INSENSIBLE WEIGHT LOSS IN PATIENTS WITH SPINAL CORD TRANSECTION

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Abstract. Insensible weight losses (IWL) were determined in each of 24 patients with physiologically complete spinal cord transection. The patients were placed on a bed balance with an accuracy of ± 5 g in an environmental chamber maintained at 24°C. dry bulb and 17°C. wet bulb temperature. Bihourly weight changes, corrected for food and fluid ingestion, were determined for a total of 24 hours. Tetraplegics have significantly lower ($P < 0.05$) IWL than paraplegics. The IWL of paraplegics are in the range of IWL of normal persons reported in the literature. We conclude that a lower allowance for IWL should be made for tetraplegics than for paraplegics or persons with intact spinal cords

Key words: Insensible weight loss; Spinal cord transection.

THERE are today more than 125 000 persons with chronic paraplegia or tetraplegia resulting from transection of the spinal cord; yet there is a paucity of information on insensible weight loss in these individuals. Those physical components and associated phenomena which influence insensible weight loss (IWL) in man were described in scientific literature almost three decades ago. Most attention has been given, however, to insensible weight loss in normal subjects, with little emphasis on precise measurement of insensible weight loss in persons suffering from various diseases and/or injuries.

It is well known that the leading cause of death in patients who survive traumatic transection of the spinal cord is renal failure secondary to pyelonephritis. The problem of maintaining adequate electrolytic and fluid balance in the cord-injured patient is complicated further by the fact that there are no accurate tables for normal values of insensible water loss in patients who have suffered cord injury.

The purpose of this study was to develop a table of standard values which could be followed and used clinically in the treatment and care of cord-injured patients hospitalised under ordinary conditions of ambient temperature and relative humidity.

Methodology

Insensible weight loss was determined for each of 24 male patients who ranged in age from 19 to 67 years and who had suffered a physiologically complete transection of the spinal cord. In addition two subjects who had not suffered spinal cord injury were studied simultaneously for the purpose of comparing techniques used to establish IWL values. Each of the 24 patients was categorised into one of the following groups depending upon his level of lesion: (A) C4-C8; (B) T1-T6; (C) T7-T12; (D) L1-cauda equina.

Since it is well known that respiration influences the amount of insensible weight loss, the groupings selected for this investigation seem defensible and valid (Burch, 1945, 1946a, b).

The first group, C4-C8, includes some patients who have suffered phrenic nerve damage; the second group, T1-T6, is characterised by involvement of the upper (and lower) intercostal and abdominal muscles; the third group, T7-T12, will be noted to display functional impairment of the lower intercostal and abdominal muscles; the final group, L1-cauda equina, generally have complete innervation of all respiratory and abdominal musculature.

Lesions involving T6 and above may reveal occasionally secondary cardiac involvement attributable to autonomic dysfunction.

Each study subject was placed on a Potter bed balance, Model 23-B (accuracy ± 5 g), for a period of 24 hours. The bed was housed in a controlled environment room maintained at 24°C. dry bulb temperature and 17°C. wet bulb temperature. All subjects were nude, but were allowed to cover themselves with a sheet and/or light blanket for comfort.

Subjects previously identified as experiencing non-thermoregulatory sweating on the forehead or chest due to autonomic dysreflexia were excluded from the study.

No subject was included in the study who was found upon examination to be suffering from decubitus ulcers or other wounds which could leak fluid.

A standard hospital diet consisting of 110 g protein, 265 g carbohydrate, and 108 g fat was provided to each subject. The morning meal was served between 7.00 and 9.00 a.m., lunch was served between 11.30 a.m. and 12.00 noon, with the evening meal served between 5.00 and 5.30 p.m. All foodstuffs and liquids were weighed accurately on a calibrated dietetic balance before delivery to the patient.

All bedding which might have absorbed water was weighed, both before and after the 24-hour exposure period, for the purpose of quantifying any moisture which might have been absorbed during the course of the experiment.

Air velocity in the controlled environment room was determined to be less than one mile per hour.

Subjects were allowed to take their normal medication both before and during the experiment. Analysis of all medications revealed that no subject consumed any medication in sufficient dosage to affect sweating or any other known source or cause of insensible weight loss (Cutting, 1969). In each instance the weight of each medication was included in the final weight loss calculation.

Urine collection was achieved via condom or indwelling catheters and urine bags which were placed on the bed balance each time a weight measurement was recorded.

Defecation in patients who have suffered spinal cord injuries is generally mechanically regulated. None of the patients in this experimental investigation experienced a bowel movement during the 24-hour testing period.

The Potter bed was calibrated before and after each experiment with weights of known mass to insure accuracy of each measurement. Weight changes reported here include the sum of: (1) cutaneous water loss; (2) water loss from the lungs; (3) weight difference between oxygen absorbed and carbon dioxide expired, *i.e.* metabolic weight loss.

Metabolic weight loss is known to be approximately 3 g per hour (D'Alton *et al.*, 1948; Mitchell *et al.*, 1972), but was not measured separately in these experiments.

The age, level of lesion and time since injury of each subject is given in Table I.

TABLE I

Physical characteristics and 24-hour insensible weight changes of patients with complete spinal cord transections

Patient	Lesion level	Months since injury	Age (years)	IWL (g)
A1	C4	2	25	488
A2	C5	18	52	768
A3	C5, 6	2	28	628
A4	C6	3	18	559
A5	C6	1	23	761
A6	C7	78	21	716
mean $\pm$ standard error = 653 ± 47				
B1	T3	1	28	772
B2	T4	35	37	800
B3	T4	1	48	1027
B4	T4, 5	38	30	1264
B5	T6	51	39	636
B6	T6, 7	1	23	1169
mean $\pm$ standard error = 945 ± 101				
C1	T9	2	34	1155
C2	T10	2	19	733
C3	T11	7	20	908
C4	T11	188	51	705
C5	T12	15	25	880
C6	T12	9	25	896
mean $\pm$ standard error = 880 ± 66				
D1	L1, 2	8	26	1023
D2	L1, 3	19	38	1114
D3	L2, 3	108	36	978
D4	L3	3	23	723
D5	L5	59	38	1278
D6	cauda equina	45	67	869
mean $\pm$ standard error = 998 ± 79				
Normal no. 1			27	1484
Normal no. 2			22	919

Upon entering the controlled environment room, each subject was thoroughly dried over his entire body. The subject was then placed on the bed balance with the weighed bedding and his nude, dry body weight determined and recorded. Weight loss measurements, corrected for food and/or water ingestion, were determined bihourly in 23 of the patients; in the 24th patient the determinations were made every 12 hours.

Upon completion of the 24-hour testing period, the bedding weight was determined again to ascertain the amount of water absorbed by the bedding. The subject's body was thoroughly dried again and the total nude, dry body weight redetermined.

A pre-investigation analysis of typical hospital conditions confirmed that the experimental subjects were exposed to testing conditions which closely approximate conditions to which patients are routinely exposed in the hospital setting.

Results

Twenty-four hour insensible weight losses are reported for each subject in Table I. The mean and standard errors for these measurements in grams per 24 hours are 653 ± 47 , 945 ± 101 , 880 ± 66 , and 998 ± 79 for groups, A, B, C and D respectively. Analysis of variance revealed a significant difference ($P < 0.025$) among these four groups. Tukey's Omega Procedure (Steel and Torrie, 1960) indicated groups B, C and D differ significantly from group A ($P < 0.05$), but not from one another.

The insensible weight losses for the two normal subjects were determined to be 919 and 1484 g respectively. These daily losses are in the range for normal subjects (666-1827 g) reported by Newburgh *et al.* (1931) who measured 24-hour insensible weight losses in subjects engaged in routine activity over long periods of time.

Bihourly weight losses (over 24 hours) for ten of these subjects are illustrated in Figure 1. In each of these subjects the amount of water absorbed by the bedding was less than 10 per cent of the total of 24-hour IWL. Analysis of variance reveals that there is a significant ($P < 0.05$) effect of time on insensible weight loss. Examination of Figure 1 suggests there is a tendency for the insensible weight loss to be higher in the mid-afternoon and lower in the early morning than at other times of day.

Discussion

Insensible weight loss is composed of three separate and distinct elements: (1) water loss from the skin, but not including sweat secreted for thermoregulatory adjustments; (2) water loss from the lungs; and (3) the so-called 'metabolic weight loss' due to the difference in weight of the oxygen absorbed by the body and the carbon dioxide excreted.

FIG. 1

Average bihourly insensible weight loss of cord injured patients. Solid line is average loss of patients; broken line is average loss of normal controls.

In neutral ambient temperatures, heat loss resulting from evaporation of the total insensible water loss (from lungs and through skin) of clothed, resting men is approximately 20 to 25 per cent of the resting metabolic rate (Hardy *et al.*, 1971). Approximately one-third of this loss is from the moist surfaces of the respiratory tract and the remainder from the skin (Bard, 1968). Several factors affect one or more of these elements: transepidermal water losses increase with increasing skin temperature (Pinson, 1942; Thiele, *et al.*, 1966; Grice, *et al.*, 1967, 1971); a rise in skin temperature of 6°C. to 10°C. approximately doubles transepidermal water loss.

It is generally agreed that increasing the water vapour pressure of ambient air decreases water loss through the skin (Taylor *et al.*, 1953; Brebner *et al.*, 1956; Bettley *et al.*, 1967; Goodman *et al.*, 1969), although at very low water vapour pressures, water loss through the skin may be impeded (Grice *et al.*, 1972), possibly due to decreased permeability of skin to water in very dry environments.

Taylor and Buettner (1953) demonstrated that increasing the air velocity in a controlled environment room increased insensible water loss through the skin. It has been shown that insensible water loss through the skin is increased in dermatitis (Shahidullah *et al.*, 1967) and through burned skin, even after healing (Wilson & Moncrief, 1965). although the diffusion rate of water through skin of cadavers is the same as the diffusion rate of water through the skin of living persons which has been separated from underlying tissue by cantharides (Burch & Wilson, 1944). This process results in changes in the stratum spinosum layer of the epidermis (Benedek, 1939). It may not be valid to assume, therefore, the skin from living persons, obtained in this manner, has the same permeability to water as intact skin.

Resting metabolic weight loss is influenced primarily by the type of foodstuff oxidised for energy. If one assumes a resting oxygen consumption of 250 ml per minute and a respiratory quotient of 0.85, it can be calculated easily that metabolic weight loss is about 90 g per day.

Insensible water loss through the lungs is dependent primarily on the water content of the expired air and the rate of pulmonary ventilation (Burch, 1945, 1946a, b). Water loss from the lungs is increased in both deep and slow breathing, and rapid and shallow breathing, when compared to breathing with a normal tidal volume and frequency (Burch, 1946a, b).

Quadriplegics often exhibit rapid, shallow breathing because the intercostal muscles lack proper innervation and the diaphragm assumes virtually the entire function of ventilation (Bergofsky, 1964).

The reason for decreased IWL in the quadriplegic patients is not clear. It may be that the insentient skin of persons with spinal cord injury is less permeable to water than sentient skin, or that the decreased mobility of these patients has resulted in a higher water vapour pressure in the air layers immediately adjacent to the skin so that the vapour pressure difference between the skin surface and these layers of air is decreased.

These data suggest that a lower allowance for insensible water loss should be made for quadriplegics than for either paraplegics or persons with intact spinal cords.

RÉSUMÉ

On a déterminé les pertes insensibles de poids chez vingt-quatre patients avec des coupes transversales physiologiquement complètes des cordons médullaires. On a placé chaque patient sur un lit-peson qui est précis à ± 5 g dans une chambre à l'atmosphère réglée qui est maintenue à 24° température à bulbe sec et à 17° à bulbe mouillé. Toutes les

deux heures on a noté les changements de poids, ramenés aux conditions normales d'ingestion de la nourriture et du liquide pendant vingt-quatre heures. Les patients tétraplégiques tiennent les pertes insensibles de poids qui sont d'une manière significative plus basses ($P < 0.05$) que celles des patients paraplégiques. Les pertes insensibles de poids des paraplégiques sont à la portée de celles des personnes normales rapportées dans la littérature. Nous sommes arrivés à la conclusion qu'on doit tenir compte que les pertes insensibles de poids sont plus basses chez les personnes tétraplégiques que chez les personnes de cordon médullaire intact.

ZUSAMMENFASSUNG

Insensible Gewichtsverluste wurden in allen 24 Patienten mit kompletter Querschnittslähmung gefunden. Die Patienten wurden auf eine Bettwaage mit einer Genauigkeit von ± 5 g gelegt, welche in einer Spezialkammer mit 24°C . trockener und 17°C . feuchter Temperatur stand. Zwei stündliche Gewichtsveränderungen, korrigiert für Flüssigkeit und Nahrungsaufnahme, wurden in einer Gesamtzeit von 24 Stunden gemessen. Tetraplegiker haben bemerkenswert niedrige ($P < 0.05$) Insensible Gewichtsverluste als Paraplegiker. Die Gewichtsverluste von Paraplegikern bewegt sich in den Grenzen des insensiblen Gewichtsverlustes von gesunden Menschen, die aus der Literatur bekannt sind. Wir schliessen daraus, dass eine niedrigere Grenze für insensible Gewichtsverluste muss bei Tetraplegikern im Vergleich mit Paraplegikern oder Personen mit gesunden Rückenmark erfolgen.

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