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Sensory Stimulation to Promote Deep Breathing in the Chronic Obstructive Pulmonary Disease Patient

Sharon Kay Sauer

Abstract

SENSORY STIMULATION TO PROMOTE DEEP BREATHING IN THE CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENT

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Breathing retraining has been an integral part of respiratory rehabilitation for the patient with chronic obstructive pulmonary disease (C.O.P.D.). Techniques used for breathing retraining have been studied for many years. These techniques include such breathing retraining modalities as relaxation conditioning, positioning maneuvers, abdominal-diaphragmatic breathing, pursed lip breathing and intermittent positive pressure breathing. Controversy concerning the therapeutic value of many of these techniques has developed. In this descriptive case study on three subjects with C.O.P.D. the experimental technique of sensory stimulation was investigated as a breathing retraining method. Sensory stimulation consisted of five minutes of repetitive brushing and two to three seconds of quick icing. The areas brushed and iced were the anterior and lateral thoracic dermatomes T_6-T_{12}. Repetitive brushing has been suggested as a technique to stimulate the C-fibers of afferent pathways. Quick icing has been suggested to stimulate A-delta fibers of afferent pathways. Two subjects were placed in the head-down position of 12.6 degrees for sensory stimulation testing, while one subject was left in supine position. Tidal volume and end-tidal PCO_2 were used to measure effectiveness of sensory stimulation in promoting deep breathing. Tidal volume was computed from minute volume taken on a Bourns Ventilation Monitor LS-75 model. End-tidal

PCO_2 was measured by the RMS II by Perkin-Elmer Company. Sensory stimulation occurred over a period of four days in which data were collected before and after sensory stimulation. No significant change in tidal volume was found following sensory stimulation. Significant change ($p=0.05$) was observed in the end tidal PCO_2 of two subjects following sensory stimulation.

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by

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The persons whose signatures appear below certify that they have read this thesis and that in their opinion it is adequate in scope and quality as a thesis for the degree Master of Science.

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INTRODUCTION TO THE STUDY

The importance of a comprehensive rehabilitation program for the patient breathless from chronic airflow obstruction has been discussed extensively in the literature (Hugh-Jones and Whimster, 1978; Lertzman and Cherniack, 1976; Hodgkin, and Others, 1975). The nurse caring for the breathless patient must collaborate with physicians, physical therapists, respiratory therapists and other health team members to help the patient with chronic obstructive pulmonary disease (C.O.P.D.) live as productive a life as possible. Coping with his periods of breathlessness is an ever-challenging problem for this patient. This research was designed to evaluate one technique to promote deeper breathing, thus improving ventilation, the nurse might use when caring for the patient with C.O.P.D.

Sensory stimulation using repetitive brushing and quick icing over the lateral and anterior T_6-T_{12} dermatones was the technique investigated to promote deep breathing in the C.O.P.D. patient. This technique was first introduced by Rood in the early 1950's. Rood suggested that somatosensory stimulation of the area previously mentioned would activate C and A-delta nerve fibers, resulting in discharge over multisynaptic neural pathways to the diaphragm thus causing an increase in excursion. This empirical concept of sensory stimulation to promote deep breathing has been reported to work successfully with patients diagnosed with C.O.P.D. and may relieve difficult breathing for a prolonged time when coupled with a program of conditioning exercises (Rood, 1962). Elizabeth in 1966 encouraged the use of brushing and icing to improve breathing for patients with asthma and emphysema. Recent studies have used brushing and icing for sensory stimulation to promote micturition, to improve body awareness and to strengthen reflexes. To date, however, no studies have been found which use a scientific approach to determine if sensory stimulation with brushing and icing promotes deep breathing. Thus, parameters were selected to study and evaluate the effectiveness of this technique.

BACKGROUND AND NEED FOR STUDY

Any scientific investigation is based on the need for study of the specific problem selected. Background information forms the basis for determining whether the research is beneficial to the population being studied. The incidence of increasing C.O.P.D., coupled with the need for documented physiologic benefit from breathing retraining for the patient with C.O.P.D., forms an important basis for this research. It is also necessary for the nurse, being the primary investigator, to relate the research to practice in patient care.

Incidence of C.O.P.D.

C.O.P.D. is a term which applies to those patients with chronic bronchitis, asthma, or emphysema who exhibit persistent obstruction of bronchial air flow as described by the American Lung Association in 1973. Assessment of the prevalence of C.O.P.D. within any population must take into account that the disease is often too mild to be symptomatic. Statistics until recently have not grouped chronic bronchitis, asthma and emphysema under a term such as C.O.P.D. and thus general identification of the whole C.O.P.D. population is difficult. It would also be desirable if statistical studies considered age, sex, environmental pollution, climate and smoking habits. Allowing for these limitations, the general prevalence of C.O.P.D. can be discussed (Petty, 1974, p. 130).

The prevalence of C.O.P.D. and the death rate from it have increased to epidemic proportions in recent years. In 1975, C.O.P.D. was listed as the eleventh leading cause of death. In the recent decade ending 1970, deaths from emphysema increased 145 per cent and from chronic bronchitis 72 per cent according to the American Lung Association in 1973. In San Bernardino County, C.O.P.D. ranked ninth in the leading causes of death during 1975 according to statistics of the San Bernardino County Public Health Department in 1975. Studies have shown that more men get emphysema than women though the gap is closing in the last decade. More smokers than non-smokers have emphysema, and emphysema generally increases with age and may be dependent upon where the individual resides. Many environmental factors are presently being researched for their influence on C.O.P.D. The increased contamination of the air we breathe may be a factor in the increasing prevalence of C.O.P.D. (Thurlbeck, and Others, 1973).

Even more important than the number of cases of C.O.P.D. is the disabling effect C.O.P.D. has on the individual and thus on society. The latest estimates by the Social Security Administration showed that for 1974 there were 175,000 persons (under age 65) receiving disability allowances for respiratory tract diseases. According to the Social Security Administration in 1975, payments of $500 million went to their dependents. Based on the above statistics, a definite need is demonstrated to find methods of encouraging the most productive life available to these individuals. Family and patients coping with C.O.P.D. have been shown to have a diminished ability to adjust when faced with a lack of educational and personal resources (Cunningham, 1978). Families of C.O.P.D. patients often feel helpless as to how to aid the patient who becomes breathless. If a simple procedure, such as brushing and icing, could facilitate deep breathing, this technique could be used by the family member to aid the patient in periods of breathlessness or act as a part of a reconditioning exercise program.

Need for Physiological Documentation of Breathing Retraining

Even though controversy exists concerning the objective and subjective value of breathing retraining, most progressive rehabilitation programs for the patient with C.O.P.D. include breathing retraining. "Breathing retraining has two specific goals: 1) to increase alveolar ventilation in order to maintain adequate gas exchange, and 2) to restore the diaphragm to better function as a main respiratory muscle in order to decrease the cost of breathing." (Hodgkin, and Others, 1975, p. 1253)

Some of the most common breathing retraining techniques are relaxation maneuvers, pursed lip breathing, abdominal-diaphragmatic breathing, slow deep breathing, intermittent positive pressure breathing, and changes in positions. Some breathing retraining studies demonstrate temporary beneficial effect by improvement in breathing and ventilation

(Miller, 1955; Barach, 1955; Meuller, and Others, 1970; Petty and Guthrie, 1971), while other breathing retraining studies have shown no beneficial effect in improving breathing and ventilation even though basically the same techniques were tested (Sinclair, 1955; Campbell and Friend, 1955; Lefcoe and Patterson, 1973). The reasons for inconsistent findings regarding breathing retraining are thought to be 1) poor patient selection, 2) lack of sophisticated controlled techniques for measuring results, and 3) inadequate means by which to measure improvement in diaphragmatic function (Petty, 1974, p. 130).

In addition to the above techniques mentioned, the possibility of improving breathing and ventilation by means of sensory stimulation has only been empirically suggested in the literature and not scientifically documented. Comroe in his Textbook of Respiratory Physiology mentioned breifly that "appropriate stimulation of afferent nerves can increase rate and depth of breathing." (Comroe, 1974, p. 91) Keating and Nadel in 1965 noted that a cold shower to the trunk of anesthetized cats instantaneously caused hyperpnea (Keating and Nadel, 1965). Studies using sensory stimulation of afferent neural pathways have been performed in animals using electrical stimulation; however, there is an absence of studies in the literature which center on natural stimulation using such techniques as brushing or icing to sensory afferent fibers. Empirically, it has been advocated that both the physical therapist and the nurse use sensory stimulation of afferent A through C-fibers to bring about a temporary hyperventilation and improve breathing for patients with C.O.P.D. (Rood, 1962; Elizabeth, 1966). Through personal communication with Rood, it was learned that a combination of exercise and a technique of sensory stimulation using brushing and icing to activate afferent neural pathways has been used successfully with many C.O.P.D. patients as part of a basic rehabilitative program. It then seems important to begin scientific documentation of such a technique in the care of patients with C.O.P.D.

Sensory Stimulation as a Nursing Intervention

One of the basic roles of the respiratory nurse is to teach the patient deep breathing and coughing to maintain a patent airway (Traver, 1975). The respiratory nurse daily encounters the person whose efforts to breathe are a concern to both himself and his family. The patients most often experiencing difficult breathing have C.O.P.D. Basically, the nurse relies on a quiet, composed manner and a calming touch to reassure the patient and ease his breathing.

"The act of touch is an integral part of nursing intervention and is to be used judiciously between nurse and patient as a fundamental mechanic of communication." (Burnett, 1972, p. 102) However, does the nurse's touch ease the breathing of a patient gasping for breath until other medical means can be instituted? If so, what is the best technique to use in touching the breathless patient?

Lewis stated that touch can be used with therapeutic intent (Lewis, 1976, p. 97). Traver extended the use of touch that could be used by the respiratory nurse caring for the breathless patient with C.O.P.D., by advocating an exact method of touch.

> The hands are placed on the chest so that the patient feels some resistance upon inhalation; then on expiration a more sustained pressure is placed on that area of the chest, encouraging exhalations. This maneuver can be simultaneously used to encourage deep breathing and decrease the patient's respiratory rate. By the pressure of the nurse's hands and the compression of the chest on exhalation, inspiration can be somewhat delayed by forcing a more prolonged expiratory phase. On the following breath the patient will take a deeper breath and his rate can be gradually slowed as well as the depth increased. (Traver, 1975, p. 408)

This again is an empirically based statement advocating a specific maneuver of touch. As a respiratory nurse, the researcher was concerned that a physiological base be established to support touch as a therapeutic intervention in promoting deep breathing.

In the present era of nursing, excellence in practice means patient care should have scientific bases, not tradition or unvalidated assumptions. The emphasis in nursing today is on promoting self-care in clients or in assisting them with self-care functions. Procedures are being developed to aid the independence of a person in meeting his needs and goals to maintain wellness (Levin, 1978). The technique of brushing and icing to promote deep breathing possibly could be administered by the concerned spouse who desperately needs something to do to aid the C.O.P.D. patient in his efforts to breathe.

Specific techniques for sensory stimulation should be investigated for their effectiveness in helping patients with C.O.P.D. to breathe more easily.

THEORETICAL FRAMEWORK

The theoretical rationale supporting the experimental technique of sensory stimulation of breathing was based on three concepts: 1) that sensory stimulation of C and A delta fibers has neuroanatomical and neurophysiological bases, 2) that sensory stimulation of C and A delta fibers produces hyperventilation, and 3) that there was a physiological basis for breathing retraining for C.O.P.D. patients.

The Neuroanatomical and Neurophysiological Sensory Stimulation of C and A Delta Fibers

Studies of single afferent fibers of sensation in animals were pioneered by Adrian in 1926. Zotterman was the first actually to record impulses from C fibers in cats. He found that mechanically stroking the hair of cats resulted in recording of an action potential response on an oscilloscope. The more hairs stroked the greater the amplitude of the discharge. Zotterman also cooled the cats' cutaneous surface finding that sudden cooling evoked the greatest response of these fibers (Zotterman, 1939, p. 24). Classification of response of cat afferent fibers continued, and in 1960 repetitive brushing was found to produce a significant response in C-fiber activity (Iggo, 1960, p. 339). A classification of afferent fibers which responded to varying mechanical, thermal and painful sensations evolved. The fibers were grouped from A to C depending upon fiber diameter and conduction velocity (Zotterman, 1939, pp. 25-27); Douglas and Ritchie, 1957, pp. 392-397; Iggo, 1960, p. 340). Since their classification, some basic characteristics of A and C fibers have been established through animal research. A fibers have been divided into four subsections: A-alpha, beta, gamma, and delta. Since the research under investigation assumes that C and A delta fibers will be stimulated by the experimental technique, an understanding of their differing characteristics was necessary. It is believed that C and A delta fibers enter through the hairy skin with neural interconnections through dorsal root of spinal nerve (see Figure 1), then ascend to the somatic sensory area of the brain over the lemniscal and spinothalamic system (see Figure 2).

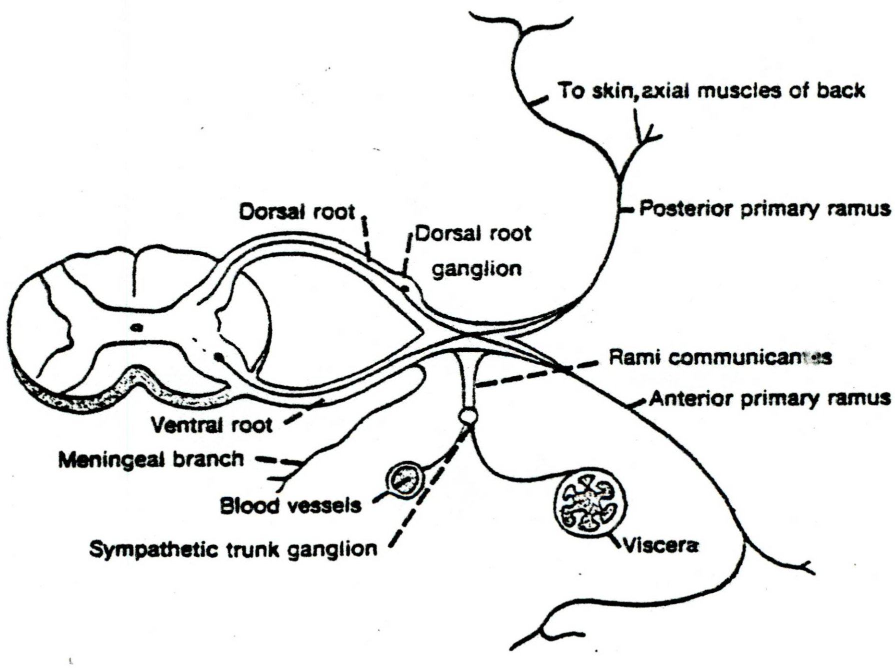


Figure 1

Schematic Representation of a Spinal Nerve
(Frownfelter, 1978)

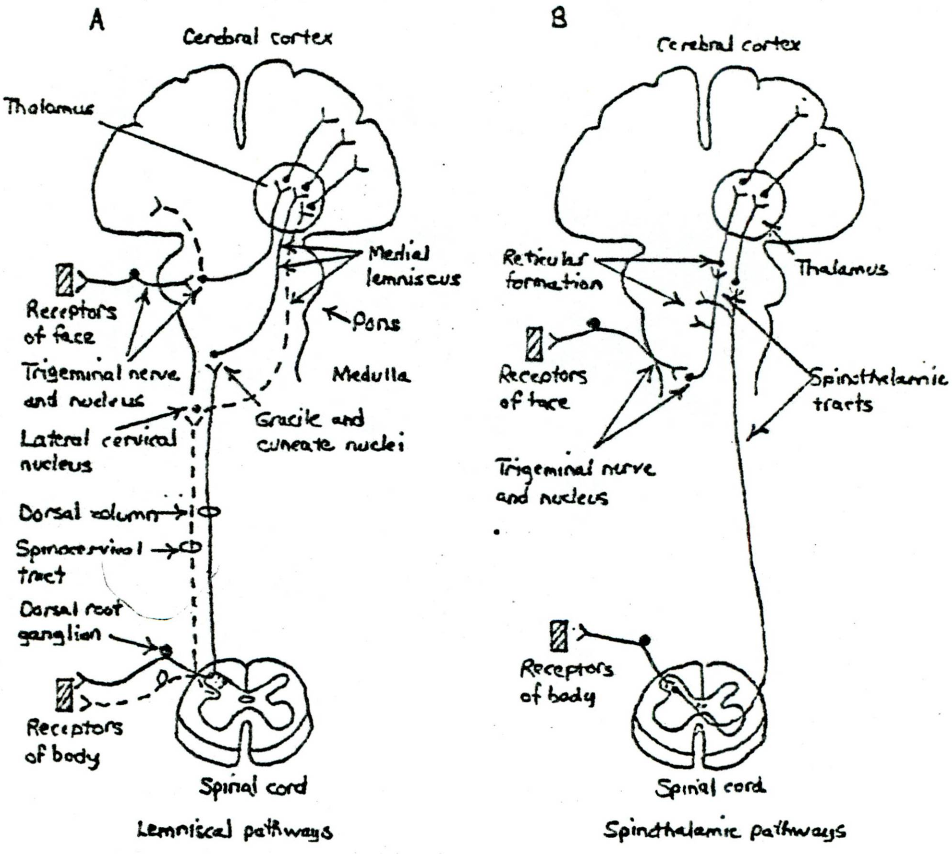


Figure 2

Schematic Diagrams of the Lemniscal and Spinothalamic Pathways of the Somatic Sensory Systems (Thompson, 1967)

A-Delta Fibers	C-Fiber
Smallest myelinated	Unmyelinated
Twenty times less sensitive than C-fibers	High sensitivity, high threshold
Fast conducting	Slow conducting
Most responsive to sudden cooling	Most responsive to light mechanical touch
No latency in response	Latency up to 1 millimeter per second
Transmits impulses to dorsal root of spinal cord	Transmits impulses to dorsal root of spinal cord
Predominant in hairy skin	Predominant in cutaneous surface
Facilitated by C-fiber stimulation	May be inhibited by preceding A-fbier stimulus

These characteristics have been confirmed in numerous animal studies since Zotterman (Iggo, 1960; Melzack and Wall, 1965; Franz and Iggo, 1968; Bessou, and Others, 1971; Zimmermann, 1975). Kornhuber's recent review of studies in animals supported the above characteristics (Kornhuber, 1975, pp. 5-21).

Rood, in 1954, was the first to apply findings from animal studies to treatment modalities in humans. Though Rood did not present any scientific investigations supporting her theories, the physiological basis described in her article has laid the groundwork for several treatment modalities in both the fields of physical therapy and nursing. A few scientific investigations using sensory stimulation of afferent fibers have evolved from Rood's physiologically based concepts (Rood, 1962).

Rood advocated repetitive brushing to stimulate C fibers in the hairy skin and quick icing to stimulate A-delta fibers on the skin surface. Topographical landmarks were mapped according to dermatome areas on the skin surface for specific treatment modalities. Rood's rationale for using the anterior and lateral dermatome area T_6-T_{12} was to stimulate a stretch reflex response in the diaphragm. This was based on the fact that referred pain from a torn diaphragm is referred to these skin surface sites (Ruch, 1965). Since C-fiber and A-delta afferent fibers both transmit impulses from pain as well as touch and temperature, it seemed physiologically sound that referred pain sensation pathways from the diaphragm converging on the skin surface would be the same afferent pathway to transmit C and A-delta impulses from the skin surface to the diaphragm (Ruch and Patton, 1965; Rood, 1962). Based on the convergence-projection theory, "one adequate explanation is that some visceral afferent converge on the same neuron at the same point in the sensory pathway. . . . The system of fibers is sufficiently organized topographically to provide the dermatomal reference." (Ruch and Patton, 1965, p. 357) Thus, the specific pain referral sites on the anterior and lateral thoracic area T_6-T_{12} (see Fig. 3) were designated to be the area stimulated by "repetitive brushing and quick icing. Fast brushing stimulates the muscle spindle so that the threshold of stretch reflex is powered." (Rood, 1962, p. 31) Quick icing activates the muscle spindle by enhancing the conduction of C-fiber impulses sensitized by brushing (Rood, 1962; Ruch, and Others, 1965).

Studies of C-fiber response in cats by electrical stimuli have shown a latency response up to one millimeter per second in conduction time (Zimmermann, 1975, p. 52). This response was also noted by Rood who stated that a "latency of thirty seconds occurred following stimulation of C-fibers." Rood also noted an augmentation and recruitment phase occurring post stimulation of the C-fibers resulting in a prolonging of

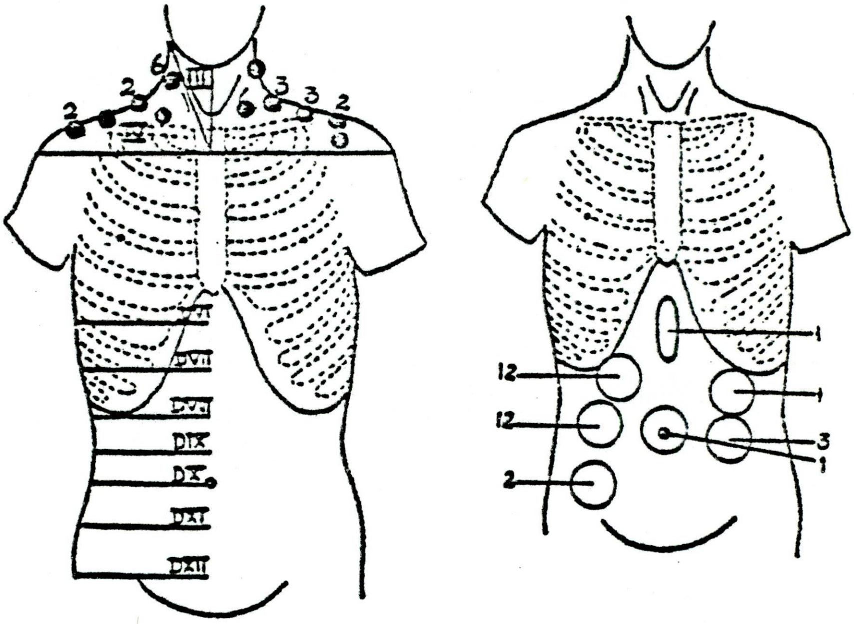


Figure 3

Superficial Reference of Pain from Diaphragm

<u>Left</u>: Reference of pain from stimulating <u>central zone</u> of diaphragm. Black dots and attached numbers represent position and frequency of reference in a series of observations. Pain is also referred to corresponding territory on dorsal surface of neck and shoulders (not shown). Roman numerals identify 3rd and 4th cervical and 6th to 12th thoracic dermatomes (D). <u>Right</u>: Reference of pain from visceral disease affecting <u>margins</u> of diaphragm. Circles represent points of reference, numbers the frequency of reference; in two cases pain was referred to back. Margins of diaphragm are innervated by lower six thoracic posterior roots. (Rush and Patton, 1965, p. 356)

the neural response evoked by stimulation. If increased diaphragmatic excursion results from repetitive brushing and quick icing, then a sustained period of improved ventilation should result. Zimmermann in cat studies noted this same withdrawal response (Zimmermann, 1975). Rood, through personal communication, stated that this augmentation and recruitment of C-fiber response to stimulation may last up to three hours after stimulation. The prolonged response was possible if the subject being stimulated by repetitive brushing and quick icing had been on a conditioning exercise program to improve ventilation prior to sensory stimulation. To date, there is no research to confirm the length of response of C-fibers following withdrawal of stimulus.

Currently, controversy exists regarding the presence of C-fibers in human skin. In 1972, impulses from 25 afferent C-fibers were recorded following mechanical stimulation. Impulses were recorded by the use of microelectrodes in healthy adults. The superficial branch of the radial nerve was used. Simple finger touch, moderate pressure and continuous stroking with a flat probe were used to stimulate C-fibers. These did not activate C-fiber response. Light needle pressure and von Frey hairs easily activated C-fibers. The results suggested that in man only painful stimuli activate C-fibers unlike studies reported in cats (Van Hess and Gybels, 1972, p. 398). A similar study on six healthy males also confirmed that light stroking of hair, light puffs of air, stretching and pinching folds of the skin all decreased the excitability of afferent C-fibers. Again, C-fibers responded most vigorously to intense stimuli such as pain induced by pinpricking and heat stimulation (Torebjörk and Hallin, 1974, p. 402).

These two studies were the only ones found in the literature dealing with this subject. These studies refute the theory that C-fibers respond to mechanical stimuli. It has been stated that C-fibers are very sensitive to pressure and touch well below the noxious level and that the techniques used to record C-fiber response may have distorted results due to the sensitivity of C-fibers (Coleridge and Coleridge, 1977). Articles since the two human studies presented above still suggest the presence of C-fibers in man (Sampson, 1977; Coleridge and Coleridge, 1977). The repetitive brushing and quick icing to the skin area were not tested in the two human experiments described above.

Controversy has also developed over the interconnecting nerve pathways between C and A fiber impulses that volley to activate dorsal root potential. It is postulated that C-fibers, dependent on method of stimulation, either facilitate or inhibit impulses to A-fibers (Melzack and Wall, 1965). Studies of the sural nerve stimulation in cats by A and C fibers revealed that C-fibers can no longer be regarded as facilitating A fiber response (Gregor and Zimmermann, 1972). Electrical stimulation of the sural nerve in cats showed that C-fibers can be depressed by preceding A fiber stimulation (Janig and Zimmermann, 1971). In complete contrast to these studies was a study done on sural nerves in 20 cats using natural repetitive stimulation of C-fiber. The findings indicated that C fiber reflexes were not influenced by preceding A fiber firing (Schmidt and Weller, 1970). Much of C and A fiber physiological information on the somatic excitatory and inhibitory actions still remains largely speculative. The role of receptors in somatic sensation, particularly the C-fibers, is far from clarified (Schmidt and Weller, 1970). To add to the confusion, research over the last decade has centered around electrical impulse studies of C and A fibers in animals. The two studies in man referred to above attempted to use natural modes of stimulation by touch and temperature to elicit somatic stimulation.

Sensory Stimulation of Afferent C and A Fibers on Respiration

Studies documenting the neural regulation of respiration have been reviewed in recent literature over the past decade (Guz, 1975; Mitchell and Berger, 1975; Mitchell, 1977; Wyman, 1977). The neural control of respiration occurs over afferent pathways from the central nervous system or peripheral control over afferent pathways from chemoreceptors, irritant receptors and other sensors (Mitchell and Berger, 1975). Three categories of afferent receptors that innervate the airways are known. These are: 1) the pulmonary stretch receptors, located in the airway smooth muscle and responsible for the Hering-Breuer reflex, 2) the J-receptors, non-myelinated nerve fibers, or C-fibers, located in alveolar tissue and 3) the irritant receptors located in the epithelium of the airways responding to chemical and mechanical irritants, gas and aerosols (Widdicombe, 1977, p. 90). These afferent fibers have been studied most recently in the airways; however, Widdicombe stated that it is inevitable that . . . the reflex responses will be due to the interactions of many afferent systems (Widdicombe, 1977, p. 103).

The studies which support afferent C and A fiber stimulatory effects on respiration have been done in animals by electrical charges to the afferent nerves; Koizumi and others studied afferent nerves from skin and muscles as they affect respiration. They pointed out in their study that repetitive stimulation of afferent fibers in the skin can result in discharges from muscle receptors which initiate hyperpnea. Specifically, they gave evidence of "the existence of reflex circuits and interactions at the spinal level in the course of reflex control of respiration by peripheral receptors." (Koizumi, and Others, 1961, p. 683) Studies followed which supported and contradicted the original work of Koizumi and others (Davies, 1966; Howard, 1969; Hodgson and Matthews, 1963; McCloskey, and Others, 1972).

An important study which supported the theory of reflex hyperventilation as a result of C-fiber stimulation in the muscle was done on the gastrocnemius muscle of dogs. Natural stimulation using stretching, pressing, and squeezing produced an increase in tidal volume; thus, a reflex hyperventilation. By cooling, blocking of the faster conducting fibers occurred, indicating that C-fibers in the muscles were responsible for producing this reflex hyperventilation (Kalia, and Others, 1972, p. 189).

In contradiction to afferent fiber control of respiration were studies in triceps muscles in cats. Vibration to these muscles produced no appreciable influence on respiration. Since vibration has been shown to be a powerful stimulus of afferent fiber, it then was argued that no reflex response from afferent fiber stimulation was present (McCloskey, and Others, 1972, p. 623).

In 1976, repetitive somatic afferent stimulation to nerves supplying radial and hamstring muscles in cats recorded electrical activity on the phrenic nerve. Femoral arterial blood pressure was measured along with end-tidal CO_2. Stimulus threshold was measured with an oscilloscope. Results showed the existence of a mechanism capable of locking frequency of respiration to that of periodic somatic afferent input from afferent fiber stimulation (Iscoe and Polosa, 1976, p. 138). It was from this study that afferent stimulation of high threshold fibers (C-fibers) was linked with the central mechanism or brainstem control of expiratory and inspiratory switching (Iscoe and Polosa, 1976, p. 138).

The exact center that controls the timing of inspiratory and expiratory phases of respiration is not known. Mitchell has proposed that the center for generation of respiratory rhythm is located in the dorsal respiratory group of the medulla (Mitchell, 1977) (see Figure 2). Iscoe and Polosa believe this center could be affected by short trains of stimuli from afferent nerves. Thus, stimulation of C fiber and A delta fibers may not only produce a reflex response in the diaphragmatic muscle, but may also affect the central neurons which control phase switching, wherever they are located (Iscoe and Polosa, 1976, p. 138). It seemed logical that if sensory C-fibers are just being discovered in airways that many peripheral C-fibers and their interconnecting pathways have yet to be established in the skin (Coleridge and Coleridge, 1977, p. 251). Iscoe and Polosa (1976) believe their research suggested that cutaneous afferent fiber input interacts with a respiratory oscillator to produce hyperpnea.

The question of whether afferent impulses from C and A delta fiber stimulation can affect diaphragmatic control is a relevant one. Also, additional effects of C and A fiber stimulation on the medullary controls of respiration are still speculative (Iscoe and Polosa, 1976).

Rood believed there was a physiologic basis to support the use of repetitive brushing to activate C-fibers and quick icing to activate A-delta fibers, resulting in a relfex response of increased diaphragmatic excursion (Rood, 1962).

Wyman summarized by saying, "Breathing is one of the few areas of brain activity where function is anywhere near to being understood on the basis of unit activity of nerve cells." (Wyman, 1977, p. 4431) There are still many gaps in our knowledge of the sensory neurophysiology controlling respiration (Sampson, 1977, p. 107). An understanding of the physiology of afferent pathways was basic for the use of the researcher's experimental technique. The literature suggested that C and A delta afferent fiber pathways do exist and can be stimulated by repetitive brushing and quick icing.

Patients with C.O.P.D. Physiological Basis for Breathing Retraining

C.O.P.D. comprises three disease entities: emphysema, chronic bronchitis and asthma. Many patients have a combination of two or more of those disease entities. Each of these diseases in a chronic state will produce pathological changes in the lungs which obstruct the airway. Thus, a common term, chronic obstructive airway disease, forms an umbrella for all.

The emphysemic patient is characterized by increase in the size and destruction of the alveoli, or by a destruction of the respiratory bronchiole and thickened bronchiolar wall. Airway obstruction is caused by a loss of elastic recoil and radial traction on the bronchioles. On inhalation airway diameter increases due to the negative intrapleural pressure. On exhalation airways collapse because of the loss of radial traction of fibers on the bronchioles (Frownfelter, 1978, p. 69).

Chronic bronchitis patients are characterized by having a productive cough for at least three months out of the year for two consecutive years. In airways blocked by increased sputum there is an increase both in resistance to airflow and in the work of respiratory muscles. With obstruction from sputum and increased cough, more accessory muscles are used to aid in breathing (Hodgkin, and Others, 1975, p. 1243).

Asthmatic patients are characterized as having a narrowing of airways. Various atopic allergic reactions or irritant stimuli to the trachea or bronchi cause bronchospasm. Recurrent respiratory tract infection is also known to cause asthma. Attacks of bronchospasm come on suddenly and occur repeatedly. Inflammation narrows the airways already obstructed by bronchospasm (Frownfetter, 1978, p. 77).

Pulmonary function studies, radiological examinations and laboratory analysis of arterial bloos bases are all used in the diagnosis of the diseases causing chronic airway obstructions. Probably the most indicative diagnostic studies are pulmonary function tests. Pulmonary function studies, including spirometry and lung volumes, which denote C.O.P.D., are shown in the following diagram (Hodgkin, and Others, 1975, p. 1244).

Function	Normal %	Obstructive
FVC+	80%	N or
FEV_1+	80%	N or
FEV_1 X 100/FVC	75%	
FEF 25-75%	80%	
Total Lung Capacity	80-120%	N or
RV(&)X 100/Total Lung Capacity	25-40%	

Normal (N) values represent per cent of predicted value except for FEV_1 X 100/FVC and RV X 100/Total Lung Capacity;

FVC indicates forced expiratory vital capacity;

FEV_1 indicates forced expiratory volume in one second;

RV indicates residual volume (Hodgkin, and Others, 1975, p. 244);

FEF 25-75% indicates forced expiratory flow between 25 and 75 per cent of the FVC.

The changes in pulmonary function may be confirmed by radiological evidence of a hyperinflated lung (with emphysema). Arterial blood gases usually indicate mild to moderate hypoxemia. Arterial blood oxygenation usually differs from alveolar oxygen levels indicating poor ventilation/perfusion matchup (Hodgkin, and Others, 1975, p. 244). Arterial carbon dioxide levels increase in chronic bronchitis and eventually in severe emphysema (Frownfelter, 1978, p. 86), indicating reduced alveolar ventilation.

These physiological changes alone are enough to influence the respiratory patterns of C.O.P.D. patients. A weakened diaphragm makes it harder for these patients to exhale against gravity. Accessory muscles are used to breathe. Air hunger results from additional oxygen demands placed on the patient from increased muscle work. The patient reacts by initiating inspiration before expiration has finished, producing increased ineffective breathing (Frownfelter, 1978, p. 86).

The aim of breathing retraining is to train the C.O.P.D. patient to breathe more normally. The diaphragm must be strengthened to improve use when possible. Oxygen demand must be limited by relaxing accessory muscles, slowing the breathing and finishing expiration (Frownfelter, 1978, p. 87). Further information on breathing retraining for C.O.P.D. patients will be discussed in Chapter 2.

From the above theoretical framework evidence was available to support the need for development of a sensory stimulation technique applicable in the care of the C.O.P.D. patients. Thus the following assumptions will be made.

Assumptions Evolved from Theoretical Framework

If it is true that

1. Sensory stimulation by repetitive brushing stimulates C fibers of the hairy skin, and

2. Sensory stimulation by quick icing stimulates A delta fibers by sudden cooling, and

3. Sensory stimulation of C and A delta receptors of the anterior and lateral T_6-T_{12} dermatomes reflexly produces increased diaphragmatic excursion following relaxation of the abdominal muscles, thus improving breathing, and

4. Improved diaphragmatic excursion and breathing can be measured by an increased tidal volume and decreased end-tidal PCO_2, and

5. Patients with severe C.O.P.D. frequently present with inadequate alveolar ventilation, as manifested by increased end-tidal PCO_2, and

6. Breathing retraining using sensory stimulation is an acceptable treatment to increase tidal volume and decrease end-tidal PCO_2 in C.O.P.D. patients,

then it should be true that

Sensory stimulation will improve ventilation of patients with C.O.P.D.

The role of the respiratory nurse is to work with the C.O.P.D. patient to help him improve the quality of his life. Breathing retraining by the technique of sensory stimulation is one method that the nurse or patient might use to maintain depth of breathing needed in daily activity. With a maintained depth of breathing, exercise tolerance hopefully will result which in turn will encourage the patient toward as much independence as possible (Traver, 1975, p. 408). Quality patient care implies that nursing practice be supported by scientific rationale. It is for this reason a design evolved to study one sensory stimulation method of breathing retraining.

DESIGN OF STUDY

Purpose

The purpose of this study was to determine the effect of sensory stimulation, using the experimental technique of repetitive brushing and icing, on respiration. The specific intent was to find out if the experimental technique would be a useful adjunct to breathing retraining of C.O.P.D. patients.

Problem

The problem was to investigate whether the C.O.P.D. patient, with whom the experimental technique of sensory stimulation was used, would demonstrate an increased tidal volume and decreased end-tidal PCO_2, thus reflecting an improvement in breathing.

Hypothesis

It was hypothesized that application of the experimental technique of repetitive brushing and quick icing to the T_6-T_{12} anterior and lateral dermatomes will significantly improve ($p<.05$) tidal volume and end-tidal PCO_2. (Improvement would be indicated by an increase in tidal volume and a decrease in end-tidal PCO_2.

DEFINITION OF TERMS

Certain terms were given specific definitions for this study.

Sensory Stimulation

The external application of either brushing or icing to the exteroceptors in the hairy or skin surface.

Brushing

Repetitive brushing with a #12 quill brush at 50-60 revolutions per minute applied over the anterior and lateral T_6-T_{12} dermatomes for five minutes.

Icing

Quick rubbing lasting 2-3 seconds with an ice cube, wrapped on all sides except the side in contact with the skin to avoid additional stimulus by dripping, to the anterior and lateral T_6-T_{12} dermatomes skin area.

End-Tidal PCO_2

A measurement of carbon dioxide tension by means of continuous breath by breath sampling by the Respiratory Monitoring System II mass spectrometer manufactured by the Perkin-Elmer Company. The end portion of an expired volume is analyzed for carbon dioxide tension and is reflective of the arterial carbon dioxide, $PaCO_2$.

Minute Volume

Tidal volume multiplied by respiratory rate is equal to minute volume. Minute volume is the total volume of expired gas in one minute. Minute volume was measured by the Bourns Ventilatory Monitor Model LS-75.

Tidal Volume

Calculated from minute volume the volume of gas expired and inspired during each respiratory cycle, reflecting depth of breathing (Comroe, 1974).

The remaining steps taken to solve the problem of this study include:

1. Review of the literature for: (a) similar studies using the same experimental technique; and (b) the current methods used in measuring effectiveness of breathing retraining and exercise when caring for the patient with C.O.P.D.

2. Pilot study of two patients with Margaret Rood present, observing technique.

3. After obtaining consent for use of the respiratory critical care unit from the Medical Director of the respiratory intensive care unit, Director of Nursing and Charge Nurse at Medical Center, interviewing and selecting participating patients, and explaining experimental technique to patients.

4. Arranging five days when objective data could be collected.

5. Interpreting data in relation to hypothesis.

6. Summarizing data, drawing conclusions and making recommendations.

Chapter 2

LITERATURE REVIEW

Research studies are based upon previously documented theories and studies with an effort to expand upon that knowledge with new information gained through further scientific investigation. Literature was reviewed to relate the present problem to background theory and similar studies. The purpose of this review was to develop a better understanding of the specific problem chosen for clinical investigation.

The anatomy and physiology of the somatic afferent pathways which can be stimulated to effect respiration have been discussed in the previous chapter. The studies which establish a definite relationship between somatic afferent nerve stimulation and the synchronization of respiration are numberous. This review will focus on a few animal studies and studies in man.

ANIMAL STUDIES OF AFFERENT PATHWAYS

Kalia, and Others (1972) supported the belief that nonmedullated fibers (C fibers) stimulate stretch receptors in the muscles which produce a reflex increase in ventilation. Using 20 dogs, they postulated that stimulation by stretching and pressure on the sensory receptors in the nerve to the gastrocnemius muscle would produce a reflex hyperventilation. The dogs were anesthetized and a spirometric recording of the expiratory minute volume was obtained through a tracheal cannula. Natural stimulation using pressure and stretching was applied to the lateral gastrocnemius nerve. Ten dogs at 37°C. rectal temperature showed an increase in ventilation ranging from 25 to 32 per cent when the nerve was stretched, and 19 to 81 per cent increase in ventilation when the pressure was applied to the nerve. The rectal temperatures of ten dogs were then reduced to 5°C. which blocks all fiber pulses except the C fiber, and ventilation still increased 3 to 28 per cent when pressure was applied and 10 to 15 per cent from the effect of stretch on the nerve. The mean increase in minute ventilation over the control level was highly significant ($p<0.01$) (Kalia, and Others, 1972).

Two conclusions were drawn from this investigation: "1) that there are endings in the muscles connected to . . . C fibers . . . which are stimulated by pressure and stretching, and 2) that stimulation of these nerve endings produces a reflex increase in ventilation." (Kalia, and Others, 1972, p. 192) This would therefore support the use of C fiber stimulation to produce an increase in ventilation. Animal studies allow for control of variables which human studies cannot. For this reason, studies such as the one by Kalia and others are important before further human studies can be designed.

Remmers, in 1973, studied 28 cats for specific extrasegmental reflexes derived from intercostal afferent nerves. This experiment was done to determine the phrenic response from middle and caudal intercostal afferent stimulation and to trace the afferent fibers responsible for the reflex.

The cats were anesthetized, intubated orally and placed on a positive pressure respirator. Arterial blood PO_2, PCO_2 and pH were determined by electrodes. Electrical stimuli were pulsed relative to the respiratory cycle. In most cases, two pairs of external intercostal nerves, T_5 and T_6, T_9 and T_{10} were stimulated.

The results suggested that extrasegmental intercostal reflexes could initiate respiration and were greatly dependent upon the point in the expiration cycle at which the stimulus occurred. The later in the expiration cycle the stimulus occurred, the more pronounced the reflex in respiration. The neural pathway involved was traced to the dorsal root with a reflex contraction of the diaphragm via the phrenic nerve. This nerve pathway was traced by a series of surgically placed electrodes. This study suggested that a somatic afferent stimulus can result in a reflex contraction of the diaphragm. This study supported the use of somatic afferent stimulation to produce hyperventilation (Remmers, 1973). It should be kept in mind that a natural stimulus was not used and an electrical stimulus was. In humans, the use of natural stimuli may produce a different response than the use of electrical impulses.

Response of the central nervous system to afferent fiber stimulation was still uncertain. To date, there were no studies which link somatic afferent stimulation through specific circuitry to the central nervous system (Remmers, 1973, pp. 45-62).

In 1976, Iscoe and Polosa supported the work of Remmers, using a similar study of 27 cats. The experimental conditions were similar to Remmers' except the cutaneous radial and hamstring afferent nerves were used. "The results demonstrated the existence of a reflex mechanism capable of locking respiratory frequency to that of periodic somatic afferent input."

(Iscoe and Polosa, 1976, p. 135) Again, the mention that data regarding central circuitry of respiratory reflex from afferent stimulation existed. Remmers believed "the (afferent) reflexes derived from midthoracic regions are mediated by the bulbopontine respiratory mechanisms which does seem plausible since the timing of expiration-inspiration cycles are affected by somatic afferent stimulation." (Remmers, 1973, p. 45)

Studies were reviewed which contradict the use of sensory stimulation to improve ventilation. McCloskey and others (1972) tested the response of tricep muscle vibration on respiration. Eight cats were used in the study. The muscles were vibrated by an electromagnetic vibrator. Frequencies of 100-300 cycles/second were used. Respirations were recorded as airflow by a low resistance pneumotachometer connected to the tracheal cannula and integrated electronically to give tidal volume. In six out of eight cats vibration produced no increase in either the rate or depth of breathing (McCloskey, and Others, 1972).

In 1958 a similar study using seven cats was performed. Vibration by an electromagnetic vibrator was applied to the gastrocnemius, plantaris, and soleus muscles at 100-300 cycles per second. The vibration effect on respiration was measured by a flowmeter attached to the tracheal cannula. No changes in ventilation were recorded on the flowmeter flowing vibration.

Squeezing was then applied to the same muscle to evoke a change in respiration. The squeezing was done to affirm the presence of afferent fibers' function in the muscle. Squeezing resulted in a 65 per cent increase in ventilation ($p<0.01$). Since squeezing established the presence of afferent fibers in the muscles, the investigator concluded that vibration of the muscle was not effective in regulating respiration (Hodgson, and Others, 1968, p. 555).

Two points should be made regarding the use of vibration to stimulate afferent fibers. First, vibration was done directly to the muscle of those cats. Often the sensitivity of C-fibers can be obliterated by too forceful an applied stimulation (Coleridge and Coleridge, 1977). Secondly, the use of frequencies of 100-300 cycles per second vibration may fatigue a C-fiber. According to studies on slow conducting afferent fibers by Johnson, the most effective frequency for vibration stimulation of C-fibers was 40-60 cycles per second (Johnson, 1974, p. 48). Talbot also reports the same frequency to stimulate slowly adapting afferent fibers in the skin in the hand of both monkeys and man (Talbot, 1968). Vibration and repetitive stimulation may not follow the same afferent circuitry, although both are types of tactile sensory input.

The fact that sudden cold affected afferent A delta fibers was not contradicted in the literature (Iggo, 1975). However, the effect of cold on respirations of cats was not studied specifically in the articles reviewed. Previously it was mentioned that Keating observed marked hyperventilation when cold showers were applied to the trunk of cats. This was alluded to by Comroe in 1974.

The studies reviewed in animals indicate that afferent fibers can stimulate hyperventilation when mechanical squeezing or electrical stimulation occurs. Studies of vibration at high frequencies were the only ones found which did not support afferent stimulation of C fiber to improve respiration. The specific technique of repetitive brushing and quick icing to afferent C-fibers was not related to control of respiration in the literature. The circuitry affecting the synchronization of respiration from afferent fiber stimulation was still only speculative.

Application of sensory stimulation by repetitive brushing and quick icing was then reviewed in human subjects.

EFFECT OF SENSORY STIMULATION ON RESPIRATION IN MAN

Physical therapists were the first to apply sensory stimulation by the use of brushing and icing to increase diaphragmatic excursion in man. Rood, in a personal communication, indicated that the use of brushing and icing does aid in the rehabilitation program of asthmatic and emphysematous patients. To date, Rood has published no scientific data to support her conclusion, although she has given the sound neurophysiological basis to support such statements in the literature (Rood, 1962). Rood, in 1962, suggested that fast repetitive brushing and quick icing of 2-3 seconds would stimulate a reflex excursion of the diaphragm. When C-fibers are stimulated tension in the abdominal muscles increases and A-delta fiber stimulation inhibits these surface abdominal muscles and activation of the antagonist. Thus, C-fibers and A-fibers may facilitate each other to volley a reflex response via the dorsal root to the diaphragm causing increased excursion (Rood, 1962). Rood chose specific areas at which to start the brushing and icing based on the site of referred pain from a torn diaphragm. These referred pain sites on the anterior aspect of the thoracic region were discussed by Ruch and Patton in their Textbook of Physiology and Biophysics in 1965.

Sister Elizabeth studied under Rood and in 1966 introduced the technique of brushing and icing into the practice of nursing. It was in her article that the precise tools and technique to be used by the nurse in sensory stimulation were described. Elizabeth suggested that brushing and icing specific areas "could induce micturition, check dribbling, stop enuresis, alleviate headaches partially or completely, help severe asthmatic or emphysematous patients to establish normal breathing, or a person with a brain lesion to perceive a complete body image." (Elizabeth, 1966, p. 281)

These two articles by Rood and Elizabeth laid the physiological and practical groundwork even though they were empirically presented without scientific data to support the suggestions. Nursing and physical therapy have since evolved some research to support the theory of sensory stimulation using icing and brushing. To date, there is no literature with clinical investigations into the effect of sensory stimulation using brushing and icing to promote deep breathing. The research by other nurses and physical therapists which used brushing and icing to promote micturition, improve body image, and increase tendon reflexes was reviewed to increase the researcher's knowledge of human responses to sensory stimulation.

Two nursing studies were the first to test through clinical investigation the effect of brushing and icing on micturition.

In 1967, Bergstrom used icing and brushing to specific areas of the skin that related to the urinary bladder reflexes as described in Rood's and Elizabeth's articles. Bergstrom hypothesized that post-operative patients with urinary retention would void following brushing and icing of specific skin areas. Sixteen patients were included in the investigation. Nine of these patients voided following icing and brushing while seven were unable to void. Though the sample size was small, the scientific rationale laid the groundwork for further study in this area (Bergstrom, 1968).

Pearce (1970), using the exact experimental technique as Bergstrom, studied sixteen cardiovascular accident patients with urinary retention. Eight patients were used in the control group and eight patients had brushing and icing to produce micturition. Pearce hypothesized that these patients would urinate within a prescribed time at a prescribed place following brushing and icing. A statistically significant number of patients were found to have increased control of micturition (Pearce, 1970). Again, the sample size was small and could not be generalized to the total population. However, the fact that a few patients were aided by the technique of brushing and icing to promote micturition made it a feasible technique to employ when patients are having difficulty voiding, especially if catheterization can be avoided.

Another study using the technique of sensory stimulation by brushing was completed by Bradley in 1972. Bradley studied fourteen patients diagnosed as hemiplegic using brushing to improve body awareness of affected limb. With seven patients serving as controls, the technique of repetitive brushing was applied to the affected limb of seven other hemiplegic patients. Clinically, only three patients showed any subjective or objective improvement following application of repetitive brushing. The results were not statistically significant. Still, the fact that this specific technique helped three hemiplegics in improvement of their awareness of the affected limb, makes this a helpful mode of treatment for some hemiplegic patients in their struggle with body awareness of an affected limb (Bradley, 1972).

The most recent study using the technique of sensory stimulation by repetitive brushing and quick icing to afferent C and A delta fibers was published by Weisberg in 1976. Weisberg, a physical therapist, used repetitive brushing and quick icing to stimulate the skin area over the gastrocnemius muscle. He hypothesized that sensory stimulation of this area would increase the Achilles tendon reflex. Thirty-one adult subjects were tested. All persons on the experimental group demonstrated a more active increase in the Achilles reflex following repetitive brushing and quick icing. This study had the largest sample size. The measures used in recording the results in displacement of the foot following sensory stimulation were well controlled. By selecting to study a reflex which could be objectively measured, Weisberg was able to demonstrate that brushing and icing could enhance reflex activity (Weisberg, 1976).

Although Weisberg's research was not directed to promote diaphragm muscle reflex, he did use the same sensory stimulation technique as used in the present study. The use of repetitive brushing and icing has shown some beneficial results in all studies. For this reason, the use of repetitive brushing and quick icing to stimulate diaphragmatic excursion in C.O.P.D. patients seems to merit clinical investigation.

It was therefore decided to proceed with testing the effect of sensory stimulation in promoting deep breathing in the C.O.P.D. patient.

CURRENT METHODS USED TO MEASURE THE EFFECTIVENESS OF BREATHING RETRAINING IN C.O.P.D. PATIENTS

Breathing retraining incorporates relaxation maneuvers, slow deep breathing exercises, abdominal-diaphragmatic exercises, positioning maneuvers, pursed lip breathing and intermittent positive pressure breathing with a mechanical respirator (Frownfelter, 1978). Clinical benefit from these techniques shows inconsistent results. However, in the United States the treatment plan for C.O.P.D. patients in large medical centers includes most of these techniques (Petty, 1974). To review comparative studies on each breathing retraining technique was beyond the scope of this study. Some studies on breathing retraining techniques were reviewed to determine measures that could be used to demonstrate clinical benefit from breathing retraining techniques. This review would give the investigator guidelines to use in measuring the effectiveness of the breathing retraining technique tested in this study.

Breathing retraining studies are conducted to promote short-term and long-term clinical benefit for the C.O.P.D. patient. The sensory stimulation technique of breathing retraining has short-term goals. First it should be emphasized that any breathing retraining technique acts only as a part of a comprehensive respiratory rehabilitation program. Secondly, breathing retraining must be done in conjunction with learned exercise reconditioning in order to be effective in promoting the optimal results. However, for research purposes it was necessary to isolate the specific breathing retraining technique of sensory stimulation in order to test its effectiveness.

The fact that any person trained in methods of relaxation could breathe more effectively seems obvious. Relaxation instruction provided the C.O.P.D. patient with a sense of security making him a better match for the terrifying dyspnea which captivates him (Motley, 1963). Relaxation techniques were studied in twenty-four patients with asthma. The patients were composed of severe asthmatics and non-severe asthmatics. The severe asthmatics were identified because they were receiving cortisone therapy at the time of the study. The non-severe asthmatics were receiving no therapy. Half of the subjects were tested using a relaxation technique, the Jacobsen technique, while the other half were treated with the same relaxation technique plus biofeedback. Electrodes were placed on the forehead skin (most indicative of overall muscle relaxation), and feedback was registered on a Bioelectric Information System Machine. Relaxation training sessions were 30 minutes five days a week (Davis, and Others, 1973).

The respiratory benefit from relaxation technique was measured by a Wright Peak Meter which measured only reduction or increase in airway resistance. Peak flow rates were taken for a baseline period of eight days prior to any relaxation training. Flow rates were taken for five days during treatment and eight days following treatment (Davis, and Others, 1973).

The study demonstrated that relaxation training, including biofeedback, resulted in the greatest reduction of asthmatic symptoms in non-severe asthmatic patients. Peak flow measurements were significant ($p=0.05$) in this group (Davis, and Others, 1973.

An increase in the peak expiratory flow rate does indicate a decrease in airway resistance. However, to correlate this benefit to improvement from a relaxation technique, a cleared airway, less bronchoconstriction or improved perfusion is difficult. The peak flow rate for this reason was not used to measure the effect of sensory stimulation (Davis, and Others, 1973).

Motley (1963) studied fifty-five patients with severe asthma. He tested the effectiveness of slow deep breathing training on blood gas levels, pulmonary function studies, tidal volume, and respiratory rate. Twenty-five patients were in a control group and twenty-five patients were tested after slow deep breathing training. Motley used an electronic respiration stimulator device to slow down the rate of breathing. This device was attached to the patient's pillow and the rate of breaths were set at eight to twelve per minute. Subjects listening to these sounds would tend to match the breathing pattern of that instrument.

Results demonstrated a 40 to 50 per cent slowing of respiratory rate per minute and a 50 to 100 per cent increase in tidal volume. There was a significant increase in the elimination of carbon dioxide, the average being about 3.3 mm of mercury of $PaCO_2$. Minute volume was also recorded but considerable variation occurred from case to case as compared to tidal volume. Though lung volumes of vital capacity at one and three seconds were taken along with maximal breathing capacity these were not discussed in the results (Motley, 1963, pp. 484-491).

Miller studied the effects of diaphragmatic exercise training on respiration in 1954. His study was the one most frequently referred to in the literature for demonstrating beneficial effects of a breathing retraining technique. Twenty-four patients were included in the study. Patients were all diagnosed as having chronic pulmonary emphysema. Patients were trained in diaphragmatic breathing techniques described by the Asthma Research Council of England. Training lasted six to eight weeks.

Diaphragmatic excursion improvement was measured by fluoroscopy. Arterial blood gases, respiratory rate, tidal volume and pulmonary function studies were used to measure improvement in respiration. Before and after values were recorded and compared to determine effectiveness of dia-hragmatic breathing training. Fluoroscopy of diaphragm showed an increase of excursion of 3.0 centimeters post training ($p<0.01$). Respiratory rate decreased 5.1 per minute ($p<0.01$). Tidal volume increased 162 ml ($p<0.01$). Oxygen removal reflected an increase of 9.1 ml per liter of ventilation ($p<0.05$). This lead to the conclusion that diaphragmatic breathing is an effective adjunct in the treatment of pulmonary emphysema (Miller, 1954).

In 1954 Barach and Beck observed 24 patients with emphysema for the effects of position on breathing. The patients were observed in sitting, supine and head down positions. Arterial blood gases were used to determine effects of position on respiration following forty-five minutes in the position. In most instances, a decline of 16 degrees was used for the head down position, with a pillow placed under the head. A Collins' spirometer with a Reichert attachment recorded pulmonary ventilation. Fluoroscopy was used to determine change in diaphragmatic excursion.

Results from the study showed a diaphragmatic excursion of 1.5 cm when standing, 2.4 cm when supine and 4.0 cm when in the head down position. The change in oxygen saturation was most significant in the head down position, rising from 83.4 to 87.0 per cent. The pulmonary ventilation averaged a 26 per cent fall. The greatest decrease was in the head down position, demonstrating a reduction in minute volume. No change was noted in the pH and PCO_2 in most cases.

It was concluded that the head down position was most effective for diaphragmatic breathing training with less oxygen demand on the patient due to relaxation of the accessory muscles. Relief of dyspnea was marked in this position (Barach and Beck, 1954).

In 1971 Petty and Guthrie studied ten patients with severe chronic airway disease. They compared the effectiveness of four methods for augmenting breathing. These methods were: 1) lower chest and abdominal compression; 2) intermittent positive pressure breathing; 3) voluntary deep breathing; and 4) abdominal deep breathing with pursed lip expiration.

Changes in ventilation were determined by arterial PCO_2 and minute volume. Tidal volume was measured by the Wright Respirometer. Arterial PCO_2 was determined by blood gas analysis. All patients were studied in a sitting position; all patients' conditions were stable. Each procedure was done following a ten-minute control period with ten minutes of study with various methods.

Results demonstrated a significant reduction in PCO_2 following all treatment methods ranging from $p<.5$ to $p<.01$. The greatest drop in PCO_2 was produced by IPPB with a reduction in PCO_2 of 11 mm of mercury. Tidal volume increased significantly with all procedures, ranging from $p<.01$ to $p<.02$. Again IPPB produced the greatest change increasing tidal volume 796 cc from baseline. Respiration rate decreased significantly from $p<.01$ to $p<.05$ with all maneuvers. Again the greatest results occurred following

IPPB. However, when minute volume was compared to PCO_2 to determine ventilation and perfusion changes together the most significant change produced was from diaphragmatic breathing in conjunction with pursed lips on exhalation. The investigators therefore advocated diaphragmatic breathing with pursed lip exhalation as an effective technique for improving a patient's breathing pattern (Petty and Guthrie, 1971, p. 104).

Breathing retraining techniques have also been reported not to be beneficial for the chronic obstructive pulmonary disease patient.

Becklake, and Others (1954) studied fifteen emphysematous subjects using two forms of breathing retraining. Breathing with prolonged expiration was one method. The second technique incorporated the first and added electrical stimulation by a faradic current to chest and abdominal wall. Pulmonary function studies were used to measure results before and after breathing retraining. Results showed only two of the fifteen patients had any improvement on pulmonary function studies with either method. It was concluded that no efficacy of these methods could be shown because of lack of objective improvement from the breathing exercises used (Becklake, and Others, 1954, p. 180).

Sinclair, in 1969, supported the views of Becklake and others. Studying twenty-two patients with pulmonary emphysema, abdominal-diaphragmatic exercises were used to evaluate diaphragmatic excursion, vital capacity and maximal breathing capacity. Diaphragmatic excursion was measured by vertical movement of the diaphragm from a selected midpoint. Vital capacity and maximal breathing capacity was measured by Benedict-Roth spirometer. Values were recorded before and after breathing retraining.

Results demonstrated only a slight but not significant improvement in lung function studies. No diaphragmatic excursion improvements were assessed. The conclusion was that abdominal-diaphragmatic breathing was not a successful mode of treatment for chronic pulmonary emphysematous patients (Sinclair, 1969, p. 246).

Breathing retraining has been advocated in most treatment programs for patients with C.O.P.D. throughout the world. Having reviewed the literature and finding contradiction in benefits from many training techniques used for breathing exercises, the investigator felt it was still necessary to continue research to test the breathing retraining method of sensory stimulation.

The review of literature did help the investigator determine the measures to use in testing the effectiveness of sensory stimulation, Diaphragmatic excursion changes seemed best measured by tidal volume changes since the cost and risk of fluoroscopy made its use impractical. It must be noted, however, that changes in tidal volume could well be due to accessory inspiratory muscle contraction rather than diaphragmatic contraction. End-tidal carbon dioxide was selected to reflect changes in alveolar gas exchange, since end-tidal carbon dioxide is the most accurate noninvasive method of reflecting changes in arterial carbon dioxide. Respiration rate, minute volume and heart rate were also selected for measures because they reflect cardiopulmonary changes which might occur as a result of sensory stimulation. The blood pressure value was also selected for measurement because a change in blood pressure could reflect an increase in carbon dioxide (Comroe, 1974). Other pulmonary function studies were not used to measure results because the studies reviewed using these measures reported no significant changes in their values. A head down position was also used because one of the goals of breathing retraining is to limit oxygen cost during breathing. The head down position relaxes the accessory muscle work and limits the oxygen consumption used in this effort (Smey, 1970, p. 44).

SUMMARY

Literature reviewed has focused on the sensory stimulation of afferent fibers which could influence respiration. Animal studies and studies in man have been reviewed. Contradiction does exist regarding the effectiveness of afferent fiber stimulation. Also there was disagreement as to the technique which should be used to stimulate afferent fibers. There are still many gaps in knowledge in the field of sensory neurology and its effect on respiration. For this reason it was necessary to assume from the positive studies using repetitive brushing and quick icing, for sensory stimulation of micturition and tendon reflexes, that sensory stimulation could be a technique for breathing retraining.

Chapter 3

RESEARCH METHOD

This study used the case study method of research. This method provided descriptive background of the subjects studied. The case study method also provided more control of emotional variables that can affect the degree of shortness of breath the C.O.P.D. patient experiences (Dudley, 1969). Daily contact with subjects for eight hours provided a more relaxed environment in which caring for the patient as a total person could be demonstrated by the investigator. A descriptive history of the patient was obtained through chart review and personal interview, conversation with the patient during contact hours, observation of the patient, and testing. Testing used a sensory stimulation technique to promote deep breathing. The subjects acted as their own controls; the independent variable was the application of the sensory stimulation technique. No generalizations were made to the entire population of C.O.P.D. patients due to the few subjects studied. In studying only a few subjects repetition of the technique tested could allow for problem solving for further research which might include more subjects.

The descriptive case study method seemed most appropriate for the primary investigator, a nurse. Fox stated, "One specific type of descriptive survey worthy of attention and which has wider applicability or nursing than one could suspect from the incidence of such study is the case study." (Fox, 1976, p. 186)

SAMPLE SELECTION

Sample selection was purposive and convenient. Subjects were selected that would limit, as much as possible, extraneous variables. Extraneous variables not controlled were described and their effect analyzed whenever possible.

Sample Criteria

Subjects were selected according to the following criteria:

1. Diagnosis of C.O.P.D.

2. Presently on a comprehensive respiratory rehabilitation program.

3. Stable history of chronic disease for past year.

4. Subjects volunteering for study would have enough free time to participate.

5. Subjects would live in the radius of 20 miles from study setting.

Rationale for Sample Criteria

The rationale of the sample criteria will be explained below, explaining separately each sample criterion.

Diagnosis of C.O.P.D. Pre-existing C.O.P.D. was established by chart review, physician's history and examination, radiographical study, pulmonary function studies, and arterial blood gas studies. C.O.P.D. patients were selected because literature suggested that sensory stimulation might benefit respiration in this patient group (Rood, 1962;

Elizabeth, 1966). Current literature on C.O.P.D. reported the need for C.O.P.D. patients to participate in breathing retraining (Frownfelter, 1978; Lertzman and Cherniak, 1976; Hodgkin, and Others, 1975).

Presently on comprehensive respiratory rehabilitation program. A comprehensive respiratory rehabilitation program included clinical evaluation, patient and family education, pharmacological treatment modalities, physical and respiratory therapy rehabilitation, counseling and psychotherapy as needed, vocational rehabilitation training and extensive follow-up (Hodgkin, and Others, 1975). Subjects with C.O.P.D. exposed to the above respiratory rehabilitation program were ready for additional instruction in breathing retraining. Prior knowledge of disease process made subjects less anxious regarding breathing retraining (Miller, 1958).

Stable history of C.O.P.D. for past year. Subjects were best suited for the program who had not been recently hospitalized. Acute exacerbation of C.O.P.D. is often associated with excessive bronchopulmonary inflammation, bronchoconstriction and increased obstructing secretion. Each of these acute symptoms could influence the results of the research. Too often skeptical views of breathing retraining are presented because physiologically, the subjects' disease states are variable (Miller, 1958).

Subject's ability to participate. The subjects were selected who were willing to spend eight hours a day for five days a week with the investigator.

Subject's location to research setting. The subjects selected were chosen because they lived within a 20-mile radius of the research setting. Since travel expenses were not paid for the subjects, it was important to keep distances reasonable for commuting each day.

METHOD OF SAMPLE SELECTION

Subjects were selected who could meet the sample criteria identified. The respiratory rehabilitation nurse and the cooperation of the respiratory physician heading the rehabilitation team made subject selection possible. Subjects were first contacted by telephone to set up a personal interview. During the personal interview explanation of the study was given with a demonstration of equipment used during data collection. The subject was asked if he would consent to participate in the study. A consent form was signed, a copy of which appears in Appendix B.

In addition to information regarding subject's diagnosis, comprehensive respiratory rehabilitation program, and stable condition that were obtained from the medical record, review of medical record was made for pertinent information needed for the case study presentation. This presentation will follow in Chapter 4.

Each subject arrived at the research setting at 7:45 a.m. where he remained for eight hours, except to leave to eat. Subjects were asked to control as much as possible food intake, exercise activities and activities of daily living while participating in study. All medications were taken routinely and maintained on the same schedule.

PILOT STUDY

The pilot study was conducted on three subjects selected from the respiratory rehabilitation program. The sensory stimulation method was used under the supervision of Margaret Rood, who critically assessed the method of brushing and icing application for stimulating deep breathing. The same parameters were measured on the pilot study patients, though a different machine was used to measure end-tidal PCO_2 in the actual study. Between the time of the pilot study and the actual study, a much more accurate computerized method of obtaining single breath analysis of PCO_2, the RMS II respiratory Monitoring System manufactured by Perkin-Elmer Corporation, was installed in the newly completed intensive respiratory care unit. Thanks to the cooperation of Dr. John Hodgkin, Chief of Pulmonary Section, the respiratory therapists and the nurses, I was able to use this more accurate way of obtaining end-tidal PCO_2 values.

It was my original intent before the pilot project to do one time sensory stimulation testing on a sample of twenty patients. From the pilot study I was able to discern that there was no way to control exactly what factor was influencing deep breathing by applying sensory stimulation once and measuring parameters before and after. Having no control over what occurred prior to the patient arriving at the test location, too many variables would be introduced. It was then decided to use a few subjects who could be available for extended repetitive testing over five days for the case studies.

DATA COLLECTION

General Procedure

Three subjects participate in the study. Sensory stimulation using repetitive brushing and quick icing to the anterior and lateral thoracic T_6-T_{12} was completed daily for four days. One day of baseline data was taken prior to testing. This will be explained later. On the second day sensory stimulation testing began. The sensory stimulation technique was applied at 10 a.m. on the second and fourth days and at 2 p.m. on the third and fifth days. Data collection on remaining days was every two hours, including every fifteen minutes for one hour following sensory stimulation times. These parameters were taken at these intervals whether or not testing occurred on second through fifth days (see Appendixes D, E, and F).

		Day 2	Day 3	Day 4	Day 5
a.m.	Baseline	Testing 10 a.m.	No test	Testing 10 a.m.	No test
p.m.	Day	No test	Testing	No test	Testing 2 p.m.

Two subjects were placed in a 12.6° head down position for sensory stimulation technique. This was done to relax the accessory muscles and reduce the oxygen cost of breathing during the procedure (Barach and Beck, 1954; Smey, 1970). One subject was unable to tolerate this position so was left supine during application of sensory stimulation technique. Sensory stimulation using repetitive brushing was done for five minutes with each test period. Repetitive brushing was started on the right side from midline of abdomen and brushing continued from anterior to lateral.

Each side was brushed for one minute and then the same routine done on the adjacent side. The right side received three minutes while the left side received two minutes of brushing. This was felt rational since more C-afferent receptors are located on the right (see Fig. 1 in first chapter). Quick icing was then initiated, following the same routine of brushing but for a limited time of 2-3 seconds, two seconds on right, one second on left, rotating sides each second.

Equipment

The equipment used in data collection included a blood pressure cuff and sphygmomanometer, a stethoscope, a Bourns Ventilation Monitor Model LS-75 for measuring minute volume and the RMS II by Perkin-Elmer Company for measuring end-tidal PCO_2.

The overall accuracy of the Bourns Ventilation Monitor, Model LS-75, was ±3 per cent at time of testing (Bourns, 1977). The overall accuracy of the RMS II by Perkin Elmer Company allows for a 5 per cent drift (Perkin-Elmer Corporation, 1977). Repetitive brushing was done with a battery-run #12 quill brush rotating at 50-60 cycles per minute.

Quick icing was applied by an ice cube wrapped in gauze on all sides except that side exposed to skin. This prevented dripping on any part of the skin area not being tested.

An intensive care bed was used for subjects which could be placed in the same head-down degrees, specifically indicated on bed, for all subjects in which position was used.

Specific Procedure

An example of the data collection form can be found in Appendix C.

Each subject was assigned a number (1, 2, 3). On day one baseline parameters were done every two hours including apical pulse rate, blood pressure, respiratory rate, minute volume and end-tidal PCO_2. Patients were encouraged to rest 15 minutes prior to any data collection. Oxygen levels were not taken because patients were on room air.

The testing of experimental technique was done as described previously on the 2nd, 3rd, 4th and 5th days, rotating time from a.m. to p.m. Parameters were obtained using the same objective values before and after application of experimental technique. On days two through five parameters were taken at 8 a.m., 10 a.m., 10:15 a.m., 10:30 a.m., 10:45 a.m., 11 a.m., 12 noon, 2 p.m., 2:15 p.m., 2:30 p.m., 2:45 p.m., 3 p.m., 4 p.m., and 6 p.m.

It was felt since Rood's experience indicated that benefits from sensory stimulation technique <u>might</u> last up to three hours that recordings of fifteen minute, thirty minute, forty-five minute, one hour, and two hour intervals were necessary to determine exactly how long benefits lasted.

In addition to objective data collected pre and post sensory stimulation, the investigator discussed daily the routines of diet, medication, activities of daily living and exercises to maintain them as constant as possible.

DATA ANALYSIS

Data analysis was begun following data collection. Parameters of tidal volume and end-tidal PCO_2 obtained on the 2nd and 4th mornings were compared before and after the sensory stimulation technique to parameters of tidal volume and end-tidal PCO_2 obtained on the 3rd and 5th mornings. On the afternoons the same parameters were compared before and after the application of sensory stimulation. Analysis was based on a general linear hypothesis model to examine changes that had occurred in the dependent variables. A computer was used to analyze these data. Measures of central tendency, such as mean, were also used to compare the before and after parameters. Graphs will be presented to compare some of the parameters not analyzed by the computer. The statistical analysis and graphs will be presented in Chapter 4.

SUMMARY

The purpose of the study was to provide descriptive information of subjects' physical and emotional health and relate these to the changes in subjects after a program of sensory stimulation. C.O.P.D. patients on a comprehensive respiratory rehabilitation program who were stable in their disease states and accessible and available for the length of study were selected.

A medical record review, patient interviews and personal observations were used for additional data for a descriptive case method presentation.

Chapter 4

FINDINGS AND DISCUSSION

The findings of the study will be presented in the following manner. A brief case presentation of each subject will be given, emphasis being placed on respiratory history and physical findings. A subjective and objective nursing evaluation will follow. Data will then be presented and analyzed as it relates to the hypothesis formed in Chapter 1. Extraneous variables will then be presented and discussion will follow.

SUBJECT ONE

Subject one was a 42-year-old Caucasian male who first noticed shortness of breath in 1962. In 1970 he was diagnosed with C.O.P.D., predominantly emphysema. He has a 30-pack year history of smoking and quit in 1970. He produces about one-half cup sputum daily which remains whitish in color unless he has a respiratory infection. He denies hemoptysis.

On physical examination his weight was 191 pounds and his height was 70 inches. His physical was essentially negative except for an increase in anterior posterior chest diameter, increased resonance of breath sounds at bases bilaterally and generally diminished breath sound. Angiogram revealed decreased vascularity of lower lobes. Minimal pulmonary hypertension was noted by a wedge pressure. Spirogram revealed a forced expiratory volume in one second of 24 per cent of predicted normal, and a vital capacity of 74 per cent of predicted normal. His maximal mid-expiratory flow rate was 75 per cent of predicted normal. Body box testing demonstrated a total lung capacity 174 per cent above normal with a residual volume to total lung capacity ratio 202 per cent of predicted normal. All tests were indicative of chronic obstructive airway disease (Hodgkin, and Others, 1975, p. 244). Emphysema was suggested because of the increase in total lung capacity. However, emphysema cannot truly be diagnosed except morphologically from autopsy findings.

Nursing Evaluation

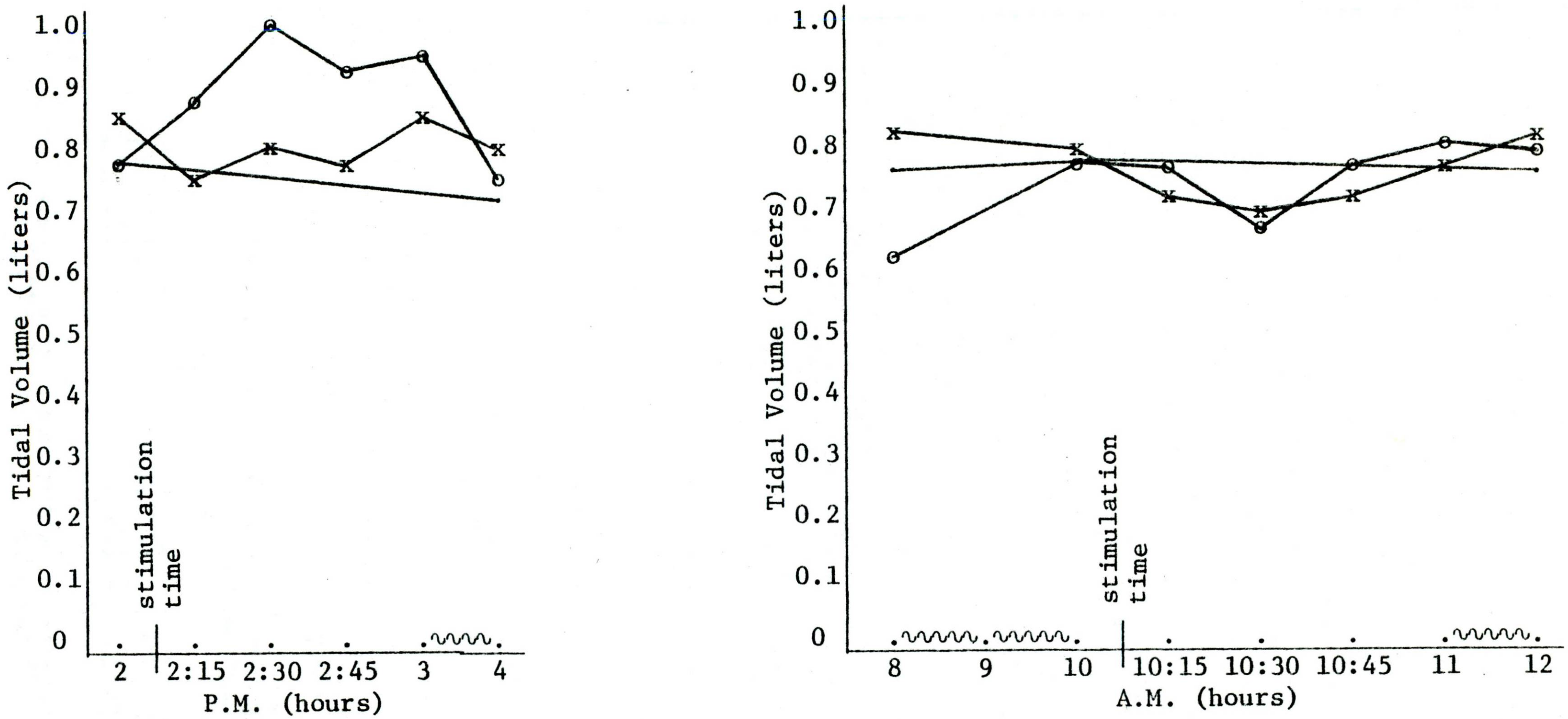
Subject one was a retired Marine who worked as a mechanic on tanks until he was placed on disability because of emphysema. He lives alone, has been married, and has four sons with whom he communicates infrequently. He was independent, totally self-caring. He cooks his own meals when he doesn't eat out. He cleans his own small house by pacing himself according to degree of shortness of breath. He sleeps with one pillow and awakens short of breath only occasionally, with this being relieved by opening the window. He takes tub baths and was not bothered by steam. His neighbor was a close friend, also disabled. He likes living alone. He rides a motorcycle and gardens when not watching television. He stated he was an agnostic.

His activities of daily living were accomplished by pacing himself slowly to prevent shortness of breath. He mows his own lawn with an electric mower. On a treadmill he walks a mile in 30 minutes. He has been advised in breathing exercises and reconditioning exercises that will help his breathing. He was anxious to learn any method that might help him cope with his shortness of breath. He drove his own car to the research setting and became more relaxed with each additional day of testing. His medications and diet were discussed in depth and maintained on the same routine throughout testing period. He uses accessory muscles when breathing.

Data Analysis

This subject was tested in a supine position. Graphs were made of parameters recorded and a mean of the second and fourth day values were compared against means from the third and fourth day values. Since the hypothesis only deals with tidal volume changes and end-tidal PCO_2 changes the significant findings of these two values were the only ones computed on a general linear model. Graphs of the two pulmonary objective data recorded will be presented and discussed briefly. However, the findings of the study can only be discussed in relationship to graphs on changes in tidal volume and end-tidal PCO_2.

Tidal volume. According to the hypothesis tidal volume was predicted to increase ($p=0.05$), following the sensory stimulation technique. The changes in tidal volume for subject one are shown in the form of two graphs on Figure 4. One graph represents morning results with and without sensory stimulation; the other represents afternoon results with and without sensory stimulation. Numbers on graphs are a mean of the same time interval recordings taken on the days compared. The baseline values were also graphed to indicate the variance from day one parameters to other days. However, the baseline parameters were not part of the general linear model computations.



• = baseline day
x = test day
o = no test day

Figure 4

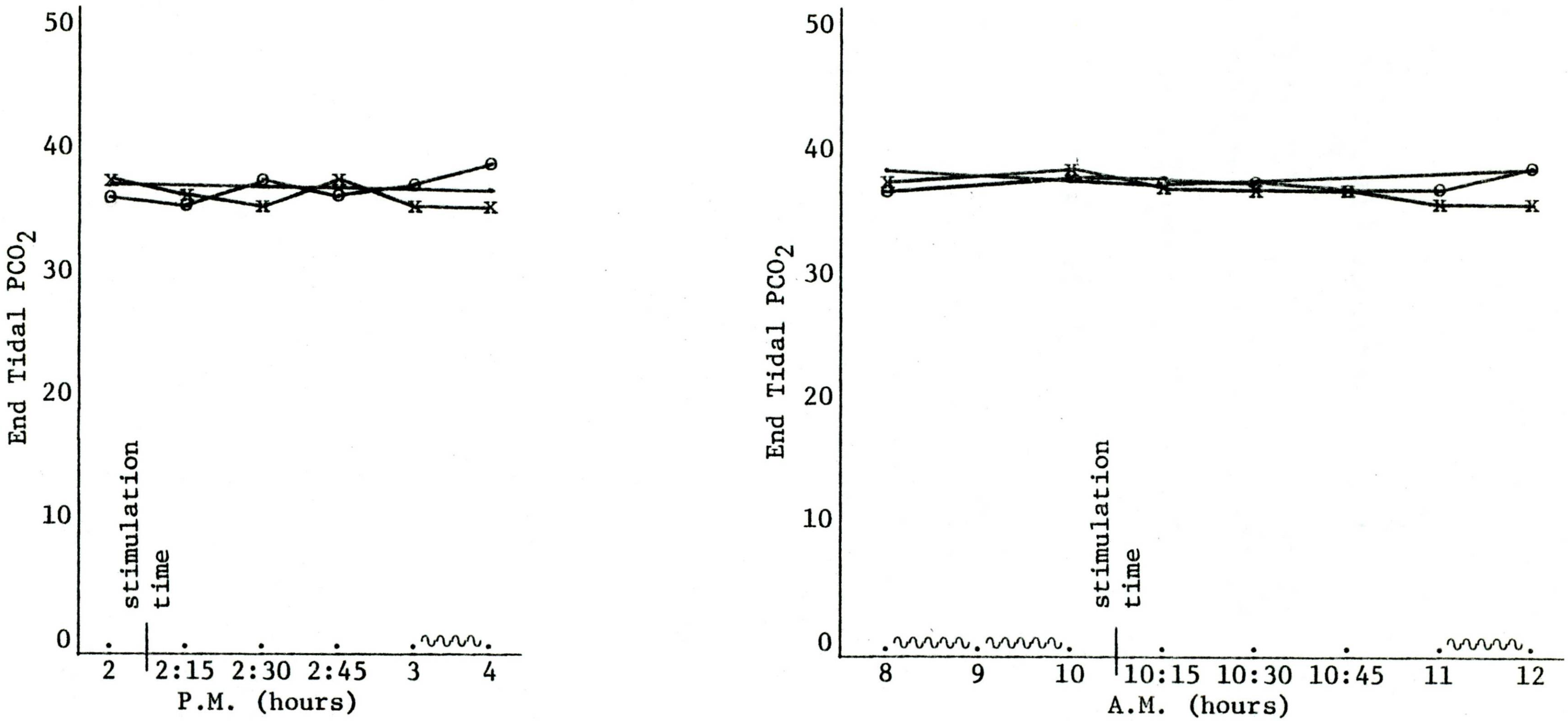
Tidal Volume Changes at Selected Time Intervals With and
Without Sensory Stimulation - Subject One

From the tidal volume graph on subject one, Figure 4, it was noted that no consistent changes in tidal volume were evident with sensory stimulation. Analysis based on the general linear hypothesis showed that this difference was not significant at the $p=0.05$ level. Tidal volume fluctuation on days of sensory stimulation and days without sensory stimulation was not varied enough to draw any significant conclusion.

End-tidal PCO_2. The two graph results of end-tidal PCO_2 for subject one can be seen in Figure 5. The graphs were set up exactly like tidal volume graphs except end-tidal PCO_2 was used. Again no consistent changes were shown from sensory stimulation technique. Analysis based on a general linear hypothesis again showed no significant difference between sensory stimulation days and no sensory stimulation days. In subject one no significant decrease in his end-tidal PCO_2 was seen with sensory stimulation.

Extraneous parameters.

1. Respiratory rate. Changes in respiratory rate with and without sensory stimulation were observed. The baseline days show that subject was very consistent in both morning and afternoon parameters. With sensory stimulation in the morning respiratory rate was higher than baseline respirations on day one but lower or equal to days without sensory stimulation. Because the results were not consistently different on the days with sensory stimulation the investigator could not determine any consequential change in respiration rate, especially when afternoon respiratory rates showed almost opposite results following testing from sensory stimulation.



- = baseline
x = test period
o = no test

Figure 5

End-Tidal PCO_2 Changes at Selected Time Intervals With and Without Sensory Stimulation - Subject One

2. Minute volume. Minute volume was also observed. The observations were recorded and used to compute tidal volume. Minute volume was very similar to tidal volume results. Sensory stimulation did not show any consequential changes in minute volume.

3. Heart rate and blood pressure. Heart rate and blood pressure were also observed to see if sensory stimulation had any effect on the cardiovascular system. No real difference could be consistently noted following technique.

SUBJECT TWO

Subject two was a 47-year-old Caucasian female with a history of asthma since 1948. She was diagnosed in 1972 as having chronic obstructive airway disease and placed on a comprehensive rehabilitation program. She has a history of smoking, 50 pack years, quitting seven years ago. She has a history of heart arrhythmias which have been well controlled by Dilantin. She has had numerous surgeries, none of which seem to affect her respiratory status at present time.

Physical examination showed her weight to be 114 pounds and her height 65 inches. The examination was unremarkable except for slight jugular vein distension. Accessory muscles are used to breathe at rest. Auscultation of lungs noted diminished breath sounds with a few inspiratory rales at the right base and scattered expiratory wheezes. Cardiac rhythm was normal; there were no murmurs or rubs. Spirogram showed a force expiratory volume per second of 39 per cent, a maximal midexpiratory flow rate of 7 per cent and a vital capacity of 22 per cent. Body box testing of volumes demonstrated a total lung capacity of 134.9 per cent of predicted normal and a residual volume x 100 over vital capacity of 195.7 per cent of predicted normal. All pulmonary function tests were indicative of chronic obstructive disease. Again, the elevated total lung capacity suggested emphysemic changes.

Nursing Evaluation

Subject two was a divorced mother of two sons. Both sons are out of the home. She claims her life to be emotionally stable for the first time in many years. She lives alone but has a male friend who provides her with emotional support. She feels she has accepted her divorce and fallen into a daily routine of living alone. She performs total self-care and was independent in house cleaning, driving, and even baby sits occasionally. She lives in an upstairs apartment and has noticed increased shortness of breath on climbing stairs but not enough to cause her to move. She was talkative about her methods of exercise training and anxious to learn any new method that might help her breathe more adequately. She feels she has faith in God but does not attend church. Her outlook on life was positive. She appeared relaxed during testing sessions and most cooperative. She sleeps with one pillow and does not admit to any orthopnea. She was supported on welfare and Medi-Cal pays medical expenses. She was on several routine medications. Medications, dietary habits and activity levels were all kept as consistent as possible during week of testing.

Data Analysis

Subject two was tested in the head-down position.

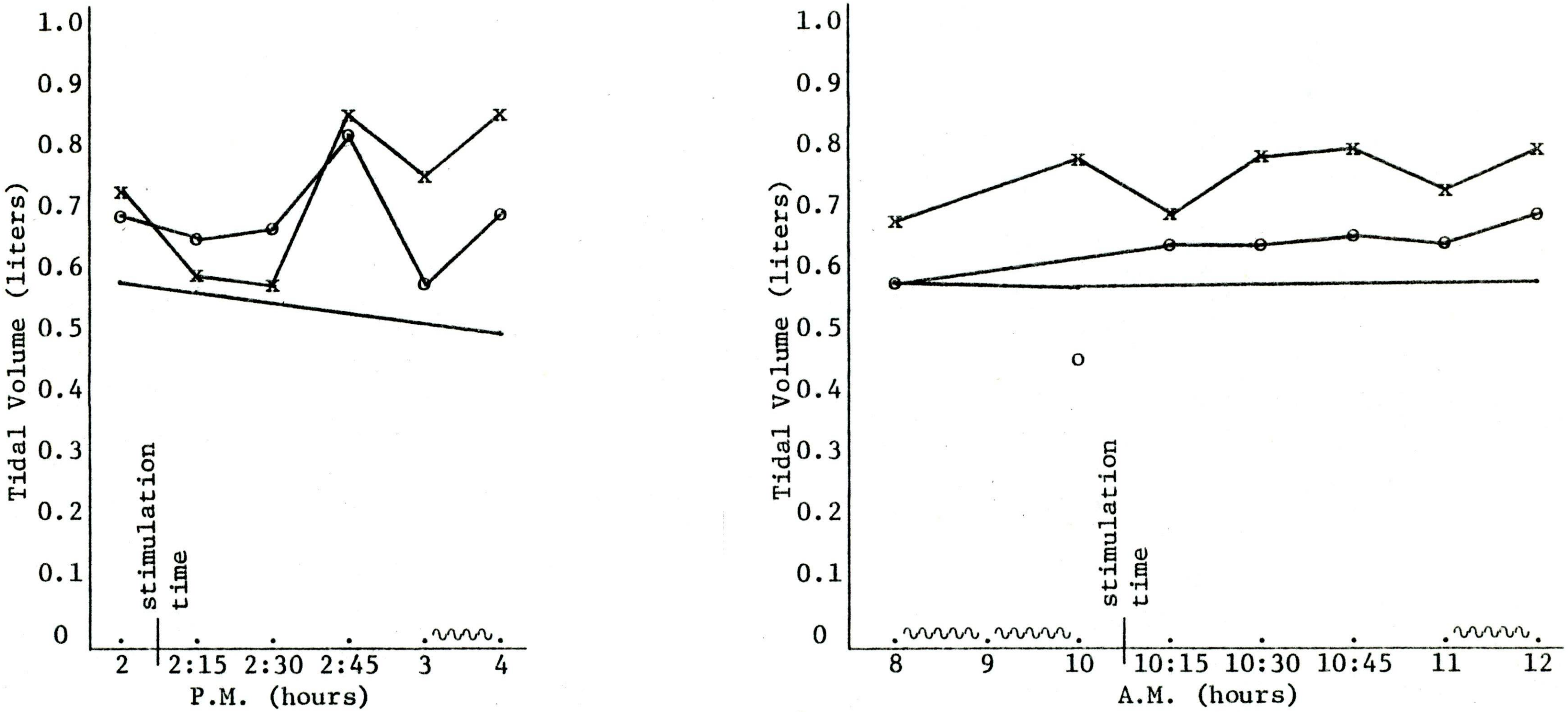
Tidal volume. The tidal volume graphs in Figure 6 demonstrate the results of the objective data obtained on mornings and afternoons with and without sensory stimulation on subject two. According to the hypothesis tidal volume was predicted to increase ($p=.05$). Numbers on the graphs are a mean of the same time interval recordings taken on the days compared. The baseline values of day one were also graphed though they were not a part of the general linear model.

From the tidal volume graph on subject two, Figure 6, it was noted that no consistent trend in results was evident. The general linear hypothesis showed no significant difference ($p<0.05$) following sensory stimulation.

End-tidal PCO_2. The end-tidal PCO_2 graph, Figure 7, was set up in the same method as the tidal volume graph. In subject two, end-tidal PCO_2 significantly decreased ($p=0.05$) up to 45 minutes following sensory stimulation. Without sensory stimulation no consistent change in end-tidal PCO_2 was observed. This would indicate that the sensory stimulation technique did steadily improve gas exchange up to 45 minutes post sensory stimulation. At one hour the decrease in end-tidal PCO_2 reached a significant level.

Extraneous parameters.

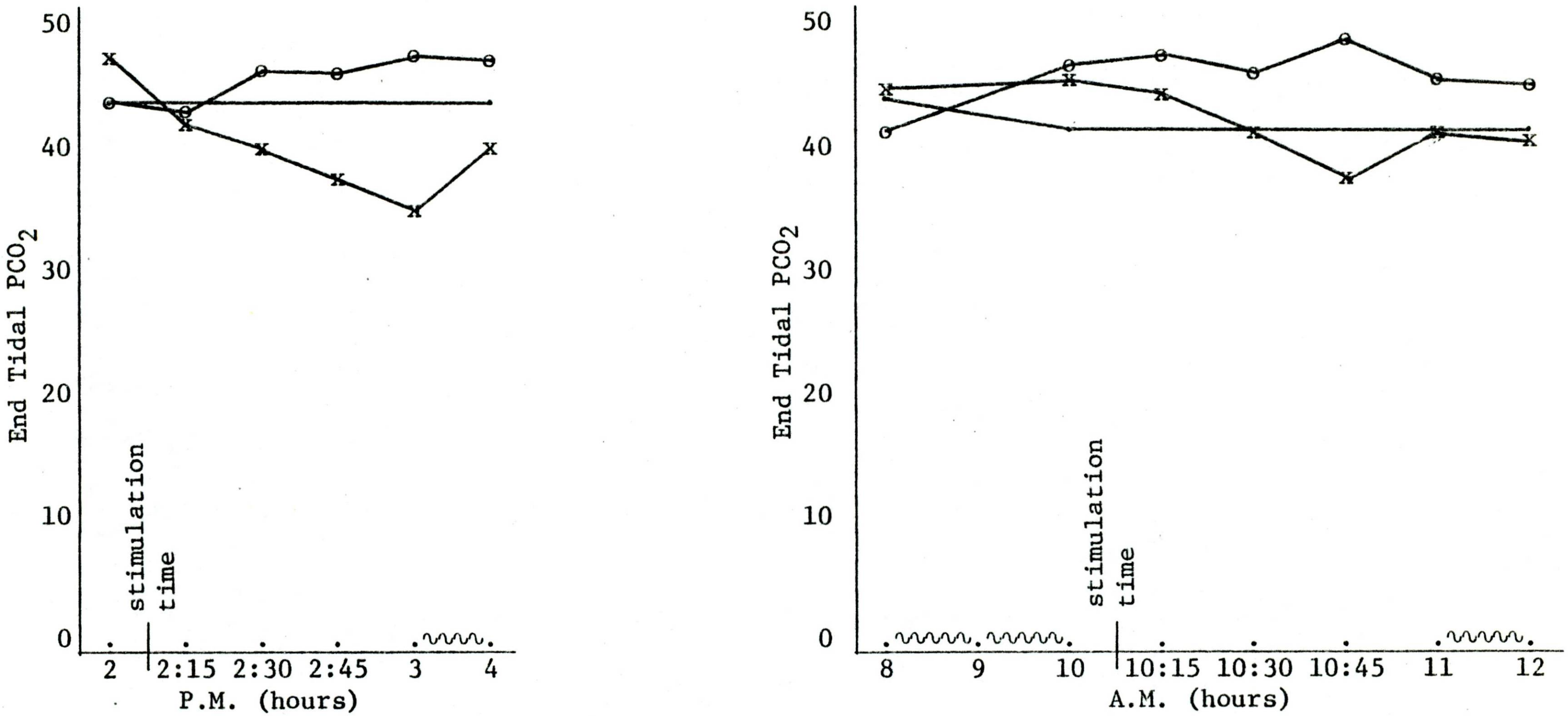
1. Respiration rate. Respiration rate did not consistently change as a result of sensory stimulation. No trend was established with and without sensory stimulation to determine any conclusions.



· = baseline day
x = test day
o = no test day

Figure 6

Tidal Volume Changes at Selected Time Intervals With and Without Sensory Stimulation - Subject Two



- = baseline
x = test period
o = no test

Figure 7

End-Tidal PCO_2 Changes at Selected Time Intervals With and Without Sensory Stimulation - Subject Two

2. Minute volume. The minute volume also observed reflected a very similar pattern to tidal volume observations. Change in values following sensory stimulation did not differ consistently from changes with sensory stimulation.

3. Heart rate and blood pressure. Heart rate and blood pressure were also observed and no effect of sensory stimulation on the cardiovascular system was noted.

SUBJECT THREE

Subject three was a 72-year-old Caucasian male diagnosed with C.O.P.D., asthma and chronic bronchitis, in September of 1975. He has a 40-pack year history of smoking and quit in 1970. He produces one-third cup of sputum daily. He denies having any episodes of hemoptysis.

The physical examination revealed a weight of 140 pounds, and a height of 69 inches. His carotid pulses were strong with no bruits. His jugular veins were not distended. He has an increase in anterior posterior diameter of the chest. His breath sounds were diminished. Cardiac examination revealed no murmurs, thrills or heaves. Radiologically his lungs were hyperexpanded. His spirogram revealed a forced expiratory volume in one second of 70 per cent of predicted normal. His maximal expiratory flow rate was 68 per cent of predicted normal and his vital capacity was 85 per cent of normal. Body box testing had not been completed at the time of the study.

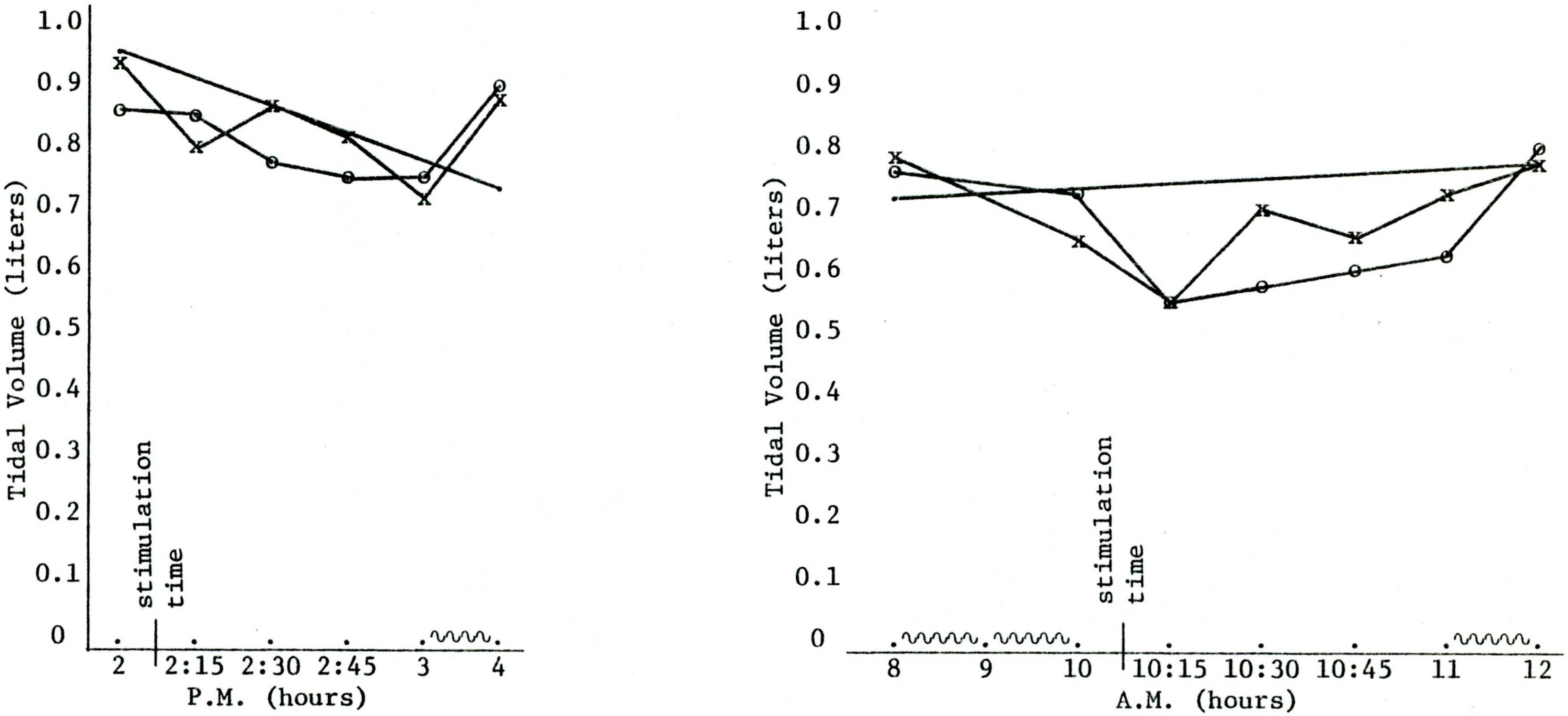
Nursing Evaluation

Subject three was a retired oil company employee. He lives with his wife and has one son who lives away from home. He was independent in self-care and does all his own gardening and lawn work. He was meticulous in dress. He was precise in his questions regarding the study and liked to know detailed answers concerning his breathing status. He had a knowledge of his disease and discussed it in depth. Emotionally he was exacting, reasoning through his reactions with great care. He was delightful in his sense of humor, when he allowed it to show. During initial experimental testing he seemed tense, relaxing more each day. He practiced daily exercise breathing methods he had learned to use when short of breath. He believed that religion should be practiced daily, not just on Sunday. His faith gives him emotional support. He and his wife are close companions. He was able to walk up several flights of stairs with minimal shortness of breath.

Data Analysis

Tidal volume. Tidal volume results were graphed on Figure 8. The tidal volume following sensory stimulation did not increase enough to have significance ($p=.05$). However, increase was noted both morning and afternoons on days when sensory stimulation occurred when compared to days when sensory stimulation did not occur. There was little increase in tidal volume above the baseline day values. These data suggest that sensory stimulation did not increase the overall tidal volume.

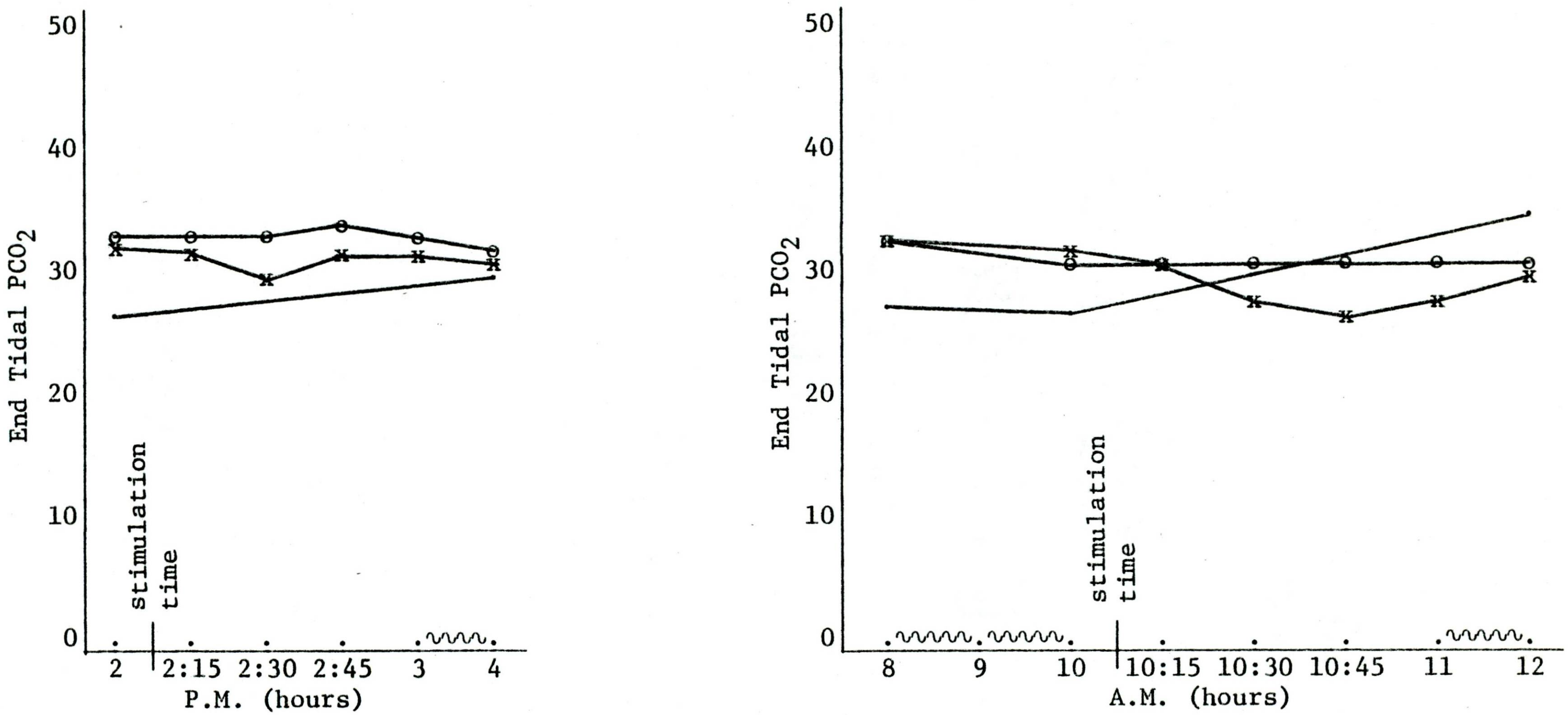
End-tidal PCO_2. The results in end-tidal PCO_2 can be found in Figure 9 for subject three. Sensory stimulation in the morning decreased end-tidal PCO_2 significantly ($p=0.05$) up to 45 minutes following stimulation. In the afternoon sensory stimulation decreased the end-tidal PCO_2



• = baseline day
x = test day
o = no test day

Figure 8

Tidal Volume Changes at Selected Time Intervals With and Without Sensory Stimulation - Subject Three



- = baseline
x = test period
o = no test

Figure 9

End-Tidal PCO_2 Changes at Selected Time Intervals With and Without Sensory Stimulaton - Subject Three significantly up to 30 minutes post stimulation. The overall significant decrease in end-tidal PCO_2 was p=0.1 at 30 minutes post stimulation. End-tidal PCO_2 increased or stayed the same without sensory stimulation.

Extraneous parameters.

1. Respiratory rate. The respiratory rate did not demonstrate a consistent trend when sensory stimulation was compared to nonsensory stimulation values.

2. Minute volume. Minute volume results with and without sensory stimulation followed much the same pattern as tidal volume results.

3. Heart rate and blood pressure. Heart rate and blood pressure were not consistently changed from sensory stimulation technique.

SUMMARY

All subjects failed to demonstrate a significant increase in tidal volume (p=0.05). Subjects two and three did have periods when the tidal volume increased with sensory stimulation. However, on days when sensory stimulation technique was not tested the tidal volumes also increased at different intervals. Consistent significant increase did not occur in the tidal volume.

The end-tidal PCO_2 showed significant decrease (p=0.05) in two out of three patients following sensory stimulation. The two subjects who demonstrated these changes were tested using the head-down position. The question could be raised as to whether it was the head-down position or the sensory stimulation technique that decreased end-tidal PCO_2. The data collected on days without sensory stimulation testing was also done with the patient in the head-down position. Sensory stimulation was the significant independent variable affecting end-tidal volume. The first subject, who did not demonstrate a decrease in end-tidal PCO_2, had more pronounced changes of obstructive airway disease which might have influenced results. Overall in the three subjects sensory stimulation decreased the end-tidal PCO_2 significantly ($p=0.05$).

Extraneous parameters of respiration rate, minute volume, heart rate and blood pressure were also recorded. See Appendixes D, E, and F. There were no consistent responses in these parameters following sensory stimulation.

The conclusion made from the data analysis will follow in Chapter 5. Recommendations were then developed based on the conclusion.

DISCUSSION OF FINDINGS

The data suggested that end-tidal PCO_2 decreased while tidal volume stayed the same or decreased in some instances. One then would ask why this occurred. The significant improvement in end-tidal PCO_2 seems to indicate that ventilation-perfusion improved even though more volumes of air were not exchanged. This suggests that more efficient gas exchange may have resulted with less effort in depth of breathing. However, measurements of ventilation-perfusion would be necessary to find out if this were, in fact, true. The decrease in end-tidal PCO_2 probably was due to some chemical effect at the pulmonary bed circulation. Rood believed this chemical effect was initiated through autonomic stimulation from sensory afferent fibers. Whether or not this was so could only be ascertained through more detailed study combining this research technique with exercise conditioning in the head-down position and taking measurements of ventilation-perfusion, calories of work expended and blood gases exchanged in comparison to tidal volume.

Subjectively these subjects felt improvement in respirations following sensory stimulation. It was also noted that sputum production increased remarkedly following sensory stimulation.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The problem which has been investigated in this study was whether a specific sensory stimulation technique would improve breathing in patients with C.O.P.D.

Background and need for the study presented an ever-increasing prevalence of C.O.P.D. The need for investigation of breathing retraining techniques to aid the C.O.P.D. patient in his effort to breathe was discussed. A theoretical framework was presented supported by the neuroanatomical and neurophysiological basis of sensory stimulation as a breathing retraining technique. It was hypothesized that a specific type of sensory stimulation would improve tidal volume and end-tidal PCO_2. Improvement would be shown by a significant ($p<.05$) increase in tidal volume and decrease in end-tidal PCO_2. The sensory stimulation technique used was repetitive brushing and quick icing to specific areas of the skin. A definition of terms was given and steps to solving the problem were developed.

The literature was reviewed. Studies were presented which gave evidence of sensory afferent pathways in both animal and man. The studies discussed specific natural and electrical stimuli which might stimulate these afferent pathways. Studies were also reviewed that used repetitive brushing and quick icing as a method of sensory stimulation of a variety of body functions.

A case study method of research was selected as the best method of studying the effects of sensory stimulation on a small group of persons who met predetermined criteria. Tidal volume and end-tidal PCO_2 were used as the dependent variables. Parameters were obtained from the RMS II mass spectrometer. The findings are summarized in the following paragraphs.

1. Tidal volumes were not significantly ($p=.05$) increased in any of the subjects according to analysis based on a general linear model. Tidal volume did not follow any consistent changes before or after sensory stimulation.

2. The end-tidal PCO_2 did demonstrate a significant ($p=0.05$) decrease thirty minutes after sensory stimulation in two of three subjects. One of two subjects whose end-tidal PCO_2 decreased demonstrated a significant decrease ($p=0.01$) at 45 minutes after sensory stimulation. One subject demonstrated no significant changes in end-tidal PCO_2 at any time after sensory stimulation.

3. Extraneous variables of respiratory rate, minute volume, blood pressure, and heart rate were also observed. Sensory stimulation did not cause consistent variation of these parameters.

CONCLUSIONS

The hypothesis of this study stated that application of repetitive brushing and quick icing to the T_6-T_{12} anterior and lateral dermatomes will significantly improve ($p<.05$) tidal volume and end-tidal PCO_2. On the basis of the statistical analysis of these data the hypothesis must be rejected.

The subjects with C.O.P.D. did not demonstrate beneficial effects on breathing as a result of sensory stimulation as evidenced by no significant increase in tidal volume. However, a decrease in end-tidal PCO_2 in two of three subjects suggested that gas exchange was improved for a short interval following sensory stimulation. An increased tidal volume and a decreased end-tidal PCO_2 were both needed to support the hypothesis. The decreased end-tidal PCO_2 in two of three subjects implies that one or more of the following factors need to be considered.

1. Effectiveness of sensory stimulation could not be determined by an increased tidal volume.

2. The head-down position was not used in the subject who demonstrated no change in end-tidal PCO_2 following sensory stimulation technique. The position may have caused inconsistent results in this subject's end-tidal PCO_2.

3. The use of sensory stimulation as a breathing retraining facilitator may have demonstrated more benefit when coupled with an exercise program of reconditioning and both studied simultaneously.

4. The selection of subjects was too limited to demonstrate any consistent trends.

5. This was the first scientific study investigating sensory stimulation as a breathing retraining technique. The study demonstrated improved gas exchange in the two subjects using the head-down position.

Therefore, the study can serve as a basis for further investigations. Recommendations will follow.

RECOMMENDATIONS

Several recommendations were made based on the results of this study. The recommendations include changes in the design of the study, in measuring sensory stimulation effects, and ideas for additional studies.

Changes recommended in the design of the study included: 1) sensory stimulation should be studied to determine its effect on breathing in contrast to promotion of deep breathing. The depth of breathing was not as important as the efficiency of breathing. The cost of oxygen used in breathing retraining should be considered when developing a hypothesis. Sensory stimulation was believed to promote more efficient breathing rather than promote depth of breath, thus ventilation-perfusion studies might document this better; 2) sensory stimulation technique would have been better studied by working with a physical therapist through the entire study and the physiological basis establishing muscle action and calories used in muscle action could have been incorporated into the study.

Changes in measuring effects of sensory stimulation are also recommended. Tidal volume was determined not to be the best measure to represent effects of sensory stimulation. Again, measures were needed to determine efficiency of respirations. These measures should include all arterial blood gas values so oxygen and ventilation perfusion could be determined.

Calories could be measured to determine the cost of breathing in muscle work with and without sensory stimulation. Myofeedback could be used to determine the muscles used following sensory stimulation (Johnson, 1976). More subjects need to be included for a broader representation of

C.O.P.D. patients. Ventilation-perfusion scans could be used to demonstrate if end-tidal PCO_2 improvement really reflects improvement in perfusion.

Sensory stimulation, if found to produce greater gas exchange at less oxygen cost in effort of breathing might then be used in the respiratory intensive care unit to stimulate more effective breathing during nursing procedures, such as: 1) weaning the patient from a mechanical respirator, 2) preventing use of a mechanical respirator in severe episodes of illness, or 3) for encouraging patient to breathe more deeply and cough more productively.

Ideas for additional studies are also recommended. The effects of sensory stimulation need to be studied in conjunction with an exercise reconditioning program. This program might include use of a restorator to give regular leg exercises combined with sensory stimulation breathing retraining. Sensory stimulation could be used with half the patients and compared to patients who perform these exercises without sensory stimulation. It is believed such a study would demonstrate that sensory stimulation in the head-down position, coupled with exercise reconditioning, would improve efficiency in breathing and reduce the cost of breathing for C.O.P.D. patients.

Respiratory nurses are committed to improvement in patient care. The effort to breathe is often overwhelming to the respiratory patient with chronic obstructive pulmonary disease. Hopefully, this research has added one more step to strengthen the hope of the patient with chronic obstructive pulmonary disease in his effort to breathe.

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APPENDIX A

Letters of Permission

25523 State Street
Loma Linda, CA 92354
August 5, 1976

Ms. Gertrude Haussler, R.N.
Director of Nursing Service
Loma Linda University Medical Center
Loma Linda, CA 92354

Dear Ms. Haussler:

I know you are aware that the technique of sensory stimulating using brushing and icing has been investigated with patients in the past at Loma Linda University. I am now interested in exploring the effectiveness of brushing and icing for promoting deep breathing while caring for the patient with chronic obstructive pulmonary disease. This study will meet part of the requirements for a master's degree in nursing at Loma Linda University.

Selected chronic obstructive pulmonary disease patients will be tested for their response to subcostal stimulation. I will first take a daily baseline of their activities measuring respiration, tidal volume, heart rate, minute volume, and expired carbon dioxide pressure at consistent intervals. I will then introduce the technique of subcostal brushing and icing and repeat the measurement of the same values mentioned above. Results are all noninvasive measurements routinely being used on 9100 presently in nursing assessment of the chronic obstructive pulmonary disease patients. It is estimated that this study will take approximately three weeks to obtain an acceptable sample of patients.

This study has been approved by the University Research Advisory Committee for Human Experimentation and safeguards are built in for the protection of the patient. I will be working with Ms. Lucile Lewis, Dr. John Hodgkin, and Margaret Rood from University of Southern California. Ms. Rood was the originator of this sensory stimulation technique.

May I please have your permission to conduct this study in your agency? All information obtained will be available for the benefit of patient care at Loma Linda University Medical Center. I will be available for any further discussion regarding the study.

I thank you for your consideration and look forward to hearing from you soon.

Sincerely,

Mrs. Sharon Sauer, R.N.
Graduate Student in Nursing

Verbal Acceptance
August 5, 1976

25523 State Street
Loma Linda, CA 92354
August 24, 1976

Ms. Renee Weisz, Head Nurse
Respiratory Intensive Care Unit
Loma Linda University Medical Center
Loma Linda, CA 92354

Dear Ms. Weisz:

I am interested in exploring the effectiveness of brushing and icing the subcostal region for the promotion of deep breathing in the care of the patient with chronic obstructive pulmonary disease. This study will meet part of the requirements for a master's degree in nursing at Loma Linda University.

Selected chronic obstructive disease patients will be tested for their response to subcostal stimulation. I will first take a daily baseline reading of their activities measuring respiration, tidal volume, heart rate, minute volume and expired carbon dioxide pressure at consistent intervals. I will then introduce the technique of subcostal brushing and icing and repeat the measurement of the same values mentioned above. Results are all noninvasive measurements routinely being used on 9100. Each patient will be in the hospital during the hours eight a.m. to eight p.m. They will each sign a consent form before participating and have a full explanation of the procedure. I have received permission from Ms. Gertrude Haussler, Director of Nursing Service, and Hospital Administration to use empty beds on 9100 to conduct my research. It is estimated that each patient will need five days for completion of testing. I am in agreement that any time my research interferes with the smooth functioning of nursing care on 9100 it will be terminated until problems are worked out through you.

This study has been approved by the University Research Advisory Committee for Human Experimentation and safeguards are built in for the protection of patients. I will be working with Ms. Lucile Lewis, Dr. John Hodgkin, and Margaret Rood from University of Southern Califonria. Ms. Rood was the originator of this sensory stimulation technique.

May I please have your permission to conduct this study on your unit. All information obtained will be available for the benefit of patient care at Loma Linda University Medical Center. I will be available for any further discussion regarding this study.

I thank you for your consideration.

Sincerely,

Mrs. Sharon Sauer, R.N.
Graduate Student in Nursing

Verbal Acceptance
August 24, 1976

APPENDIX B

Patient Consent Form

C O N S E N T

I give my free and voluntary consent to participate in these breathing tests under the supervision of Sharon Sauer, R.N., from Loma Linda University, and in witness thereof I have signed this consent. I understand that I am free to withdraw from participation in this study at any time.

____
Signed

____
Date

____
Witness

APPENDIX C

Data Collection Form

DATA COLLECTION SHEET

Day_____

TIME	ACTIVITY	HR	BP	RR	MV	PCO_2	PO_2
08:00							
09:00							
10:00							
11:00							
12:00							
01:00							
02:00							
03:00							
04:00							
05:00							
06:00							
07:00							
08:00							

APPENDIX D

Table 1

Parameters on Subject 1

Table 1

Parameters on Subject 1

		Time	HR	BP	RR	MV	TV	PCO_2
Day 1		8:00	68	120/98	11	8.32	.756	38.6
		10:00	72	124/72	11	8.42	.765	37.6
		12:00	80	110/70	11	8.32	.756	37.7
		2:00	124	112/72	11	8.37	.761	37.2
		4:00	100	120/78	11	8.02	.729	36.1
		6:00	92	120/78	10	8.42	.842	36.7
		8:00	88	100/78	11	8.10	.736	35.8
Day 2		8:00	80	100/80	10	8.45	.845	36.1
	Test	10:00	76	118/82	10	8.98	.898	38.0
		10:15	100	116/84	12	8.13	.678	35.3
		10:30	76	122/86	11	7.13	.648	34.2
		10:45	72	122/76	12	7.73	.644	34.7
		11:00	72	116/84	12	8.68	.723	33.3
		12:00	84	122/74	13	9.11	.701	34.6
		2:00	100	130/68	12	10.48	.873	36.4
		2:15	108	110/80	13	9.17	.765	36.2
		2:30	108	124/84	11	9.90	.900	39.8
		2:45	108	140/84	12	9.80	.817	37.1
		3:00	100	118/80	12	9.74	.812	38.6
		4:00	96	130/70	12	9.64	.803	37.1
		6:00	108	130/80	14	10.73	.766	37.8
		8:00	76	130/88	11	8.27	.752	39.7
Day 3		8:00	80	130/82	15	9.88	.659	35.6
		10:00	84	128/78	13	10.89	.838	38.6
		10:15	96	120/82	11	9.13	.830	36.8
		10:30	84	110/76	14	8.49	.606	37.6
		10:45	80	120/88	11	9.21	.837	37.5
		11:00	80	110/70	11	8.98	.816	36.7
		12:00	84	100/60	11	9.18	.835	39.5
	Test	2:00	80	112/80	12	10.24	.853	38.6
		2:15	76	120/84	12	8.28	.690	35.2
		2:30	80	110/70	12	8.51	.709	33.8
		2:45	84	112/82	12	8.30	.692	36.4
		3:00	72	110/70	13	8.96	.689	33.1
		4:00	80	112/80	12	10.24	.853	33.6
		6:00	128	130/88	12	10.03	.836	38.2
		8:00	84	122/80	14	10.42	.744	38.7

Table 1 (continued)

		Time	HR	BP	RR	MV	TV	PCO_2
Day 4		8:00	84	112/60	11	8.48	.777	38.3
	Test	10:00	96	102/80	15	10.20	.680	38.6
		10:15	72	102/80	12	8.77	.731	38.1
		10:30	108	112/80	14	10.13	.724	38.8
		10:45	72	102/70	13	9.97	.767	38.8
		11:00	80	122/88	13	10.49	.807	38.0
		12:00	96	120/88	11	10.26	.933	36.4
		2:00	96	100/66	10	6.61	.661	35.9
		2:15	84	108/78	9	9.03	1.003	35.1
		2:30	82	112/70	9	9.80	1.089	35.6
		2:45	84	110/68	10	10.12	1.012	36.1
		3:00	80	112/60	9	9.72	1.080	35.5
		4:00	88	120/88	13	9.37	.721	39.9
		6:00	86	110/82	15	11.08	.739	38.5
		8:00	96	110/80	12	10.02	8.55	39.9
Day 5		8:00	80	122/82	16	8.74	.546	37.8
		10:00	88	122/70	15	10.40	.693	37.6
		10:15	88	120/80	16	11.00	.688	37.6
		10:30	88	128/60	15	10.97	.731	37.5
		10:45	80	112/80	14	9.89	.706	36.9
		11:00	76	112/80	14	10.83	.774	37.5
		12:00	76	120/82	14	10.44	.746	37.2
	Test	2:00	108	112/60	14	12.17	.869	35.9
		2:15	102	110/70	13	10.57	.808	37.6
		2:30	100	122/58	12	10.53	.877	37.6
		2:45	96	98/60	12	10.20	.850	38.5
		3:00	100	102/58	10	10.33	1.033	37.7
		4:00	80	102/62	14	10.06	.757	37.6
		6:00	96	110/60	15	11.07	.738	38.6
		8:00	96	110/80	13	9.37	.721	39.9

APPENDIX E

Table 2

Parameters on Subject 2

Table 2 (continued)

		Time	HR	BP	RR	MV	TV	PCO_2
Day 4		8:00	96	145/85	7	5.49	.784	42.7
	Test	10:00	104	138/80	6	6.01	1.002	50.3
		10:15	92	128/70	6	5.66	.809	45.7
		10:30	96	122/70	6	5.57	.928	41.2
		10:45	96	130/78	7	5.92	.846	36.0
		11:00	88	138/80	7	5.57	.796	38.2
		12:00	82	142/80	6	6.62	1.003	36.4
		2:00	96	138/80	9	6.16	.684	44.7
		2:15	88	138/82	9	6.30	.700	39.6
		2:30	84	138/80	8	4.87	.609	44.7
		2:45	88	130/72	8	7.22	.902	43.9
		3:00	88	120/70	7	5.26	.751	45.6
		4:00	88	120/70	7	5.72	.817	43.7
Day 5		8:00	88	140/84	9	5.41	.601	45.6
		10:00	84	134/82	7	3.35	.479	49.9
		10:15	84	130/76	7	4.53	.647	47.9
		10:30	84	122/70	7	4.11	.587	45.4
		10:45	80	128/82	7	4.37	.493	48.9
		11:00	80	128/80	8	3.94	.654	42.5
		12:00	80	140/80	7	4.58	.819	43.5
	Test	2:00	92	138/70	8	6.55	.686	47.8
		2:15	100	138/70	12	8.23	.625	38.4
		2:30	96	128/72	12	7.50	1.030	36.6
		2:45	96	218/70	7	7.21	.714	36.2
		3:00	88	130/70	8	5.71	.900	38.8
		4:00	96	124/70	7	6.30	.781	44.3
		6:00	78	142/80	8	6.25	.500	41.6
		8:00	96	144/84	9	4.50		44.2

Table 2

Parameters on Subject 2

		Time	HR	BP	RR	MV	TV	PCO_2
Day 1		8:00	84	140/80	11	6.45	.586	43.2
		10:00	96	130/70	10	5.58	.558	41.4
		12:00	100	138/72	11	6.25	.568	41.0
		2:00	96	142-82	10	5.64	.564	43.7
		4:00	84	128/72	12	5.72	.477	43.7
		6:00	96	140/78	10	3.91	.391	47.5
		8:00	84	138/40	10	5.46	.546	47.6
Day 2		8:00	100	138/80	10	5.43	.543	44.9
	Test	10:00	88	122/76	11	5.98	.544	43.0
		10:15	96	118/78	10	5.47	.547	43.9
		10:30	100	122/80	8	5.04	.630	40.3
		10:45	100	138/82	6	4.36	.727	41.2
		11:00	92	138/80	8	5.03	.629	43.9
		12:00	96	132/74	14	7.10	.570	43.7
		2:00	108	128/72	9	5.94	.660	42.7
		2:15	100	132.80	12	6.54	.545	45.9
		2:30	100	138/80	8	5.52	.690	46.9
		2:45	88	132/80	8	5.73	.716	46.6
		3:00	96	138/80	10	3.91	.391	47.5
		4:00	88	132/80	10	5.46	.546	47.6
Day 3		8:00	84	140/82	6	3.34	.557	42.6
		10:00	100	138/70	13	5.53	.425	44.5
		10:15	88	120/70	8	5.05	.631	48.3
		10:30	100	120/74	7	4.73	.678	47.8
		10:45	106	120/80	7	4.68	.669	50.0
		11:00	96	120/78	7	5.50	.786	48.4
		12:00	92	130/72	7	4.92	.703	46.1
	Test	2:00	102	140/81	10	6.31	.631	45.8
		2:15	92	130/80	15	7.30	.487	46.1
		2:30	100	132/80	16	8.05	.503	43.4
		2:45	100	132/82	10	6.38	.638	39.8
		3:00	96	138/80	8	6.19	.774	32.3
		4:00	84	128/76	7	5.48	.782	36.6
		6:00	96	142/84	8	6.98	.873	47.6
		8:00	96	142/84	8	6.61	.826	49.1

APPENDIX F

Table 3

Parameters on Subject 3

Table 3

Parameters on Subject 3

		Time	HR	BP	RR	MV	TV	PCO_2
Day 1		8:00	96	124/70	13	9.21	.708	27.9
		10:00	80	138/80	10	7.21	.721	27.1
		12:00	76	138/78	10	7.74	.714	34.4
		2:00	96	134/70	12	11.42	.952	26.7
		4:00	88	144/70	9	6.78	.709	29.5
		6:00	92	138/72	10	7.09	.709	31.2
Day 2		8:00	96	138/60	11	7.32	.665	33.5
	Test	10:00	84	138/78	9	4.34	.482	33.0
		10:15	84	120/60	10	4.88	.488	31.1
		10:30	84	122/60	9	5.13	.570	29.5
		10:45	76	130/70	10	5.92	.592	26.9
		11:00	80	120/60	9	5.93	.659	30.3
		12:00	84	144/60	8	5.27	.660	30.9
		2:00	84	124/68	8	6.98	.873	34.7
		2:15	84	140/80	9	7.82	.869	32.8
		2:30	84	130/64	10	5.60	.560	34.2
		2:45	96	140/64	9	6.43	.714	37.7
		3:00	88	138/78	9	6.45	.717	34.8
		4:00	96	140/80	12	10.18	.848	23.6
		6:00	96	144/80	12	9.96	.830	30.6
Day 3		8:00	100	130/60	10	7.13	.713	33.1
		10:00	84	128/64	9	6.17	.686	30.2
		10:15	76	138/60	8	3.63	.454	30.8
		10:30	80	128/62	7	4.31	.616	30.4
		10:45	84	140/70	8	4.65	.581	30.1
		11:00	76	140/70	9	5.66	.629	30.4
		12:00	84	140/70	9	6.92	.769	29.5
		2:00	96	136/66	8	7.79	.974	32.4
		2:15	88	136/62	8	6.89	.861	30.9
		2:30	84	138/60	9	6.55	.936	28.5
		2:45	84	126/60	9	6.02	.669	31.4
		3:00	84	128/66	9	6.23	.692	31.1
		4:00	80	126/60	9	8.25	.917	31.4
		6:00	84	124/60	11	8.86	.742	31.7

Table 3 (continued)

		Time	HR	BP	RR	MV	TV	PCO_2
Day 4		8:00	100	144/70	10	9.15	.915	31.8
	Test	10:00	72	124/62	6	4.70	.783	30.1
		10:15	72	124/60	8	4.64	.580	29.7
		10:30	80	128/70	8	6.55	.819	25.1
		10:45	68	134/72	7	5.00	.714	25.6
		11:00	68	144/80	7	5.70	.800	25.2
		12:00	76	140/80	9	7.86	.873	28.2
		2:00	84	128/66	9	7.54	.838	31.6
		2:15	88	124/60	9	7.50	.833	32.6
		2:30	84	128/60	8	7.09	.988	31.6
		2:45	80	138/72	8	6.29	.786	30.1
		3:00	80	138/70	9	7.01	.779	31.7
		4:00	80	124/68	8	7.78	.973	29.8
		6:00	84	120/60	11	9.32	.847	32.1
Day 5		8:00	84	128/64	10	8.21	.821	32.6
		10:00	76	124/62	7	5.11	.730	30.9
		10:15	84	124/60	8	4.91	.614	30.4
		10:30	80	128/64	8	4.38	.548	31.1
		10:45	76	138/68	8	5.07	.634	30.9
		11:00	80	134/60	7	4.26	.609	30.2
		12:00	80	124/60	9	7.39	.821	31.2
	Test	2:00	88	122/60	10	9.08	.908	32.5
		2:15	88	122/62	7	5.08	.726	32.4
		2:30	84	126/64	7	5.50	.786	31.0
		2:45	76	134/70	6	5.80	.967	31.7
		3:00	84	130/60	6	4.50	.750	31.6
		4:00	88	140/70	6	5.01	.835	30.5
		6:00	88	138/70	5	5.40	1.080	33.1