$

Where:

I = Intake
O = Output

Zero difference between measurable intake and output indicates body fluid balance or a steady state. Each of the different kinds of measurable intake and output volumes are illustrated in the following equations.

$$I = PO + IV + TF \qquad (2)$$

Where:

PO = Fluid volumes per os
IV = Intravenous fluid intake
TF = Tube feeding fluid intake

$$O = UO + GI \qquad (3)$$

Where:

UO = Urine volume excreted
GI = Fluid lost from gastrointestinal tract

Therefore in fluid balance:

$$PO + IV + TF - (UO + GI) = \emptyset \qquad (4)$$

Where:

PO = Fluid intake per os
IV = Intravenous fluid intake
TF = Tube feeding intake

UO = Volume urine excreted
GI = Fluid lost from gastrointestinal tract

Assessment of fluid balance consists of obtaining measurable intake and output volumes of fluid for a 24 hour period. The difference between the two volumes indicates fluid balance, fluid excess or deficit.

Total body water balance can be estimated from changes in body weight. Changes in body weight may be calculated from equation 5.

$$\Delta WT = I - O \text{ (solids)} + I - O \text{ (liquids)} + I - O \text{ (gases)} \quad (5)$$

Where:

ΔWT = Change in daily body weight
I (solid) = Intake of solid food weight
O (solids) = Output of solid wastes weight
I (liquids) = Measurable and unmeasurable fluid intake
O (liquids) = Measurable and unmeasurable fluid output
I (gases) = O_2 intake weight
O (gases) = CO_2 exhaled weight

Changes in weight from solids can be eliminated for patients receiving no solid food by mouth (Gump, Kinney, Long and Gelber, 1968). Solid waste may be measured when stool is excreted. Changes in weight due to gas exchange are frequently so small that they are also eliminated from equation 5. Under these conditions, equation 5 then illustrates that changes in daily weight represent the intake and output of measurable and unmeasurable fluids.

$$\Delta WT = (I + Ox) - (O + INS + Sweat) \quad (6)$$

Where:

ΔWT = Change in daily body weight
I = Fluid intake (measurable)
Ox = Water produced via cell metabolism
O = Fluid output (measurable)
INS = Insensible water loss

When the change in weight from gas exchange and solids is eliminated, then change in weight is equivalent to water balance.

$$\Delta WT = \Delta H_2O = (I + Ox) - (O + INS + Sweat) \quad (7)$$

Where:

ΔH_2O = Water balance

(Gump et al., 1968)

Assessment of total body water balance requires fluid balance assessment, as well as estimated values for water produced by cell oxidation and water lost through insensible means. Since volumes of water in sweat and insensible output are not measured, it is convenient to define their sum as unmeasured water loss (UML).

Equation 7 then becomes:

$$\Delta H_2O = (I + Ox) - (O + UML) \quad (8)$$

Several authors have recommended the use of change in daily weight as the major guide in assessing water balance (Gump et al., 1968; Murray et al., 1979; Valtin, 1973; Shires and Canizaro, 1979; Moore, 1959).

When equation 8 is applied to the hospitalized patient with altered intake and output routes, the equation then becomes:

$$\Delta WT = PO + IV + TF + Ox - (UO + GI + WD + UML) \quad (9)$$

Where:

ΔWT = Change in daily weight
PO = Fluid received per os
IV = Intravenous fluid intake
TF = Tube feeding intake
Ox = Water produced by cell oxidation
UO = Urine output
GI = Gastrointestinal fluid lost
WD = Wound drainage
UML = Insensible water loss plus sweat

When patients receive no oral liquids or demonstrate no wound drainage, the equation then becomes:

$$\Delta WT = IV + TF + Ox - (UO + GI + UML) \qquad (10)$$

In order to determine a value for unmeasured water loss, the equation can be rearranged as shown below:

$$UML = (IV + TF + Ox) - (UO + GI) - \Delta WT \qquad (11)$$

Equation 11 can then be simplified:

$$UML = (I - O) - \Delta WT \qquad (12)$$

In equation 11 the intake term, I, contains water of oxidation. Thus, when UML is calculated from water balance parameters (Eq. 11) the water of oxidation is included. However, equation 12 can be used to calculate UML from fluid balance parameters where the intake term, I, does not include water of oxidation. When UML is calculated from fluid balance data the results may be less than that obtained from water balance data.

DEFINITION OF TERMS

WATER BALANCE: The maintenance of total body water balance.

TOTAL BODY WATER BALANCE: The maintenance of total body water as related to the intake and output of water in solids, liquids and gases.

FLUID BALANCE: The maintenance of sensible water intake equal to sensible water output.

TOTAL BODY WATER: The total volume of water in the body, usually 50 - 60% of the total body weight in the adult.

INSENSIBLE WATER LOSS: The volume of water lost as a result of water diffusion through the skin and respiratory tract.

INSENSIBLE WEIGHT LOSS: The minute amount of weight that is lost as a result of water diffusion through the skin and exhaled as moist carbon dioxide, and the weight difference between oxygen consumed and carbon dioxide exhaled.

WATER INTAKE: The total volume of water taken into the body from solids, liquids and gases.

WATER OUTPUT: The total volume of water excreted from the body via solids, liquids and gases.

WATER PRODUCED BY OXIDATION: The volume of water produced by the body during cell metabolism.

NITROGEN BALANCE: The maintenance of an equal volume of nitrogen intake and output.

CHANGE IN BODY WEIGHT: The reflection of changes in water intake and output of solids, liquids and gases by weight.

INTERNAL BALANCE: The maintenance of water volume distribution among the body water compartments (Valtin, 1979).

EXTERNAL BALANCE: The maintenance of the total body water volume at a normal balance (Valtin, 1979).

UNMEASURED WATER LOSS: The added value of insensible water loss and sweat.

REVIEW OF LITERATURE

Assessment and management of water balance is often a critical factor to the recovery of severely ill patients. Management of total body water balance is often a difficult challenge for the clinician. Misunderstanding of concepts and incorrect terminology are two of the more common problems in assessing water imbalance. Use of the water balance equation (equation #7) requires a numerical value for daily insensible water loss. Reported values for insensible water loss vary from 300 ml to 1200 ml per day. The water balance equation is used less often because of the lack of either accurate or consistent values for insensible water loss. In order to provide a background for the study, the review of the literature includes information on the following component parts of the water balance equation: 1) Input and output of gases; 2) input and output of water in solids; and 3) the measures used to evaluate insensible water loss. These components of the water balance equation require further description for clarification.

The volume of water obtained from the intake and output of gases in the body is normally small. Measurement of this value is limited to volumes associated with breathing in of oxygen and the exhalation of carbon dioxide. The volume of gas inhaled or exhaled depends on an individual's respiratory quotient (RQ) (Slonium and Hamilton, 1981). The RQ is dependent on the types of fuel body cells are using for metabolism. If all body cells are using glucose, the RQ is 1.00. Body cells usually metabolize a mixture of fuels for energy, which are glucose, fat and protein. When the body cells use a mixture of fuels, the RQ is <1.00 (Slonium and Hamilton, 1981). A person with a RQ of <1.00

has a negligible change in weight from gas exchange with respiration (Gump et al., 1968).

Intake of food solids offers a route for water intake. Solid wastes that are excreted also contain water. Water volumes contained in solids can be determined in a laboratory setting. Several investigators have shown that the difference between intake and output of water in solids is minimal in patients who are not receiving food (Murray et al., 1979; Gump et al., 1968). Therefore, this factor is usually ignored.

The portion of the water balance equation that is used for assessment is shown in equation 7. Water associated with measurable intake and output is known as fluid balance. Measuring intake and output is a method of determining fluid balance. Determining intake and output consists of measuring all liquids received by the body via oral ingestion, tube feedings, and parenteral administration of fluid. Output measures include urine, gastrointestinal losses (emesis and diarrhea) and wound drainage. Water is also added to and removed from the body that is unmeasurable. The volume of water produced from metabolic oxidation must be added to the water intake value. Water volumes produced from cellular oxidation reactions may be calculated when oxygen consumption and carbon dioxide production are known. Average estimated values of 200 ml per day are used when daily caloric expenditure ranges from 1400-2200 calories (Gump et al., 1968).

Water from insensible loss must also be added to the total output. Insensible water loss is the volume of water lost from the body as a result of diffusion through the skin and expiration from the respiratory tract. This volume is difficult to measure in most clinical settings.

The usual values given for insensible water loss in both medical and nursing references are numerous and varied. Moore (1975) cites a value for respiratory insensible water loss of 500-700 ml per day for a male and 250-500 ml per day for a female. Shires and Canizaro (1979) state that 600-900 ml of water per day are lost to insensible causes. Guyton (1976) cites an average insensible water loss of 700 ml per day is usual. Bard (1956) cites 300-700 ml per day as an average insensible water loss value. Rudman (1980) reports 400-600 ml per day as the value to use. Several nursing citations for insensible water loss range from 300-1200 ml per day (Bobal, 1977; Ricci, 1977; Urrows, 1980; Aspinal and Tanner, 1981; Metheny and Snively, 1976; Luckman and Sorenson, 1980). Besides the lack of agreement among authors, a majority of the values cited are not referenced.

Research on insensible water loss has been in progress for over 300 years. Benedict and Root (1926) reviewed many historical studies on insensible water loss. Their article, which is summarized below reviewed the literature on insensible water loss from 1614 - 1923. Research in this area involved the use of several different types of scales for obtaining weights and various conditions to isolate the factors affecting insensible water loss. The earliest recorded quantitative measurement of insensible water loss was made by Sanctorius in 1614. He suspended himself on a platform balance and made innumerable measurements of his own weight loss. Dionysius Dodart of Paris (1634 - 1707) studied insensible water loss throughout his adult life. He was able to demonstrate an increase in insensible water loss in the summer months as compared to winter months. In 1906, W.P. Lombard constructed an extraordinary balance. It was a true balance with a spring scale connected to a writing arm for accurate, sensitive graphic recordings. In experiments, adult men, each weighing approximately 70 kilograms, lost an average of 40 grams of water each hour. Repeated experiments with higher ambient temperatures showed an increase of insensible loss up to 70 grams of water per hour. Professor Lombard also determined water loss from skin diffusion alone as he had his subjects hold their breath for 27 seconds and observed weight changes. From these techniques, he calculated water loss from skin diffusion to be 24% of the total insensible water loss.

In 1918, Isenschmid determined that insensible water loss was equal to the weight of the water given off plus the weight of the carbon dioxide breathed out, minus the weight of oxygen consumed. Oxygen consumption and carbon dioxide production can be determined when precise diet intake values are known. In 1921, Benedict and Hendry used scales sensitive to $\pm$ 10 grams of weight. Measurements of weight were obtained on several groups of females from 12 - 17 years of age each morning upon rising and prior to retiring. Six groups were studied with 11 to 12 females in each group. Water loss was estimated at 33 grams per hour during the night with ambient temperatures of $20^{\circ}C$ and 40% relative humidity. Jean Meyers in 1923, found a high correlation between nutrition and insensible water loss values. His research was done with infants under standard environments with an extremely precise balance, accurate to $\pm$ 1 gram. He concluded that insensible water loss increased immediately after feedings followed by a rapid decrease. Insensible water loss was doubled with protein intake as compared to "sugar" intake. The absolute values for insensible loss may be questioned because of inadequate recording techniques and potential intervening variables such as changing body temperature and respiratory rate.

Changes in body weight have also been used as an assessment tool in more recent studies on insensible water loss. Gump et al. (1968) observed hourly changes in weight on 20 hospitalized patients placed under strict environmental conditions. The ambient air temperature and relative humidity were maintained constant with central air conditioning. Subjects were clothed only in a hospital gown and a single sheet drawn to the waist. An average insensible loss of 23 gm per hour per square meter of body size was obtained from 305 measurements on afebrile patients. Murray et al. (1979) also estimated insensible weight loss by measuring hourly changes in body weight. Four hospitalized patients were followed in a special research unit to determine insensible water loss and total body water balance. Changes in weight were monitored with electronic platform scales accurate to ± 1% of body weight. A calculated daily insensible water loss for each patient is shown in Table 2.

Table 2. Determinations of insensible water loss based on body surface area and body temperature.

Insensible Water Loss ml/hr/M^2	Body Temperature F^o
23	98.0 - 99.9
27	100.0 - 100.9
34	101.0 - 101.9
37	102.0 and Above

(Murray et al., 1979).

Recently, another method of estimating insensible water loss has been investigated. Specific points on the body were evaluated for amounts of vapor loss over a period of time. Lamke, Nilsson and Reithner (1977) used several small isolated areas on the body to calculate values of insensible water loss. Cutaneous insensible perspiration was determined in 10 healthy adult subjects, 5 female and 5 male. Subjects were placed in a specially controlled climate chamber with a constant relative humidity of 30%. Recordings of cutaneous water loss were taken from the specified body areas at three different chamber temperatures. Measures were taken after a 40 minute equilibration period of 22^{o}, 27^{o} and 30^{o} C. An average cutaneous insensible water loss (without respiratory water loss included) of 500 ml per day was found in normothermic subjects with a body surface area of 1.75 square meters.

From the preceding discussion, it is clear that no one method or measure has been found for estimating insensible water loss. Much of the difficulty in assessing water balance is created by this uncertainty. Therefore, the fluid balance equation has been frequently used as a reliable guide for assessment. However, problems quickly arise with calculation of fluid balance.

Inaccuracies in measuring or recording intake or output volumes can frequently occur (Greco, Quintanilla and Huang, 1979; Grant and Kubo, 1975; Gillis, 1978; Freitag and Miller, 1980). Body fluids such as urine or emesis may be inadvertently discarded before being measured and recorded. Patients may receive additional water from family or auxillary personnel who do not inform the patient's nurse that water has been given. Errors in calculation can easily occur. Faced with numerous actual and potential errors associated with intake and output records, some authors recommend observing changes in daily body weight as a more reliable and accurate indicator of fluid balance (Valtin, 1979; Gump et al., 1968; Pflaum, 1979).

Two nursing studies investigating the fluid balance equation and its use have been conducted (Pflaum, 1979; Oveson, 1981). Pflaum (1979) investigated the accuracy of intake and output records completed by nursing staff. Data were obtained from chart records on 30 hospitalized patients with a variety of medical-surgical disorders. Nursing records were used to retrieve data on daily measures of intake and output and daily weight. These data were then used to calculate the change in daily body weight (liters) minus the difference between intake and output. The difference calculated was determined to be an error in measurement on the part of those recording intake and output. The reported mean error was 733.30 ml. Pflaum's criteria for an accurate intake-output record was a difference of no more than $\pm$ 250 ml. She concluded that intake and output was not an accurate method for estimating fluid balance. However, two elements Pflaum failed to consider were: 1) an estimate for insensible water loss and 2) the possibility of an inaccurate daily weight. Few procedural details were outlined in the study.

In an unpublished study, Oveson (1981) also investigated assessment of fluid balance in the clinical setting by nursing staff. Twenty-six hospitalized adult patients who received no solid food were studied. Correlation coefficients were determined between recorded intake and output and change in daily weight. She reported a correlation coefficient (Pearson's) of 0.76 for day one and 0.74 for day two between changes in intake minus output and daily weight. A mean unmeasured loss was calculated from equation 12.

$$I - O - \Delta WT = UML \tag{12}$$

Where:

I = Measurable water intake
O = Measurable water output
ΔWT = Change in daily weight
UML = Unmeasured water loss

Unmeasured water loss in Oveson's study was defined as insensible water loss plus the volume of sweat the subject lost. Results showed UML to be 0.68 $\pm$ 1.02 L and 0.75 $\pm$ 1.08 L for days one and two respectively. Low correlations were found between intake and output records and factors affecting UML, which included body surface area, body temperature and caloric intake. Oveson attributed these results to probable errors in measuring and recording intake, output and/or daily weights.

PROBLEM STATEMENT AND PURPOSE

In the midst of contradiction and controversy, nursing has accepted the challenge and responsibility for assessing, diagnosing and promoting water balance (Aspinal and Tanner, 1981; Metheny and Snively, 1976; Luckman and Sorenson, 1980; Urrows, 1980; Ricci, 1977). Usual assessment methods for nursing are focused on measures of intake and output of body fluids (fluid balance assessment) and occasionally obtaining daily weights. From the assessments and measures, nursing diagnoses are generated and the appropriate therapeutic plan of intervention is determined. However, nursing diagnoses cannot be accurately made without specific signs and symptoms indicating a fluid imbalance.

Currently, there is confusion by clinicians as to accuracy of intake and output measures. Questions are being raised as to accuracy of water imbalance diagnoses based solely on change in daily weight. Little or no information is available regarding the relationship between changes in daily weight and the assessment of fluid balance. There is also lack of agreement among clinicians regarding assessment of total body water balance. Studies in this area have been limited to highly controlled research units which can limit the application of the methods used.

It is therefore the purpose of this study to examine more accurate ways of assessing water balance by finding answers to the following questions:

1. What is the correlation between measurable intake and output (fluid balance) and change in daily weight?
2. What is the correlation between total body water balance and change in daily weight?
3. What is the correlation between unmeasured water loss and change in daily weight?

Finding answers to the above questions will have implications for nursing practice. A higher correlation between total body water balance and change in daily weight would indicate a need for nursing to include water from oxidation and insensible water loss into the assessment equation. A strong correlation would also support the use of change in daily weight as a more reliable measure for changes in water balance.

CHAPTER II

METHODS

Subjects and Setting

Ten hospitalized patients requiring medical and/or surgical intervention were selected by convenience for this study. Ages of subjects varied between 34 and 90 years (mean of 61 years). Only patients with intake and output that was both measurable and recorded were used. All patients were weighed daily on an electronic bedscale (Digitron 200 or Scale-tronix). Subjects were excluded from the study if they presented with any of the following criteria: 1) extensive burns; 2) dialysis; 3) emesis; 4) fecal incontinence; 5) draining wounds or ureterostomies. Any of these problems constitutes a route for unmeasured water loss that would affect fluid balance for that patient. Patients did receive intravenous solutions or tube feedings. Nine subjects were each followed for a 48 hour period (short term patients). A tenth subject was followed for 130 consecutive days (long term patient).

The study took place in two different intensive care units (ICU). The nine short term patients were followed for 48 hours and studied in an eight bed ICU in a community hospital. The one long-term patient was followed in the ICU of a large metropolitan hospital. The ICU setting was selected because fluid intake and output are routinely measured and recorded on all patients. Daily weights are also routinely obtained. Since these procedures are a part of routine care, no patient was subjected to any added risk or cost from procedures of this study.

The ICU environment was monitored throughout the study by means of a wall hygrometer and thermometer. A standard environmental climate was maintained via central air conditioning.

Design and Data Collection

The design for this study was descriptive and correlational. The major independent variable in this study was the difference between intake and output of fluids. Intake and output of fluids were determined for measurable and estimated volumes. Two other variables included change in daily weight and unmeasured water loss. Several variables that may affect the unmeasured water loss value are body surface area, mean body temperature, method of ventilation and ambient temperature. Data measured included sensible water intake, sensible water output, body weight, height, body temperature and ambient air temperature. Data calculated included the difference between measurable intake and output of water, the difference between intake and output of measurable water volume, water of oxidation, change in daily weight for each 24 hour period, daily mean body temperature, daily mean ambient temperature, unmeasured water loss, and insensible water loss. Body surface area was determined from a Dubois nomogram.

Sensible water intake and output was measured and recorded by the ICU staff nurses in the large metropolitan hospital for the one long term patient. For all other patients, sensible water intake and output was measured and recorded every eight hours for 48 hours by the investigator. All intravenous fluids and tube feedings were infused using an electronic infusion pump or via a 100 ml graduated infusion set.

Data Collection Procedure for Short Term Patients

Each patient room was private with a small adjacent room to facilitate storage of collected fluids for measurement by the investigator. Each subject's nurse was instructed by a written message placed in the patient's Kardex to cap and save all specimens and intravenous solution bottles used for that subject. Measures were taken and recorded at the end of each eight hour shift. The patient's nurse was instructed to mark the original full fluid line prior to administration of all intravenous solutions. Tube feeding mixtures were premeasured by the investigator to be infused over the following eight hours. Actual volumes of intravenous solution and tube feeding mixture were determined at the end of each eight hour shift. The volume of fluid remaining was measured using a graduated container. The infusion bottle was refilled to the original full fluid line as previously marked by the nurse. This volume was then measured in the same graduated container. The difference between the two measured volumes was considered to be equal to the volume infused. Calculated values for volumes of fluid infused were checked for gross error by comparing the calculated differences with values recorded by the ICU staff nurse assigned to the subject. Fluid volumes infused were summed each eight hour shift and for the three shifts to obtain a 24 hour total. This procedure was followed for two consecutive 24 hour periods.

Measurement of output fluids was done in a similar manner. All patients had an indwelling foley catheter. Urine output was measured and recorded for each eight hour shift. Urine was stored in a capped container and saved in the adjacent room for measurement by the investigator. All fluid was measured in one calibrated measuring device for each patient. Each patient's nurse was questioned to determine if spillage occurred from any specimen during the eight hour period. Subjects were eliminated from the study for that day when spillage occurred. Gastrointestinal output was saved and measured in the same manner as urine output.

Daily weights were obtained in the early morning by a nurse or the investigator. A Digitron 200 or Scale-tronix brand digital scale was used for obtaining the weights. Prior to each weighing, the scale was set at zero. The manufacturers calibrated both scales prior to shipment to each hospital. Reported accuracy of both scales was within $\pm$ 100 gm. Weights were recorded after correction for clothing worn during the procedure. The weight of all clothing worn and linen covering the patient was determined separately and subtracted from the initial weight value. This procedure was done in order to obtain the patient's actual weight.

Height for all subjects was obtained from the chart as recorded from a prior standing measurement. Body temperature was measured by each subject's nurse using an IMED brand electronic thermometer. All temperatures were taken rectally and recorded every four hours. Ambient room temperature was found to vary only between 22 - 25^{o} C. Therefore, ambient room temperature was eliminated as a variable in this study.

Body surface area was obtained from a nomogram which correlates height, weight and body surface area in square meters (DuBois and DuBois, 1916). The volume of water produced by oxidation was determined to be 200 ml per day when calorie expenditure varies between

1400 and 2200 calories per day. This is the usual caloric expenditure in most hospitalized patients (Gump et al., 1968). Values for insensible water loss were determined for each patient using a standard value reported by Murray et al. (1979) (Table 2).

The difference between sensible water intake and sensible water output was obtained by subtracting the summed 24 hour output from the summed 24 hour intake. The difference between intake and output of sensible and insensible volumes was calculated using equation 7.

Change in daily weight was calculated by subtracting daily body weight from the previous day's weight. Unmeasured water loss was calculated by subtracting daily change in body weight (liters) from the difference between intake and output for the same period. Unmeasured water loss was calculated from equation (11). Mean daily body temperatures were calculated for each patient. Patient's using ventilators or other kinds of nebulized oxygen administration were noted.

Data Collection Procedure for the Long Term Patient

Data for the one long term patient were obtained from chart records. The data included intake and output volumes, daily weight, height and body temperature. An average environmental climate of 53% humidity and 23° C was maintained by central air conditioning. Bedscales (Scaletronix) were used daily and stated by the manufacturer to be accurate to $\pm$ 100 grams. The weighing procedure included zeroing the scales prior to each measurement. The weight reported in the chart was corrected for the weight of bed clothing which was covering the patient.

Tube feedings were continuous and delivered through an electronic pump which displays the volume of fluid infused in milliliters. The nurses recorded the volume infused every eight hour shift. Hourly urine output measurements were obtained using a clear plastic graduated measuring device. This long term patient was selected for addition into the study because of the constant conditions maintained by the disease process and environment. She was also included because she represents a commonly encountered fluid management problem.

CHAPTER III

RESULTS

Characteristics of the Patient Population

A convenience sample of patients who met the selection criteria and were admitted to the intensive care unit of two different hospitals composed the population of ten subjects. Nine of the ten patients were monitored for two consecutive days (short term patients). One patient was monitored for 130 consecutive days (long term patient). Summary data of patient characteristics are presented in Table 3. Ages ranged from 34 to 90 with a mean of 61 years. One half of the subjects were female and the other half male. All but one subject had some type of neurological problem.

The nine short term patients had several characteristics in common. All but one patient were nonambulatory. One patient was able to ambulate with a cane and assistance to use the bathroom. All of the patients were well covered with closely fitting bed clothing. Seven of the nine short term patients wore thigh length support stockings. Eight of the nine patients had pillows tucked closely to the back or legs to aid in body alignment. Three patients had tightly fitted head dressings (turbans) in place. All of the short term patients received intravenous fluid therapy. Three of these subjects were also given tube feedings for nutritional supplement.

All but one of the subjects received humidified oxygen therapy. Four of the eight patients received therapy through a nasal cannula, two had oxygen administered via a facial mask and two were intubated. Of the two intubated patients, one received constant mechanical ventilation and the other constant humidified oxygen through a tracheostomy (Table 3). Body temperatures were generally within the normal range and fluctuations were small. Only two subjects had fevers of 101.0 - 101.9^0 F and these lasted approximately four hours each. One subject had a four hour fever of 102.0^0 F (Table 5).

Data from the long term patient are also shown in Table 3. This patient presented with minimal skeletal muscle activity because of generalized paralysis. Bed clothing tightly covered most of this patient's skin surface. Fluid and nutritional supplements were provided via continuous tube feedings. Constant humidified oxygen therapy was administered into her tracheostomy tube by means of a mechanical ventilator. Temperature fluctuations were remarkably small through the study period (Table 6). Occasional temperature elevations of 100.0 - 100.9^0 F were recorded with no elevations greater than 101.0^0.

Body surface areas for the ten patients ranged from 1.50 - 1.94 square meters. Heights ranged from 157 - 180 cm and weights from 52.5 - 77 kg (Table 4).

Table 4. Body Surface Area for Each Subject.

Subject	BSA m^2	Ht cm	Wt kg
1	1.85	178	72.0
2	1.72	167	66.1
3	1.58	157	59.0
4	1.85	178	70.0
5	1.94	180	77.0
6	1.75	178	61.5
7	1.70	170	62.7
8	1.57	166	53.8
9	1.68	168	60.8
10	1.50	158	52.5

Ambient temperatures ranged from 22 - 25° C with a mean of 23° C. Room humidity ranged between 52 and 55% with a mean of 54.5%. Since both ambient temperature and humidity were essentially constant they were eliminated as variables affecting changes in insensible water loss.

Summary Data for Short Term Patients

All but one of the patients had a greater measured fluid intake than measured output. The differences between intake and output ranged from 30 to 2,020 ml. Subject 9 was given frequent and large doses of an osmotic diuretic which promoted the high fluid output. A summary of data obtained are included in Table 5.

Weight did not always change in the same direction as the difference between intake and output. Weight remained unchanged or decreased in six of the eight patients who received more fluid intake than measured output. The correlation coefficient (Pearson's r) was calculated for the difference between intake and output (I - O) and the change in daily weight (Table 7; Figure 3). Even when values for insensible water loss and water production were accounted for in the water balance equation (ΔH_2O), changes in weight were not always consistent in representing changes in water balance. Four of the nine short term patients had changes in weight in the opposite direction expected from the water balance value. The correlation coefficient (Pearson's r) was calculated for the relationship between water balance and daily weight changes (Table 8; Figure 5).

According to the water balance model presented, unmeasured water loss values should closely approximate insensible water loss values. Differences between the two variables ranged from 18 to 1,384 ml for all the short term subjects. The calculated values for insensible water loss were similar to those reported in the literature and ranged from 867 to 1,170 ml. Unmeasured water loss values, however, ranged from -335 to +1,620 ml. It is apparent by visual inspection that little correlation exists between insensible water loss and unmeasured water loss (Table 5).

The relationship between unmeasured water loss and change in daily weight is shown in Figure 7. The correlation coefficient (Pearson's r) is shown in Table 9 for the short term subjects. In general, this correlation was lower than expected and quite different from the water balance and change in weight correlation reported in Table 8.

Summary Data for Long Term Patient

Data were collected for 130 consecutive days on the long term patient. These data were averaged into five day intervals which provided 26 "sets" of data for comparisons (Table 6). Intake values were all greater than output values. This difference ranged from 46 to 590 ml. Changes in weight were variable. Fourteen of the 26 averaged values indicated a loss of weight even though fluid intake was greater than output. Twelve of the 26 values indicated a weight gain. The correlation coefficient (Pearson's r) was calculated for the difference between intake and output (I - O) and change in daily weight (Table 7; Figure 4).

When insensible water loss and water production were calculated into the water balance equation, changes in weight were not consistently related to changes in water balance. Twelve of the 26 calculations indicated weight changes in the opposite direction of the water balance values (Table 6, Figure 6). Table 8 shows the correlation coefficient (Pearson's r) calculated for the water balance values and daily change in weight for the long term patient.

Unmeasured water loss and insensible water loss values were widely divergent. Differences between the two values ranged from 176 to 793 ml. Calculated values for insensible water loss were reasonably constant for the long term patient. Unmeasured water loss ranged from 35.2 to 652 ml over the study period. A correlation coefficient was calculated for unmeasured water loss and change in daily weight (Table 9). This relationship is shown in Figure 8.

Table 3. Individual Patient Characteristics Data for All Subjects

Subject	Age	Sex	Diagnosis	Respiratory Rate/Pattern	Activity	Clothing	Type Fluid Intake	Type Oxygen Therapy
1	34	M	Left frontal subdural hematoma	16-20/min. regular	Bedrest-turns self	Gown Sheet 2 Pillows Bedspread Headdressing	IV	Nasal cannula mist
2	76	M	CVA/atrial flutter	16-24/min. regular	Comatose-decorticate posturing	Gown Sheet Thigh stockings 4 Pillows	IV/TF	Nasal cannula mist
3	51	F	Colectomy	14-22/min. regular	Bedrest-turns self	Gown Sheet Thigh stockings 3 Pillows Bedspread Abd. dressing	IV	Nasal cannula mist
4	46	F	C_{6-7} fracture/ Stable	12-18/min. regular	Bedrest	Gown Sheet Thigh stockings	IV	Facial mask mist
5	63	F	Left temporal subarachnoid hemorrhage	14-24/min. regular	Bedrest	Gown Sheet Thigh stockings 3 Pillows	IV	Nasal cannula mist
6	58	M	Brainstem infarction	12-16/min. irregular	Bedrest	Gown Sheet Thigh stockings 3 Pillows	IV/TF	Tracheostomy mist
7	65	M	Brain abscess	16-24/min. regular	Bedrest	Gown Sheet Thigh stockings 3 Pillows Headdressing	IV/TF	Facial mask mist
8	90	M	Concussion	16-20/min. regular	Bedrest Ambulates with Assistance	Gown Sheet Ankle Stockings 2 Pillows Bedspread Bathrobe Blanket	IV	Roomair
9	59	F	Right temporal meningioma/ craniotomy	12/min. regular	Comatose-Flaccid	Gown Sheet Thigh Stockings 3 Pillows Bedspread Headdressing	IV	Nasotracheal ventilator mist
10	68	F	Guillian Barre'	12/min. regular	Complete paralysis C_1 and below	Gown Sheet Thigh Stockings	TF	Tracheostomy ventilator mist

Table 5. Data Collection Summary for Short Term Subjects

	ml	ml	ml	ml	ml	ml	ml	Hours of Body Temp. F^o				M^2	Kg
Subject	I	O	I-O	ΔWt	ΔH_2O	UML	INS	98.0 99.9	100.0 100.9	101.0 101.9	102.0 102.9	BSA	Wt.
1												1.85	72.0
I	1440	1275	165	+500	-684	-335	1049	24					72.5
II	1350	1020	330	+200	-580	130	1110	16	8				72.7
2												1.72	66.1
I	1555	1150	405	+200	-389	205	994	20	4				66.3
II	1255	1225	30	0	-763	30	966	24					66.3
3												1.58	59.0
I	4190	3680	510	-500	-282	1010	992	12	8	4			58.5
II	3370	3110	260	0	-412	260	872	24					58.5
4												1.85	70.0
I	1580	1160	420	0	-401	420	1021	24					70.0
II	1420	1075	345	-1100	-506	1445	1051	20	4				68.9
5												1.94	77.0
I	1260	910	350	-600	-620	950	1170	12	12				76.4
II	1455	1220	235	-200	-735	435	1170	12	12				76.2
6												1.75	61.5
I	1998	1330	668	-900	-132	1568	1000	20	4				60.6
II	1800	1025	775	-600	- 25	1375	1000	20	4				60.0
7												1.70	62.7
I	3095	1075	2020	+400	+1077	1620	1143	12	4	4	4		63.1
II	3150	1520	1630	+500	+ 728	1130	1102	8	12	4			63.6
8												1.57	53.8
I	1235	810	425	-300	-242	725	867	24					53.5
II	1800	1020	780	+200	+113	580	867	24					53.7
9												1.68	60.8
I	1522	3120	-1598	-1900	-2364	302	966	20	4				58.9
II	1122	1775	-653	- 900	-1391	247	938	24					58.0

Table 6. Data Collection Summary for Long Term Subject

5 Day Average 'Sets'	ml I	ml O	ml I-O	ml ΔWt	ml ΔH_2O	ml UFL	ml INS	Hours Body Temp. F° 98.0 99.9	100.0 100.9	101.0 101.9	102.0 102.9	M² BSA
1	1766	1408	358	40	-270	318	828	120				1.5
2	1890	1574	315	280	-312	35	828	120				
3	2070	1954	116	-120	-512	236	828	120				
4	1791	1606	186	-280	-442	466	828	120				
5	2173	1951	222	-240	-406	462	828	120				
6	2070	1843	223	60	-410	163	832	116	4			
7	2189	1792	397	20	-231	377	828	120				
8	1947	1596	351	-120	-330	471	881	76	44			
9	1920	1618	301	- 40	-326	341	828	120				
10	2278	1688	590	- 20	- 38	610	828	120				
11	2130	1882	248	180	-380	68	828	120				
12	2110	1683	295	160	-205	135	832	116	4			
13	1758	1503	254	20	-373	234	828	120				
14	2101	1594	508	260	-120	248	828	120				
15	1948	1498	450	40	-188	410	838	112	8			
16	1638	1236	401	60	-226	342	828	120				
17	1444	1398	46	-160	-582	206	828	120				
18	1495	1332	236	-200	-464	436	828	120				
19	1724	1272	452	-200	-176	652	828	120				
20	1576	1506	70	-120	-596	190	866	88	32			
21	1568	1373	195	80	-432	115	828	120				
22	1837	1548	289	- 80	-352	369	838	112	8			
23	1544	1290	253	-200	-374	453	828	120				
24	1510	1034	477	- 20	-163	497	840	110	10			
25	1574	1360	214	40	-414	174	828	120				
26	1636	1102	533	- 20	- 94	553	828	120				

Table 7. Regression Constants and Correlation Coefficients for the Difference Between Intake and Output *vs* Change in Daily Weight.

Short Term Subjects (Figure 3)

	A			B		
	Day I	Day II	$\overline{X}$	Day I	Day II	$\overline{X}$
r	0.25	0.38	0.31	0.72	0.56	0.65
Slope	0.29	0.38	0.34	0.88	0.65	0.76
Intercept	644	596	630	678	551	614
N	8	8		9	9	

Long Term Subject (Figure 4)

r	0.32
Slope	0.30
Intercept	314
N	26

Mean values for *r* were calculated using Fisher's Z transformation.

A = Excluding patient 9 } See text for details
B = Including patient 9 }

Table 8. Regression Constants and Correlation Coefficients for Changes in Water Balance *vs* Change in Daily Weight.

Short Term Subjects (Figure 5)

	A			B		
	Day I	Day II	$\overline{X}$	Day I	Day II	$\overline{X}$
r	0.24	0.39	0.32	0.72	0.57	0.65
Slope	0.26	0.39	0.32	0.85	0.63	0.74
Inter-cept	-170	-223	-196	-157	-263	-210
N	8	8		9	9	

Long Term Subject (Figure 6)

r	0.39
Slope	0.38
Inter-cept	-315
N	26

Mean values for r were calculated using Fisher's Z transformation.

A = Excluding patient 9 } See text for details
B = Including patient 9 }

Table 9. Regression Constants and Correlation Coefficients for Unmeasured Water Loss vs Change in Daily Weight.

Short Term Subjects (Figure 7)

	A			B		
	Day I	Day II	$\overline{X}$	Day I	Day II	$\overline{X}$
r	-0.53	-0.56	-0.54	-0.14	-0.35	-0.25
Slope	-0.71	-0.62	-0.66	-0.12	-0.35	-0.24
Intercept	644	596	630	678	551	614
N	8	8		9	9	

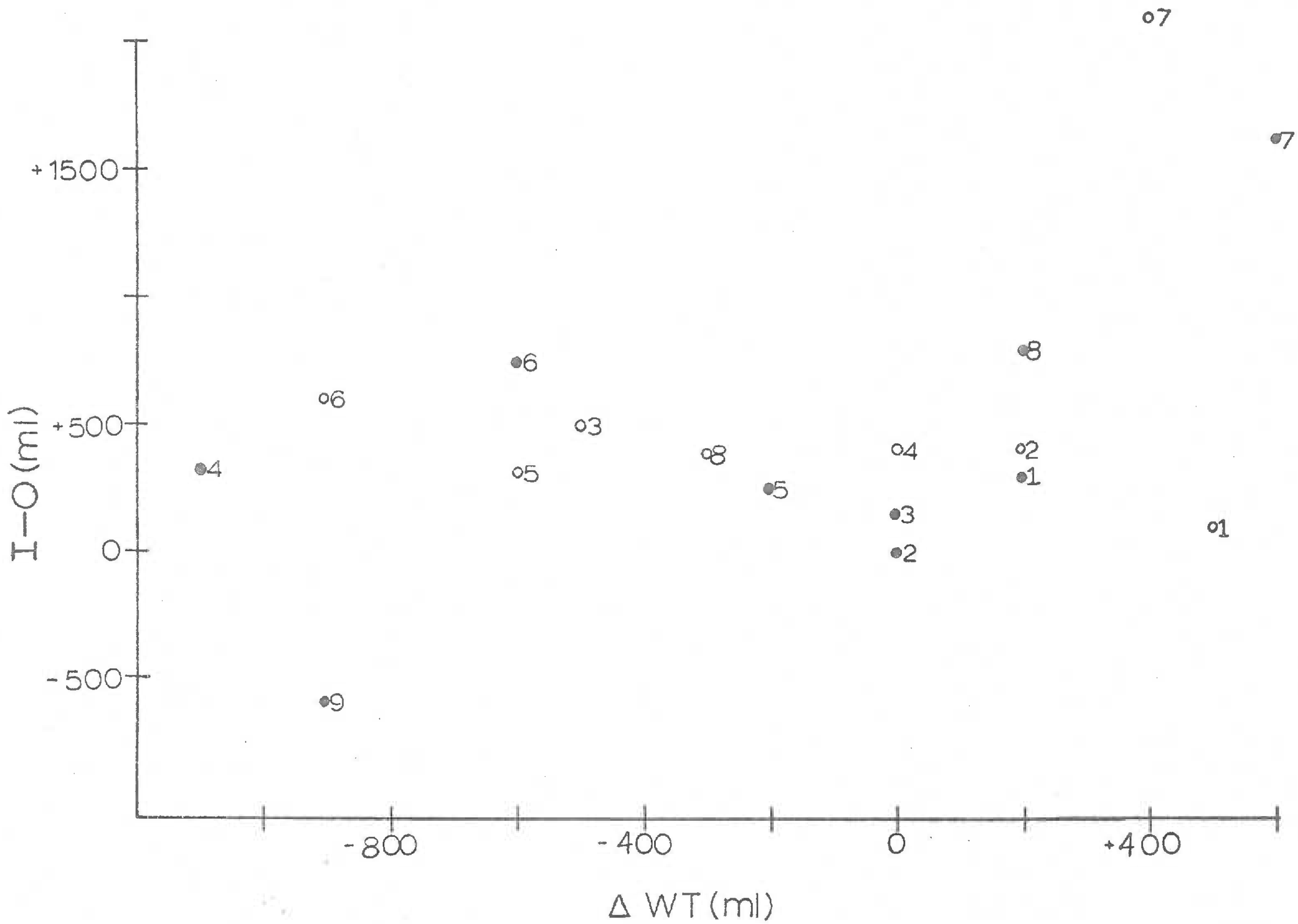
Long Term Subject (Figure 8)

r	-0.61
Slope	-0.70
Intercept	314
N	26

Mean values for r were calculated using Fisher's Z transformation.

A = Excluding patient 9 }
B = Including patient 9 } See text for details

Figure 3. The difference between intake and output (ml) *vs.* change in daily weight (ml) for short term subjects.
Day 1 = O   Day 2 = ●



I—O (ml)
+1500
+500
0
-500
-800
-400
0
+400
Δ WT (ml)

Figure 4. The difference between intake and output (ml) *vs.* change in daily weight (ml) for the long term subject. Each point represents an average of five days.

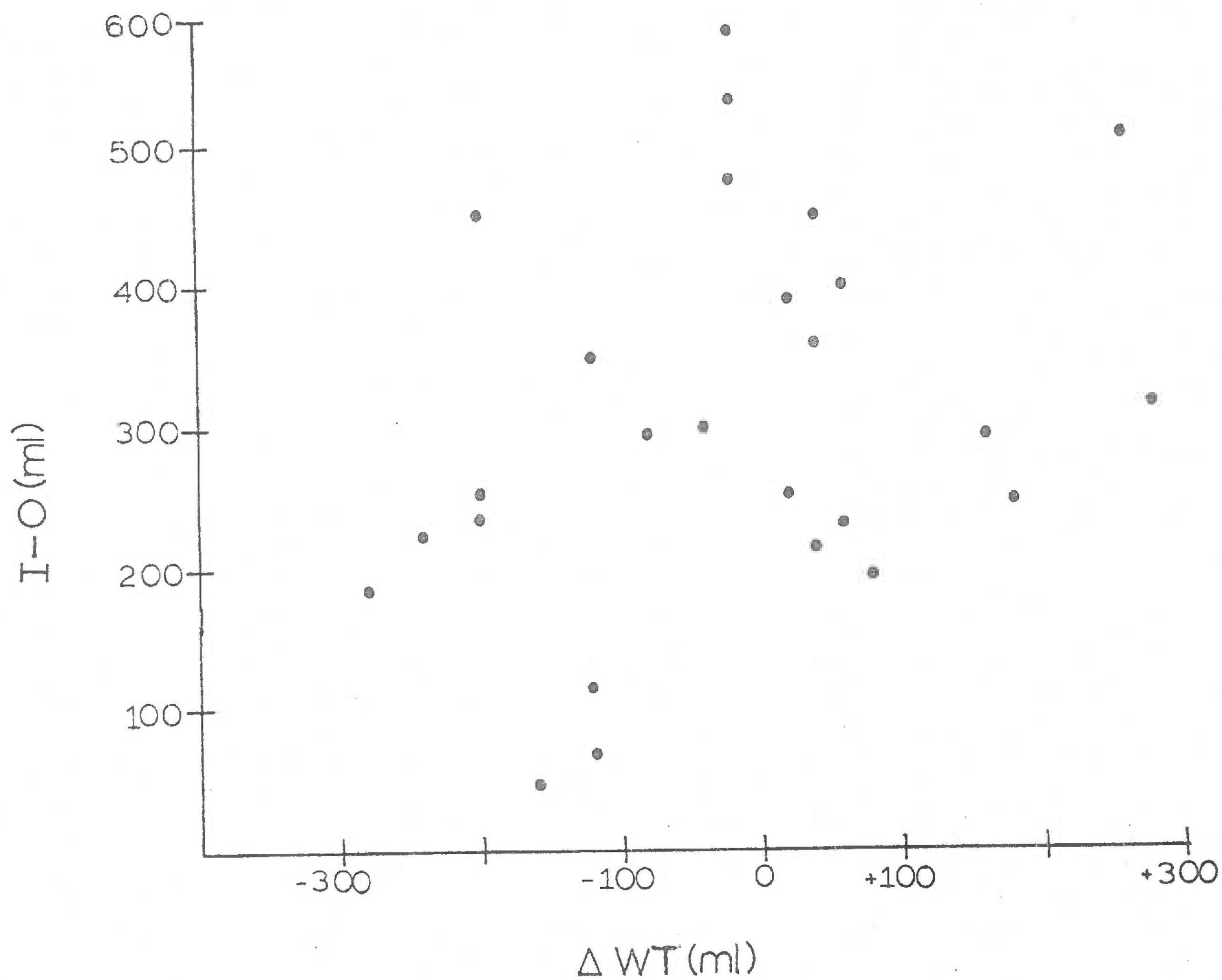
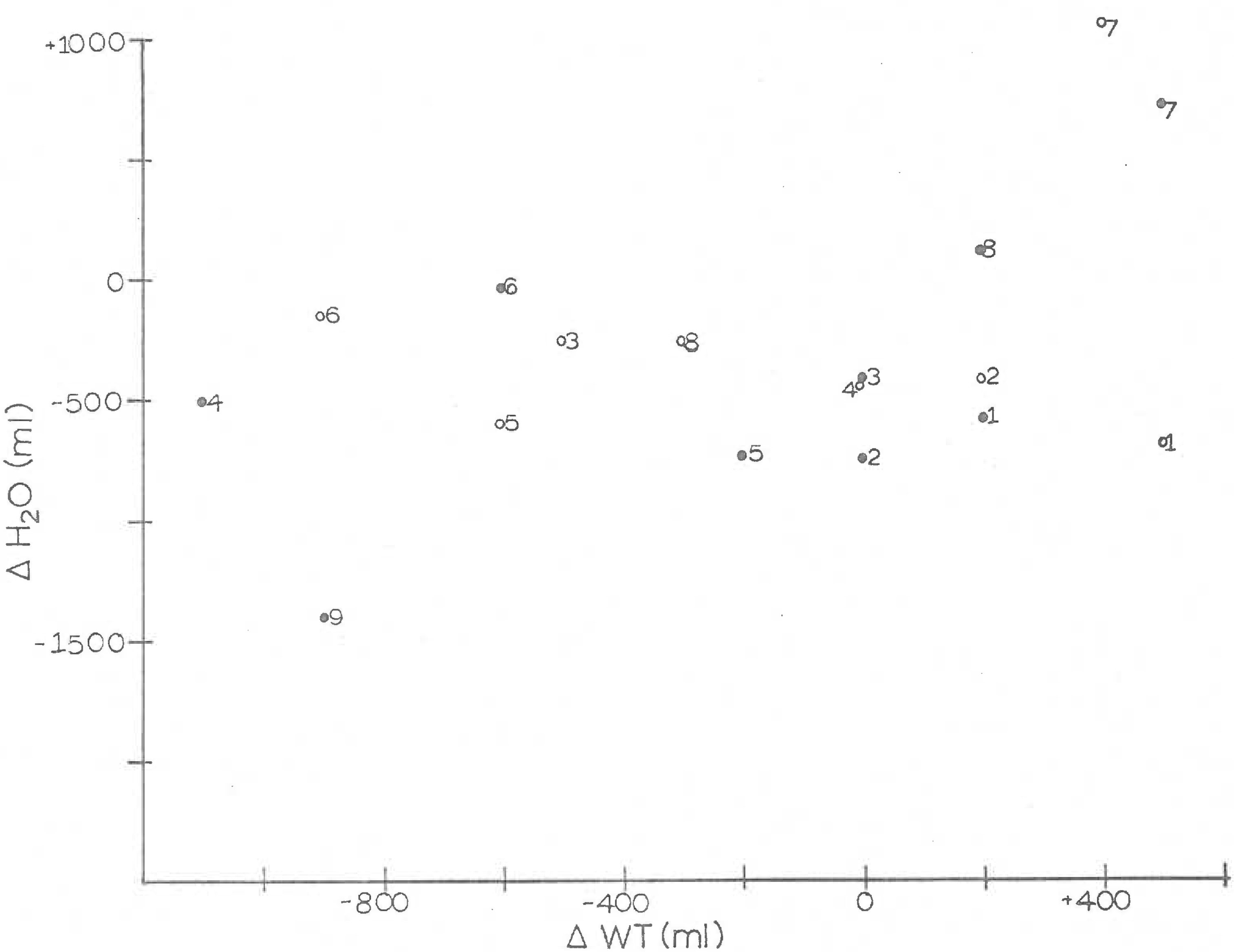

600
500
400
300
200
100
I–O (ml)
-300
-100
0
+100
+300
Δ WT (ml)

Figure 5. Water balance (ml) vs. change in daily weight (ml) for short term subjects.
Day 1 = 0 Day 2 = ●



+1000
0
-500
-1500
Δ H2O (ml)
-800
-400
0
+400
Δ WT (ml)

Figure 6. Water balance (ml) vs. change in daily weight (ml) for the long term subject. Each point represents an average of five days.

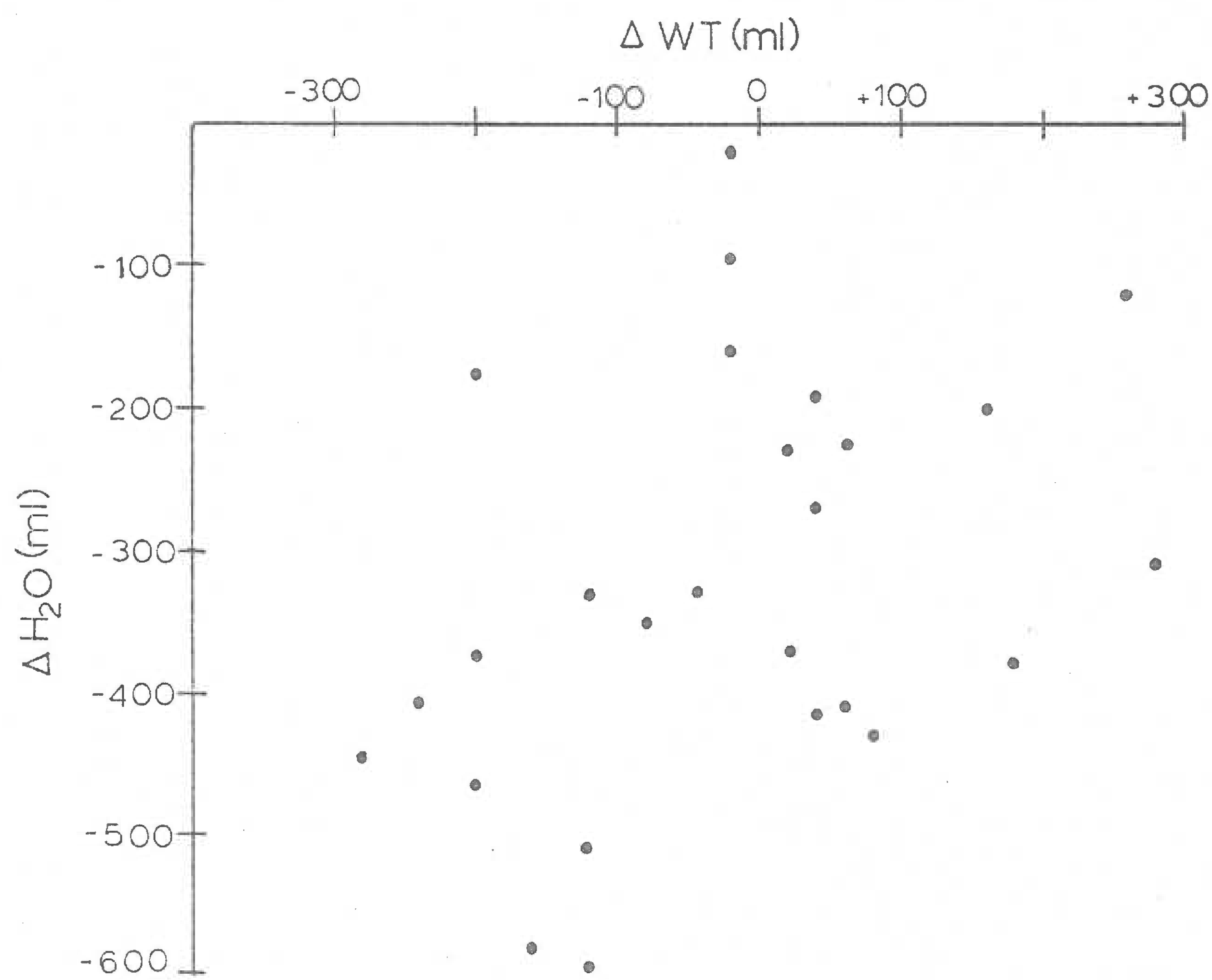
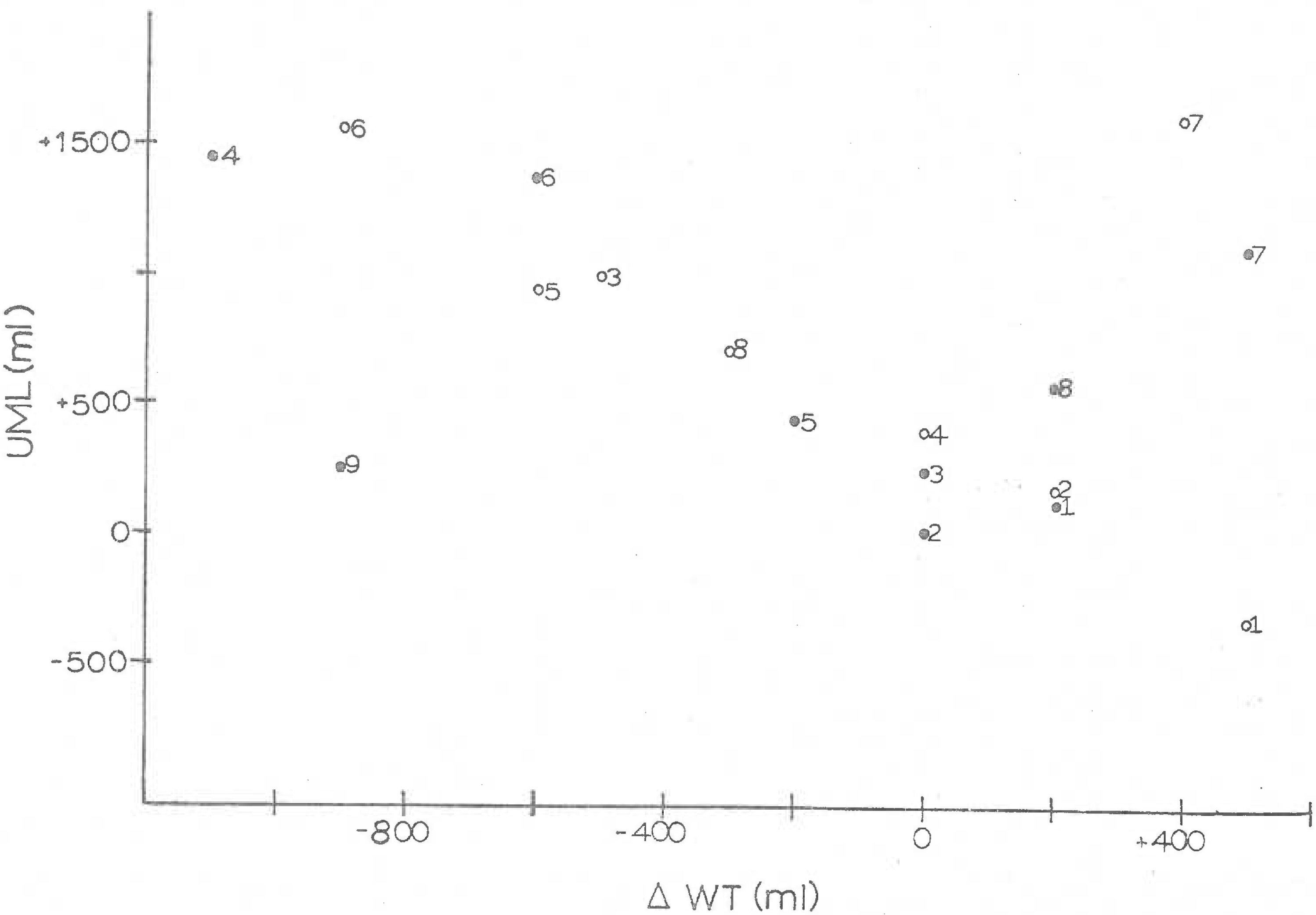
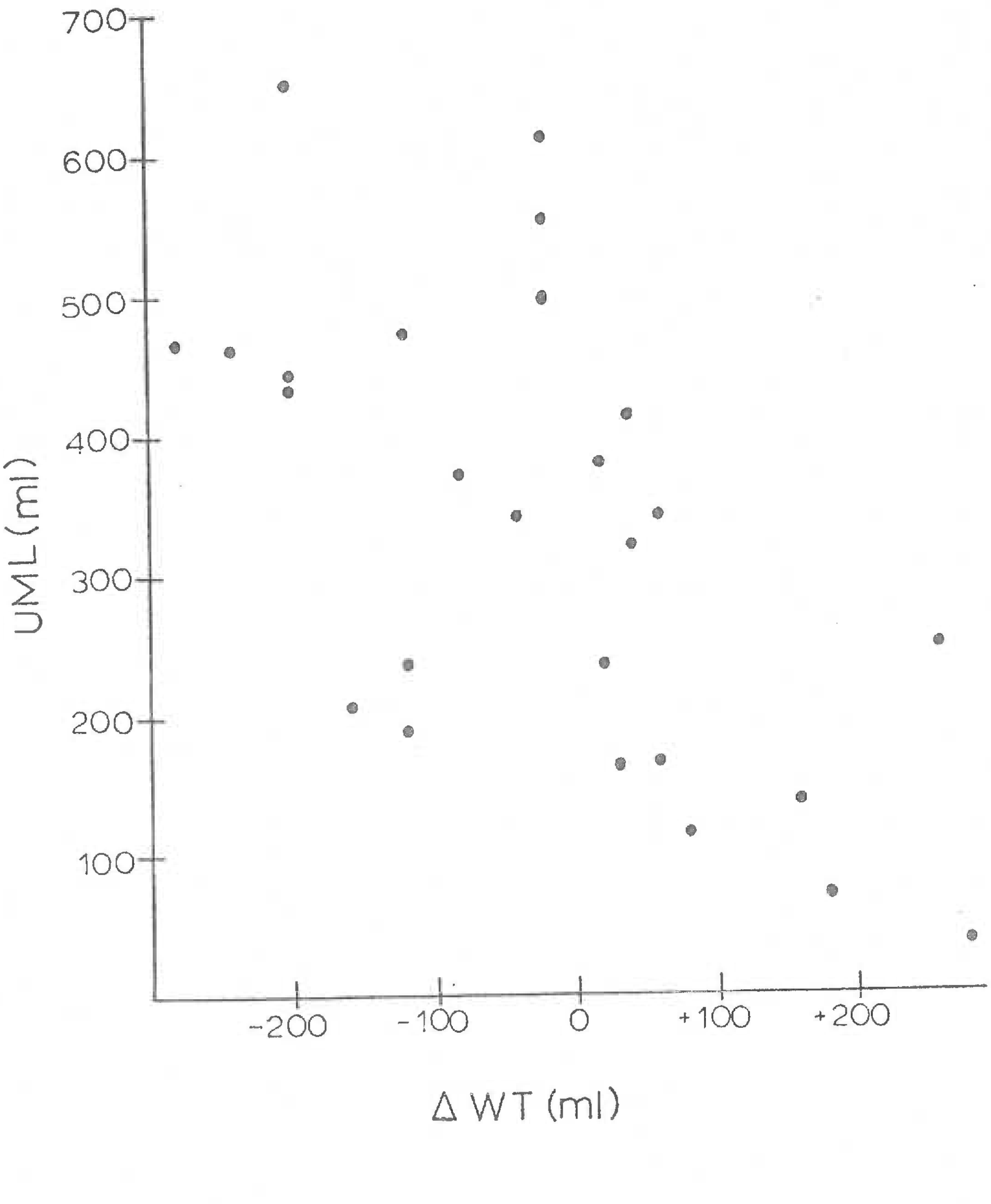

Δ WT (ml)
-300
-100
0
+100
+300
Δ H2O (ml)
-100
-200
-300
-400
-500
-600

Figure 7. Unmeasured water loss (ml) <u>vs.</u> change in daily weight (ml) for short term subjects.
Day 1 = O   Day 2 = ●



+1500
+500
0
-500
UML (ml)
-800
-400
0
+400
Δ WT (ml)

Figure 8. Unmeasured water loss (ml) _vs._ change in daily weight for the long term subject. Each point represents an average of five days.


700
600
500
400
300
200
100
UML (ml)
-200
-100
0
+100
+200
Δ WT (ml)

CHAPTER IV

DISCUSSION

The findings of this study are discussed in terms of characteristics of the patients which affect rates of water production (water from oxidation) and insensible water loss. Fluid balance, water balance and unmeasured water loss are also examined in relation to change in daily weight.

Characteristics

Subjects in this study had several characteristics in common that provided the rationale for selecting a single value for the water produced by oxidation. All but one subject had activity levels limited to bedrest. The one individual was able to ambulate with assistance for bathroom privileges. All subjects received some type of fluid therapy which provided glucose and/or nutritional supplement. This type of fluid therapy minimized or prevented muscle wasting which could increase the volume of water production. Body temperatures were also essentially normal and remained fairly constant for all subjects. Normal body temperatures maintain a stable metabolic rate and therefore, a constant rate of water production. The actual value chosen, 200 ml/day, was the mean value in the range of 150-250 ml/day reported by Gump et al., (1968).

Insensible water loss may also have been affected by various characteristics of the sample population. Individual volumes for insensible water loss were based on the values presented by Murray et al., (1979). However, the subjects in his study had characteristics that differed from those in this research study. Some major differences between the two included the type of bed clothing worn by the subjects and the use of humidified oxygen therapy. Subjects in the present study were well covered with fitted, thigh length elastic stockings and had pillows tucked closely against the skin surface. Humidified oxygen therapy was administered to all but one subject (Table 3). Both the added clothing and humidified oxygen therapy may have decreased the actual amounts of insensible water lost.

Although these characteristics may alter the value of the estimated components in the water balance equation, these are typical characteristics of patients in an intensive care setting. These subjects also represent the broad range of diagnoses and ages of hospitalized patients. However, the diagnoses and ages do not directly affect water balance. Water balance is based on measured intake, measured output, water of oxidation and insensible water loss. Correlations can therefore be derived with this age range of subjects. It is interesting to note that data from patient 8 (90 years old) lies with the main body of data in Figures 3, 5 and 7.

Fluid Balance

Fluid balance assessment is based on measurable fluid intake and output volumes. Correct assessments can only occur if all fluids are measured and recorded accurately. Pflaum (1979) and Oveson (1981) concluded that measurements of fluid intake and output are too inaccurate for clinical assessment of fluid balance. Pflaum recommended that nursing assessment of fluid balance be based on change in daily weight. Oveson noted the high potential error in collecting measurements of fluid intake and output. She recommended conducting a nursing study on fluid balance assessment where a single investigator completed the task of measuring and recording both intake and output.

In the present study, daily weights were measured as suggested by Pflaum. In addition, a single investigator measured intake and output of fluids for nine short term subjects. The long term subject had a reduced risk of error in measuring fluid intake and output as a result of having only two types of fluid to measure. Also, her tube feeding intake was measured by the use of an electronic control pump. Urine output was measured and recorded hourly using the graduated collection device attached to the foley catheter. This reduced the risk of urine spillage. Weights were measured daily using an electronic bed scale.

Calculated fluid balance (intake-output) was compared to change in daily weight. The correlation coefficients (Pearson's r) were calculated for the difference between intake and output and daily weight change for both the short term patients and the long term patient (Table 7, Figures 3 and 4). Data for short term patients (1 - 8) are shown in the first column of Table 7. When data for patient 9 were included, the correlation coefficient increased from an average of +0.31 to +0.67 and the slope from an average of +0.34 to +0.80. This separate calculation was completed because patient 9 was at an extreme range and weighted the results. Patient 9 was the only subject to receive osmotic diuretic therapy which produced a much larger output of fluid than intake. However, no other significant clinical differences were identified.

The correlation coefficient between fluid balance and change in daily weight for the long term subject was +0.32. The slope obtained from the regression analysis was +0.30 (Table 7, Figure 4). There was little difference between the correlation coefficient obtained from short term patients (1 - 8) data and that from the long term patient. These correlations are also much lower than those presented by Oveson (1981). Oveson reported correlation coefficients (Pearson's r) between changes in daily weight and the difference between intake and output for 26 subjects as +0.76 (Slope = 1.03) for Day I and +0.74 (Slope = 0.83) for Day II. Methods used by Oveson were quite similar to those used for the long term patient in this study.

Several factors may contribute to this discrepancy. First, errors may have occurred in the collection and measurement of fluid output for the long term patient in this study. Urine was measured and recorded hourly using the graduated device attached to the catheter bag. The accuracy of calibration for this device is not known. Errors may have also occurred if hourly output measurements were not read at eye level (as may occur with a foley catheter device). Volumes of unmeasured saliva from this patient who couldn't swallow because of a tracheostomy may have markedly altered the value of the correlation coefficient.

The difference between Oveson's results and results from this study may be a result of a smaller number of subjects used in the present study. This difference may account for a different value for r, but does not necessarily explain the wide discrepancy in the slopes obtained in the two studies. If patient 9 is included then the slopes and correlation coefficients for the two studies are similar.

Water Balance

Assuming that daily weight measurements were accurate and that fluid and water balance assessments were correct, one would expect to see a higher correlation between water balance assessment and change in daily weight than for fluid balance assessment and change in daily weight. A higher correlation would be expected because of the inclusion of unmeasurable as well as measurable fluid volumes.

The correlation coefficient between water balance and change in daily weight was calculated for both the short term and long term subjects. The short term subjects (1 - 8) had a correlation coefficient which averaged +0.32 and a slope of +0.32. When subject 9 was included, the value of r increased to an average of +0.65 and increased the slope to +0.74. Separate calculations were again completed because the extreme range of data from patient 9 weighted the results. The correlation coefficient and slope calculated from the data obtained from the long term patient was +0.39 and +0.38 respectively. The correlation coefficients relating change in weight to either water balance were essentially the same. The expected higher correlation between water balance and change in weight was not found.

There are at least four possible explanations for the poor correlation obtained: 1) errors in measuring and/or recording intake and output; 2) errors in measuring and/or recording daily weights; 3) inaccurate values for insensible water loss and 4) inaccurate values used for water production by oxidation reactions.

The first two errors apply to assessment of both fluid and water balance. The last two sources apply only to calculated water balance. Errors in measuring and recording intake and output can be minimized by nursing diligence when collecting these measurements. Other sources of error have already been discussed above. These include miscalibrated measuring devices and not including fluids that are difficult to collect or measure such as saliva or fecal excretion. Even when a single investigator measures all the fluids collected from the subjects, potential errors still exist.

A second source of error may have occurred as a result of inaccurate weight measurements. The scales used in both hospitals for this study are reported to have a mean error of $\pm$ 100 gms when calibrated correctly and used properly. Calibration of the scales was completed by each manufacturer prior to shipment to each hospital. Recalibration was not completed since neither hospital owned the precise weights required for this procedure. Therefore, the true accuracy of the scales is left in doubt. Besides this potential calibration error, problems can occur in the nursing procedure used to weigh the patient. Nurses must take care to zero the scale prior to use, weigh the patient at the same time each day, weigh with precisely the same amount of dry clothing and use the same scale each day. Only by this type of procedure can weights be used for comparison from one day to the next to estimate water balance. This procedure was followed for the short term patients and reportedly followed for the long term patient.

A third source of error in the water balance assessment may be from an inaccurate estimate of insensible water loss. This investigator calculated insensible water loss using the equation of Murray et al., (1979). Differences between estimates recommended by Murray and those volumes actually lost by the subjects may have occurred due to differences in the clothing worn and the presence of humidified oxygen therapy.

The fourth source of error in the water balance calculation may be in the value chosen for the volume of water produced by cell metabolism.

Although a value of 200 ml/day was chosen because of patient similarities in activity level and fluid therapy, larger differences may have actually occurred.

Unmeasured Water Loss

There are obviously many difficulties in assessing water balance. It was for this reason that the equation for calculating unmeasured water loss was created (equation 12). It was hoped that calculation of an unmeasured water loss value would reflect a more accurate volume of fluid lost insensibly and through other unmeasured routes. If one assumes the measurable fluid intake and output values have been accurately assessed and that change in daily weight has been obtained correctly, then the volume of unmeasured fluid can be accurately calculated. A high correlation coefficient was expected between the unmeasured water loss value and change in daily weight. This expectation was based on the fact that change in weight is a component of the unmeasured water loss calculation. The correlation coefficient found between unmeasured water loss and change in weight for the short term patients (1 - 8) averaged -0.54 and an average slope of -0.66. When patient 9 was included in the calculation, the coefficient decreased to an average of -0.25 and a slope averaging -0.20. The long term subject had a correlation coefficient of -0.61 and a slope of -0.70. The low correlations seen may be an indication of errors in measuring and recording fluid intake and output or in obtaining daily weights.

It is interesting to note that values for unmeasured water loss were consistently smaller than the estimates for insensible water loss. This may relfect the characteristics of the intensive care patient population who frequently have humidified oxygen therapy and occlusive bed clothing that reduce insensible water loss.

In summary, accurate fluid balance assessment coupled with carefully obtained daily weights may be the best method for generating a nursing diagnosis for fluid imbalance. Too many errors in estimating water production and insensible water loss values can occur in the water balance assessment to accept its usefulness to nursing diagnosis at this time.

Clinical Implications

Nurses must be aware of the potential errors in the methods used to assess fluid balance and daily weight changes. Accuracy must be a part of the procedure when monitoring fluid intake and output. Nurses can help to ensure accuracy in the data collection procedure for intake and output of fluids in the following ways: 1) communicate to each nurse by means of the Kardex or door sign that the patient is having fluids measured; 2) communicate to the patient and family about fluid balance assessment procedure and its importance to the patient's welfare; 3) have paper readily accessible to record all fluids measured and 4) ensure access to accurate measuring and recording equipment. Daily weights must become a natural part of the hospital routine, with accessible calibrated bed scales. Decisions by the primary nurse regarding the amount of clothing worn or not worn by each patient should be made and communicated to the other staff who weigh the patient. Realistic amounts of time should be allotted for each weighing procedure to assure accuracy and reproducible readings.

Limitations of the Study

The major limitation of this study was the small sample size. A larger sample may have determined whether patient 9 were from a unique and different population or if he were a subject from this population of hospitalized subjects. The data from all these subjects may have been affected by potentially inaccurate bed scales. Recalibration of the bed scales would provide a more precise means of data collection.

Another limitation involves the estimates for unmeasured fluid lost by insensible means and values for water production. Large errors were quite possible in the estimate of insensible water loss. More research is needed on insensible water loss from patients who are critically ill. More accurate estimates for values of water from oxidation are also required if water balance should become a necessary assessment. Lack of calibrated devices for measuring intake and output can lead to very large errors in calculating both water and fluid balance.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

Assessment and diagnosis of fluid imbalance is an important goal of nursing practice for the critically ill patient. The first step toward this goal is to carry out complete and accurate nursing assessment procedures including measuring fluid intake and output and obtaining daily weights. Nursing diagnoses of fluid imbalance are then based on these results. This study explored the assessment procedures used in identifying fluid and water balance and values for unmeasured water loss. These data were then compared with the change in daily weight.

Ten subjects from two different intensive care units were selected for this study. Nine short term patients were observed for 48 consecutive hours. One long term patient was observed for 130 consecutive days. Descriptive data were recorded for each subject including total fluid intake and output, daily weights, body temperature, activity level, type of fluid and oxygen therapy, ambient temperature and humidity and type of bed clothing worn. Calculated data included fluid balance, water balance, unmeasured water loss, body surface area and change in daily weight.

Correlation coefficients (Pearson's r) were calculated for both short and long term subjects for three different relationships: 1) the difference between measurable intake and output (fluid balance) vs. daily weight change; 2) water balance vs. daily weight change and 3) unmeasured water loss vs. daily weight change. Results showed low coefficients for all categories indicating possible errors in measuring and recording data.

Conclusions

The findings of this study indicate that changes in daily weights do not adequately correlate with clinical fluid and water balance assessments. Although errors may have occurred in the fluid and water balance assessments, the implication for clinical practice, although tentative, is that change in daily weight cannot be used alone as a direct reflection of fluid or water balance.

In this study, it was possible that the small number of subjects and potential errors in obtaining accurate and complete data may have resulted in the low correlation coefficients. It is clear that nurses must use all methods possible on which to base a nursing diagnosis of fluid imbalance.

Recommendations

On the basis of this study, it is suggested that the following recommendations for further study be considered.

1. A replicated study with a larger sample and three investigators to assist in complete data assessment for each eight hour shift.
2. Additional research on the accuracy and reproducibility of clinical daily weights.
3. An expost facto study using data collected by Murray et al. (1979) or Gump et al. (1968) in their research units.
4. Additional research on the unmeasured water loss equation evaluating its accuracy and relationship to insensible water loss.

5. Additional research on the effect of humidified oxygen therapy and typical hospital bed clothing on insensible water loss.
6. Research on a population of subjects receiving diuretic therapy and its effect on fluid and water balance.

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APPENDIX A

DATA COLLECTION TOOL

DATA COLLECTION TOOL

APPENDIX A

Patient #__________ Patient Initials__________ Age______ Sex____

Date______________ Diagnosis____________________________________

Height__________cm Activity level during 24° 7-3____________________

Weight__________kg Insensible loss_______ml 3-11____________________

BSA__________m^2 11-7____________________

Clothing worn during 24° i.e., gown, sheet, dressing, thigh stockings, pillows next to body, splints against skin,
7-3______________________________
3-11______________________________
11-7______________________________

Ambient room temperature/humidity
7-3__________/__________
3-11__________/__________
11-7__________/__________

Type - Quanity Fluid Intake
7-3______________________________
3-11______________________________
11-7______________________________

Type - Quanity Fluid Output
7-3______________________________
3-11______________________________
11-7______________________________

	0500	0900	1300	1700	2100	0100
Rectal temperature every 4 hours						
Respiration rate/ pattern every 4 hours						

Computation Record

Total Intake______________

Total Output______________

Fluid Balance______________

(Total Intake + 200 ml) - (Total Output + INS) = ΔH_2O

(________ + 200) - (________ + ___) = ____

(Intake - Output) - (Weight Day 2 - Weight Day 1) = UML

(_____ - _____) - (________ - ________) = ___

APPENDIX B

LONG TERM SUBJECT RAW DATA

APPENDIX B

Long Term Subject Raw Data

Day	Total Intake	Total Output	Weight	Day	Total Intake	Total Output	Weight
0			52.5				
1	1983	2210	52.4	29	1732	1758	50.9
2	1530	1307	52.3	30	1900	1753	51.2
3	1465	1317	52.4	31	1796	1487	50.3
4	1930	1030	52.9	32	2528	1758	51.3
5	1925	1180	52.7	33	2425	1829	51.4
6	1640	1485	53.1	34	2182	1945	51.0
7	1925	1438	53.0	35	2013	1940	51.3
8	1935	1313	53.7	36	1905	1980	50.3
9	1893	2092	53.8	37	1698	1217	50.4
10	2056	1545	54.1	38	2147	1354	50.7
11	1859	1977	53.2	39	1999	2030	49.4
12	1935	1630	53.7	40	1986	1398	50.7
13	1983	1907	54.8	41	2101	1898	50.4
14	2127	2060	53.4	42	1784	1451	50.3
15	2447	2195	53.5	43	1911	1474	50.2
16	2265	1575	53.6	44	1924	1880	50.3
17	1784	2095	53.0	45	1874	1391	50.5
18	1825	1275	52.5	46	1791	1926	50.3
19	1483	2078	51.8	47	2058	1717	50.2
20	1600	1006	52.1	48	2204	1229	50.3
21	1848	2129	51.0	49	3070	2060	50.1
22	2381	2060	51.9	50	2270	1510	50.4
23	2038	1805	51.1	51	2473	2020	49.9
24	2605	2063	51.0	52	2357	1761	50.4
25	1995	1700	50.9	53	1897	1610	50.9
26	2540	1548	52.3	54	2041	1920	51.5
27	2044	2017	51.9	55	1885	2100	51.3
28	2133	2158	51.0	56	2186	1240	51.4

APPENDIX B (Cont'd)

Day	Total Intake	Total Output	Weight	Day	Total Intake	Total Output	Weight
57	2115	2170	51.3	89	1379	1292	52.4
58	2245	1827	51.2	90	1628	1300	52.2
59	2068	1600	51.3	91	1670	1360	52.3
60	1940	1580	52.1	92	1768	1175	52.9
61	1515	1479	51.2	93	1850	1535	52.7
62	1990	1330	52.3	94	1666	1364	52.8
63	1567	1552	51.5	95	1669	927	53.2
64	1885	1586	52.1	96	1700	1184	53.2
65	1834	1570	52.2	97	1190	1206	54.2
66	2129	1615	52.4	98	1714	1536	52.4
67	1822	1685	53.2	99	1421	1588	52.8
68	2325	1955	52.9	100	1855	2018	52.6
69	1781	1399	53.2	101	1488	1142	53.1
70	2450	1315	53.5	102	1533	1126	53.2
71	1880	1450	53.5	103	1493	1307	53.1
72	1980	1465	52.7	104	1372	1348	53.0
73	2065	1460	54.1	105	1956	1943	53.0
74	2323	1912	53.8	106	1846	1849	52.4
75	1491	1202	53.7	107	1588	1330	53.0
76	1739	1125	53.4	108	2079	1393	53.6
77	1647	1367	54.0	109	1930	1871	52.6
78	1635	1171	53.1	110	1743	1297	52.6
79	1436	1030	53.8	111	1709	1495	52.9
80	1735	1490	54.0	112	1689	1482	52.7
81	1344	1150	53.5	113	1246	1145	53.3
82	1360	1045	54.6	114	1343	1096	53.3
83	1345	1095	53.5	115	1733	1236	53.6
84	1632	2010	54.2	116	1589	1063	53.4
85	1541	1690	53.2	117	1493	1090	53.6
86	1533	1410	52.2	118	1774	1150	53.7
87	1405	1230	52.2	119	1230	860	53.8
88	1531	1427	52.1	120	1467	1005	53.5

APPENDIX B (Cont'd)

Day	Total Intake	Total Output	Weight	Day	Total Intake	Total Output	Weight
121	1520	1095	53.5	126	1399	905	53.7
122	1724	1485	53.4	127	1662	982	53.8
123	1504	1405	53.5	128	1439	1310	53.9
124	1852	1475	53.6	129	1620	1015	54.0
125	1271	1340	53.7	130	2004	1300	53.8

AN ABSTRACT OF THE THESIS OF

VICKI DIANE BECK

For the MASTER OF NURSING

Date of Receiving this Degree: June 11, 1982

Title: ASSESSMENT OF BODY WATER BALANCE BY ANALYSIS OF THE DIFFERENCE BETWEEN MEASURED INTAKE AND OUTPUT AND CHANGE IN DAILY WEIGHT

APPROVED: [redacted]esis Advisor

Nurses are accepting the responsibility and challenge of assessing and diagnosing fluid and water imbalance. Nursing diagnoses must be based on specific and identifiable signs and symptoms. Intake and output records and changes in daily weight are frequently used clinically to assess fluid imbalance. The purpose of this study was to explore the water and fluid balance relationships to changes in daily weight.

Ten hospitalized patients receiving no solid food were selected by convenience for subjects in this study. Nine of the ten subjects were observed for 48 consecutive hours (short term subjects). The tenth subject was observed for 130 consecutive days (long term subject). Correlation coefficients (Pearson's r) were calculated for three different relationships. These included 1) the difference between intake and output _vs._ daily weight change; 2) water balance _vs._ daily weight change and 3) unmeasured water _vs._ daily weight change.

The following results were obtained:

1. Correlation coefficients (Pearson's r) for the difference between intake and output and change in daily weight were 0.31 for short term subjects and +0.32 for the long term subject.
2. Correlation coefficient (Pearson's r) for water balance vs. change in daily weight for the short term subjects was +0.32 and +0.39 for the long term subject.
3. Correlation coefficients (Pearson's r) for unmeasured water loss vs. change in daily weight for the short term subjects was -0.54 and -0.61 for the long term subject.

Conclusions drawn from this study are that nurses must use a high degree of accuracy when obtaining intake, output and weight measurements. It is recommended to carefully observe other assessment parameters when generating a nursing diagnosis.