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A COMPARISON OF THE EFFECTS
OF TWO METHODS OF SPINAL IMMOBILIZATION
ON RESPIRATORY EFFORT IN THE OLDER ADULT

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

By
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*****

The Ohio State University
1997

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ABSTRACT

Injury in older adults often results in increased mortality and morbidity compared to younger adults. The first hour after injury is critical for older adults since the longer substantive care is delayed, the more likely that complications or mortality will result. The care delivered during this crucial first hour most often occurs in the prehospital setting which incorporates care delivered at the scene of the accident and during transport to the hospital. One measure commonly used in the prehospital setting is immobilization of the spine. The effect that spinal immobilization may have on respiratory status in the older adult has not been determined.

The specific research question for this study was, "What is the effect of two different types of spinal immobilization on respiratory effort in older adults, aged 65-75?". The two different types of spinal immobilization apparatus were the traditional full length wooden backboard and a vacuum immobilizer device. The sample consisted of 57 noninstitutionalized older adult volunteers from the central Ohio area, with an age range of 65 to 75 years. A counterbalanced design was used with subjects randomized to the order in which they were placed on the device. The subjects remained on each device for 30 minutes. Respiratory effort was measured by respiratory inductance plethysmography. Physiologic indices of respiratory effort included rate, tidal volume, inspiratory time, percent rib cage contribution to tidal volume, total compartment displacement volume/tidal volume ratio and inspiratory flow. Subjective indices of
respiratory effort included subject's rank ordering of difficulty breathing and visual analogue scores.

Chi square analysis was used to analyze demographic data and revealed no significant differences between the order groups for age, sex or race ($\chi^2 > .05$). Repeated measures analysis of covariance, controlling for baseline values of respiratory indices, was used to compare respiratory effort on the two devices. Results revealed a significant difference ($p < .05$) between the two devices for all indices of respiratory effort. Mean values tended to increase over time for the backboard, suggesting that the longer the subject remained on the backboard, the more respiratory effort was required to breathe.
ACKNOWLEDGMENTS

I would like to thank Dr. Kathleen Stone, my adviser, for her invaluable guidance, encouragement, and support in this research endeavor. Dr. Stone exemplifies all that I hope to be as a researcher.

I am also indebted to Dr. Mary Ellen Wewers for her comments and suggestions. Her willingness to share her expertise and knowledge has helped me to refine the research.

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I would like to thank my husband, Ron, and my family for their love and support which have sustained me in this endeavor.

The setting for data collection was provided through the General Clinical Research Center grant (M01-RR00034, National Center for Research Resources), located in The Ohio State University Hospital. The assistance provided by the staff of the General Clinical Research Center in data collection was sincerely appreciated. Funding for the research was provided, in part, through a Graduate Student Alumni Research Award from The Ohio State University. I would also like to thank all the participants of the study. Their willingness to share their time made this research possible.

Finally, I would like to acknowledge the Grant Medical Center LifeFlight program for helping me to develop my clinical expertise in the prehospital setting. My clinical experience as a flight nurse was the initial stimulus for this research.
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<td>AB</td>
<td>abdomen</td>
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<tr>
<td>ANCOVA-RM</td>
<td>analysis of covariance with repeated measures</td>
</tr>
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<td>ATPS</td>
<td>ambient temperature, pressure, saturation with water vapor</td>
</tr>
<tr>
<td>B</td>
<td>backboard</td>
</tr>
<tr>
<td>BTPS</td>
<td>body temperature, pressure, saturation with water vapor</td>
</tr>
<tr>
<td>FREQ</td>
<td>respiratory rate</td>
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<td>FRC</td>
<td>functional residual capacity</td>
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<td>ISOCAL</td>
<td>isovolume maneuver calibration method for respiratory plethysmography</td>
</tr>
<tr>
<td>LSQ</td>
<td>least squares method for calibration of respiratory plethysmography</td>
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<tr>
<td>MEP</td>
<td>maximal expiratory pressure</td>
</tr>
<tr>
<td>MIP</td>
<td>maximal inspiratory pressure</td>
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<tr>
<td>PaO₂</td>
<td>partial pressure of arterial oxygen</td>
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<td>Pdi max</td>
<td>maximum static transdiaphragmatic pressure</td>
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QDC qualitative diagnostic calibration method for respiratory plethysmography
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<td>RC</td>
<td>rib cage</td>
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<td>%RC/Vt</td>
<td>per cent rib cage contribution to tidal volume</td>
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<td>RIP</td>
<td>respiratory inductive plethysmography</td>
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<tr>
<td>RV</td>
<td>residual volume</td>
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<tr>
<td>SEQ</td>
<td>simultaneous equation method for calibration of respiratory plethysmography</td>
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<tr>
<td>SEM</td>
<td>standard error of the mean</td>
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<tr>
<td>SMSA</td>
<td>standard metropolitan statistical area</td>
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<tr>
<td>TCDV</td>
<td>total compartment displacement volume</td>
</tr>
<tr>
<td>TCD/Vt</td>
<td>total compartment displacement volume ratio</td>
</tr>
<tr>
<td>T1</td>
<td>inspiratory time</td>
</tr>
<tr>
<td>TLC</td>
<td>total lung capacity</td>
</tr>
<tr>
<td>V</td>
<td>vacuum immobilizer</td>
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<td>VAS</td>
<td>visual analogue scale</td>
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<td>VMIN</td>
<td>minute ventilation</td>
</tr>
<tr>
<td>Vt</td>
<td>tidal volume</td>
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<tr>
<td>Vt/T1</td>
<td>inspiratory flow</td>
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CHAPTER 1
INTRODUCTION

Significance of the Problem

Each year between 26,000 and 30,000 older adults die as a result of injuries (National Center for Health Statistics, 1990; National Safety Council, 1996). The incidence of injury among the elderly is actually lower that that of the younger population but the elderly clearly suffer greater morbidity and mortality (Hogue, 1982; McCoy, Johnstone & Duthie, 1989). Older adults have the highest rate of admission to acute care hospitals for injury compared to any other age group (Baker, O'Neill, Ginsburg & Li, 1992).

The type of injury most likely to result in death among older adults, through the age of 79, is motor vehicle accidents (National Safety Council, 1996). From the age of 80 and above, falls become the primary mechanism of injury. The death rate from injuries, for those aged 65 and older, is higher than for any other age group (National Safety Council, 1996). Compared to other age groups, older adults who do survive have greater complications and have two to three times as many days of restricted activity and bed confinement (Finelli, 1989; Hogue, 1980).

Currently, persons 65 years or older comprise 12.7% of the United States population, yet they consume more than one third of all resources devoted to trauma care (American Association of Retired Persons, 1995; Champion, 1989; Day, 1996; Duensing, 1988). The problems associated with injury in the elderly will only continue to increase as the population over 65 continues to expand. Although the proportion of our population aged 65 and over is growing rapidly, few studies have been conducted to
determine optimal strategies to improve trauma care for the elderly (Demaria, Pardon, Merriam, Casanova, & Gann, 1987).

The first hour after injury is especially critical for the older adult. The first hour after injury is often referred to as the "golden hour" since mortality increases significantly for each additional hour that definitive care is delayed (Cowley, 1976). The care delivered during a significant portion of this "golden hour" occurs in the prehospital setting. The prehospital component of trauma care extends from the time initial care is delivered at the scene of the accident, transport of the injured person to the hospital and up to the point of arrival in the emergency room.

One measure commonly used in the prehospital setting is immobilization of the spine on a backboard (American Academy of Orthopedic Surgeons, 1987; Beaver, 1990; Perry & Zedlik, 1992). This measure is used to prevent or minimize injury to the spine which may occur as a result of falls, motor vehicle accidents or other mechanisms of injury. Immobilization of the spine is a high priority, but the injured older adult is also very vulnerable to hypoxia and hypoxemia. Levy, Hanson and Townsend (1993) stress that priorities in prehospital care of the older adult should be directed toward supporting the airway and preventing further injury. Kauder and Schwab (1991) also stress that even relatively minor injuries can lead to an impairment in oxygenation. To maximize respiratory function in the prehospital setting, methods for spinal immobilization which also support respiratory effort need to be evaluated.

**Purpose of the Study**

The purpose of this study was to determine the effect of two different types of spinal immobilization apparatus on respiratory effort in the older adult. De Keyser (1994), in
her review of trauma nursing research, indicated that studies are needed which evaluate
the benefits and risks associated with different transport mechanisms. This study
represents a beginning attempt to fill a void in the literature related to the effects of a
prehospital intervention on respiratory effort in the older adult. Findings of this study
will contribute to the development of knowledge related to measures for cervical spine
immobilization that will best support the airway in the older adult. Providing optimal
respiratory support in the prehospital setting may ultimately reduce complications, length
of hospital stay, and improve outcomes related to trauma (Drury, 1978).

The specific aim of this study was to compare the effects of two different types of
spinal immobilization apparatus on respiratory effort in older adults, aged 65-75. The
two types of spinal immobilization apparatus were the traditional wooden backboard and
a vacuum immobilizer device.

Research Question

The research question for this study was : What is the effect of two different types of
spinal immobilization on respiratory effort in older adults aged 65 to 75?

Definition of Terms

For the purposes of this study, the following definitions were used:

1. Injury is defined, according to the National Safety Council, (1996) as "physical
harm or damage to the body resulting from an exchange, usually acute, of mechanical,
chemical, thermal or other environmental energy that exceeds the body's tolerance"
(p.151).

2 Trauma is defined, according to the American Trauma Society, as "the condition
resulting from an injury" (American Trauma Society, 1996, p. 2). Trauma includes the
responses to unisystem as well as multisystem injury.
3. Spinal immobilization refers to: (a) the process of placing an individual on a firm surface in a supine position, in a straight line, with the neck in a neutral position without flexion, extension or rotation and (b) securing the individual to the device to maintain spinal alignment and to minimize movement of the cervical spine (American Academy of Orthopedic Surgeons, 1990; Baxt, 1985; McSwain, 1994).

The two types of spinal immobilization which were used in this study are the traditional long or full length wooden backboard and a vacuum splint mattress (Med Tech, Sweden). Specifications for the long board have been determined by the American College of Surgeons, Committee on Trauma (1990). The traditional long or full length wooden backboard is a 72" long by 16" wide board and is made from 3/4 inch exterior plywood finished on both sides. Both ends of the long board are tapered so that the board will slide as easily as possible under the patient. Strap holes are located 3/4 of an inch from the edge of the board and allow the patient to be secured to the board with a belt-type strap equipped with a friction buckle. Each strap is two inches wide and nine feet long.

The vacuum splint mattress is a full-body immobilizer which consists of a shell made of reinforced polyvinylchloride filled with round polystyrene beads. It was developed in Sweden by a nurse/paramedic and was first introduced in the United States in 1987-88. When the air is withdrawn from the vacuum mattress the beads are drawn toward each other, compressing them against each other. This produces a rigid device which conforms to the patient without producing inward pressure. Since it exerts no pressure or force, any wrinkles in the shell are inverted into the splint rather than putting pressure on the patient's skin. The apparatus is lightweight, weighing only ten pounds. (Dick, 1988). It can be folded for storage and, when the device is unfolded for patient use, it measures 77.75" X 27.75" X 3". Since this device conforms to the patient it may offer
less impedance to respiratory muscle contraction. Both of these spinal immobilization
devices have been used in the prehospital setting but the effect that these devices may
have on respiratory status has not been examined.

4. Respiratory effort is defined as the motor output of the thoracoabdominal muscles
which is required to generate the necessary force for adequate ventilation (Nield, Kim &
Patel, 1989). Respiratory effort includes time, volume and flow components, as well as
a subjective perception of the amount of energy expenditure required to breathe.

The time component of respiratory effort includes respiratory rate (FREQ) and
inspiratory time (TI), where inspiratory time is the time differential between the start of
inspiration and the peak inspiratory flow (NIMS, 1989). The volume component
includes tidal volume (VT), which is the volume of gas that is inspired and leaves the
lungs during expiration (Berne & Levy, 1988); minute ventilation (VMIN), which is the
VT multiplied by respiratory rate for one minute; the per cent that the rib cage contributes
to the VT (%RC/VT); and total compartment displacement volume (TCDV), which is the
absolute sum of the volume displaced by the rib cage and abdominal muscles during
inspiration. The flow component of respiratory effort is expressed as the mean
inspiratory flow (VT/TI), which is determined by dividing the VT by the TI. Synchrony
of the thoracoabdominal muscles during breathing is reflected by the ratio between the
TCDV and VT. When the rib cage and abdominal muscles are in synchrony, this ratio
approximates 1.00 (Krieger, 1990).
CHAPTER 2
THEORETICAL FRAMEWORK

The theoretical framework for this study is based on Haddon's Model of Injury (Haddon, 1963, 1968, 1972). Haddon primarily applied the model to automobile crashes but the model also has utility for other forms of energy damage.

Haddon divided the injury event into three phases. The first phase is the preinjury or pre-event phase. In this phase, a variety of factors determine whether a potentially harmful energy exchange will take place. During the pre-event phase some source of energy frequently goes out of control. The energy may be physical, chemical, electrical, radiation, or thermal in origin. This is more commonly viewed as the mechanism of injury.

The relationship between use of seat belts and motor-vehicle fatalities is one pre-event factor that has been reviewed in the literature (Evans, 1986; U.S. Department of Transportation, National Highway Safety Administration, 1984). Lap/shoulder belts, when worn correctly, can reduce chances of death in a motor vehicle crash by approximately 45-50% (Baker, O'Neill, Ginsburg & Li, 1992; Evans, 1986). Only about one third of all older adults, however, wear a seat belt all or most of the time (United States Public Health Service [USPHS], Office of Disease Prevention and Health Promotion, 1986). The lack of seat belt use, therefore, represent a pre-event factor that may increase the potential for injury in the older adult.
The second phase of the injury event is the injury phase or the energy transfer phase. During this phase the actual energy exchange between the person and the source of energy takes place. The type and severity of injury produced during this phase depends on the amount of energy released and the nature of the transfer of this energy to tissues. According to Hogue (1982), "it is only when energy dissipation exceeds human thresholds that injury occurs." (p. 276). Age-associated shifts in the threshold at which injury occurs are being documented (Oreskovich, 1984). The older adult, because of physiological changes associated with aging, is at a higher risk for injury.

The third phase of the injury event is the post-injury or post-event phase. During this phase multiple factors may contribute to the outcome of the event. These factors may be either internal or external to the person. Internal factors include personal homeostatic mechanisms which may affect the amount of tissue damage sustained. For example, tissues which can spread the energy over a larger or more pliable surface may sustain less damage than tissues which are more brittle, such as bones with osteoporosis, which occurs in some older adults. External factors include the nature and quality of immediate, acute, and rehabilitative care provided which may significantly affect the outcome for the person. Haddon theorized that effective intervention in the immediate period after the injury could reduce the extent of injury sustained by controlling or minimizing the effects of the energy transfer. The purpose of this study was directed toward enhancing the homeostatic mechanisms which support respiratory function to prevent extension of injury sustained. Maintenance of spinal immobilization with optimal support of respiratory effort may improve care and reduce costs in the post-event phase.

For each of the phases identified by Haddon, three groups of factors were also described which could affect the nature and extent of injury sustained. These factors were: 1. the human factor or host, 2. the vehicle and equipment (for automobile crashes)
Hogue (1982) compares the combination of these factors to the development of disease, "Injury, like disease, results from an unfavorable relationship between etiologic agent and host within an environmental setting. Abnormal energy exchange is the agent when injury occurs." (p. 279). A two-dimensional matrix was developed by Haddon (1966) to provide a framework for analysis of injury. This matrix is presented in Figure 1. Using Haddon's framework, this study focused on two factors within the post-event phase. Both human and environmental factors were examined. The human factor was respiratory effort and the environmental factor was the method of spinal immobilization. The ultimate goal of the study was to reduce the energy damage loss by providing optimal support of respiratory effort during spinal immobilization.

**Respiratory Effort**

Respiratory effort represents an internal homeostatic factor that may affect the outcome of injury in the post-event phase. Respiratory effort can be defined as the motor output of the thoracoabdominal muscles which is required to generate the necessary force for adequate ventilation (Nield, Kim & Patel, 1989). Respiratory effort is closely related to, but can be distinguished from, dyspnea which has been defined as "the subjective sensation of difficult or labored breathing" (Gift, 1989). Respiratory effort may or may not result in difficult or labored breathing. The resting state, for example, requires less effort to breathe than during exercise.

Sweer and Zillich (1990) contend that increased respiratory effort is a primary factor contributing to the sensation of dyspnea. According to Sweer and Zillich (1990), dyspnea occurs when the individual perceives that increased or elevated ventilatory effort is required in the act of breathing. LeBlanc, Bowie, Summers, Jones and Killian (1986) also suggest that respiratory effort represents the stimulus which gives rise to the
**Figure 1.** Matrix for classification of factors in each of the three phases of injury that lead to the outcomes of damaged people and property (Adapted from Haddon, 1972, p. 197).
sensation of dyspnea. Their study of breathlessness and exercise in patients with cardiorespiratory diseases was based on the hypothesis that respiratory effort is the primary mechanism responsible for the sensation of dyspnea.

Respiratory effort includes both subjective and physiologic components. The subjective component is the sensation, as perceived and interpreted by the individual, of the intensity of muscle expenditure that is required during or in association with the act of breathing. (Altose, 1985; DeVito, 1990). The individual, therefore, rather than the observer, determines the amount and degree of effort required. The greater the sensation of effort the more likely it is that the individual will experience feelings of apprehension and anxiety associated with breathing. Mahler, Weinberg, Wells and Feinstein (1984), in their attempt to develop an index which would measure dyspnea, included subjective determinations by the patient of magnitude of effort, magnitude of task and functional impairment as indicators of breathlessness. Altose, Chonan and Mulholland (1988), in an attempt to evaluate the contribution of the sense of effort to the sensation of dyspnea, studied respiratory sensations in healthy subjects during progressive exercise on a bicycle ergometer. They concluded that dyspnea is not solely based on the effort of breathing.

Silvestri and Mahler (1993) present a comprehensive review of dyspnea in the older adult. The terminology of dyspnea, assessment of dyspnea, and management of dyspnea in the elderly is presented. They conclude that "no study has directly examined the effect of aging on breathlessness" and there is "limited knowledge about respiratory sensation in the elderly" (p. 394)

In addition to the subjective sensation associated with respiratory effort, respiratory effort also includes a physiologic component. Physiologic mechanisms contributing to respiratory effort include the strength of the respiratory muscles; the velocity and extent of muscle shortening; the length of the muscles; interaction between the muscle groups; and
the impedance opposing the action of the respiratory muscles (Killian & Jones, 1988; LeBlanc, Bowie, Summers, Jones, & Killian, 1986). Increased respiratory effort is required, for example, when the respiratory muscles become weak, when the velocity of contraction increases, when the muscles shorten, and when there is increased impedance to the action of the inspiratory muscles.

The respiratory muscles are central to the determination of respiratory effort. The diaphragm, muscles of the rib cage and the abdominal muscles all contribute to the work associated with breathing (Troyer & Estenne, 1988). The diaphragm is the primary muscle of inspiration (Berne & Levy, 1988).

During inspiration, the dome of the diaphragm flattens, which increases the vertical, anteroposterior and lateral dimensions of the thoracic cage. As the diaphragm descends during inspiration, the abdomen is displaced outward. The contribution of the diaphragm to $V_t$ can be measured indirectly by determining the extent of the abdominal movement associated with inspiration. Since the diaphragm is the most important respiratory muscle it accounts for most of the $V_t$ at rest.

The external intercostal muscles elevate the ribs and produce changes in the dimensions of the rib cage that are inspiratory in their action. The internal interosseous intercostal muscles lower the ribs and have primarily an expiratory effect on the rib cage.

The abdominal muscles also influence the act of breathing. The abdominal muscles have two primary actions associated with breathing (Troyer & Estenne, 1988). First, the abdominal muscles play an important role in expiration. When the abdominal muscles are contracted, the abdominal wall is pulled inward thus increasing intraabdominal pressure. The increase in pressure causes the diaphragm to move into the thoracic cavity, thereby increasing pleural pressure and decreasing lung volume. Secondly, the abdominal muscles play a significant role in displacing the rib cage. This action can influence both
inspiration and expiration. The inspiratory action is related to the effects that the abdominal muscles have on the lower rib cage and diaphragm. The abdominal muscles also influence movement of the rib cage on expiration by virtue of their attachments which tend to pull the rib cage down. The contribution made by the abdominal muscles to Vt can be recorded by measuring the movement of the abdominal muscles during breathing.

Physiologic indicators of respiratory effort include tidal volume (Vt), minute ventilation (VMIN), respiratory rate (FREQ), inspiratory time (Ti), mean inspiratory flow (Vt/Ti) and movements of the rib cage and abdominal muscles. Tidal volume is defined as "the volume of gas inspired or expired during a normal respiratory cycle," (Ng & McCormack, 1982). The normal Vt is approximately 5cc/kg. Tidal volume reflects the extent of inspiratory muscle contraction (LeBlanc, Bowie, Summers, Jones, & Killian, 1986). As disparity increases between the volume generated for each breath and the volume demanded, more effort is perceived as being needed.

Killian and Jones (1988) also identified respiratory rate as a component and indicator of respiratory effort. As demand increases, increasing the frequency of breathing minimizes discomfort associated with the increased effort.

Inspiratory time, as an indicator of respiratory effort, reflects the time required for inspiratory muscle contraction. With increased effort, more time may be needed to complete the inspiratory phase of the respiratory cycle. As respiratory frequency increases, however, less time may be available for inspiration and the Ti and Vt may actually decrease. The relationship between Vt and Ti is reflected in the flow component of respiratory effort (mean inspiratory flow), which is determined by dividing the tidal volume by the inspiratory time (Vt/Ti). Mean inspiratory flow serves as an index of respiratory drive (Tobin, Mador, Guenther, Lodato & Sackner, 1988). As respiratory effort increases, respiratory drive also increases.
Another measure which can be used to assess the movement of rib cage and abdominal muscles, as an indicator of respiratory effort, is the per cent that the rib cage contributes to the tidal volume (%RC/Vt) (Tobin, et al., 1983). The total compartment displacement volume/tidal volume ratio (TCDV/Vt) is a ratio that expresses the total excursion of the rib cage and abdominal compartments during inspiration divided by the tidal volume (Chadha, Watson, Birch, Jenouri, Schneider, Cohn and Sackner, 1982). In fully synchronous respiration, the total compartment displacement volume and the tidal volume are equal, so the ratio would be expressed as 1.00. Paradoxical motions, which reflect increased respiratory effort, would produce a higher ratio.

A variety of physiologic indicators have been described for respiratory effort. The complexity of the construct is reflected in the diversity of indices which can be used to assess respiratory effort.

**Spinal Immobilization**

According to Haddon's Model of Injury, spinal immobilization represents an external factor within the post-event phase of the injury. The use of spinal immobilization in the prehospital setting is considered routine for victims of motor vehicle accidents who have a potential for cervical spine injury (Baxt, 1995). Little attention has been given, however, to the effects that this intervention may have on respiratory effort.

Effective spinal immobilization requires that the injured person be placed in a supine position with the neck in a neutral position (American Academy of Orthopedic Surgeons, 1990). Placing the person on a rigid surface, such as the traditional wooden backboard, increases resistance to the thoracoabdominal muscles. Increased resistance may inhibit expansion of the rib cage and contribute to increased respiratory effort.

In addition, the more rigid the device, the less likely it will be to conform to differences in body contour. Older adults with kyphoscoliosis, for example, may
experience increased respiratory difficulty when placed on a backboard because of the inability of the device to conform to the altered spinal curvature. Use of a spinal immobilization device which conforms to the spinal curvature, such as the vacuum splint mattress, may provide less resistance to movement of the thoracoabdominal muscles and may ultimately decrease respiratory effort.
CHAPTER 3
REVIEW OF THE LITERATURE

Trauma in the Older Adult

Major studies related to trauma in the older adult have primarily been epidemiological in origin. Oreskovich, Howard, Copass and Carrico (1984) followed 100 older adults, aged 70 and older, who had sustained multiple trauma and were admitted to a metropolitan trauma center. Although 85% of the injured patients survived, only 12% of these were able to return to their previous level of independence. Prior to their injuries, 96% had been independent.

Bobb (1987) provided a retrospective review of 122 older adults, aged 55 and older, who were admitted to an urban trauma center from the scene of an accident. Bobb found that age alone was not a highly significant determinant of survival. Bobb also identified that "too little is known about the elderly response to injury" (p. 30).

McCoy, Johnstone and Duthie (1989) provided evidence that age should be incorporated as a factor in injury scales, such as the Injury Severity Score (ISS), used to determine the extent and severity of injury. McCoy, et al. suggested weighting injury scales to adjust for outcomes related to age. Current methods for quantification of injury severity tend to underestimate injury severity in the older adult.

DeMaria, Kenney and Merriam (1987) recognized this problem and did develop an injury severity scale for older adults. The method developed by them considered age, injury severity score, and septic and cardiac complications, to predict survival of older
adults who had been injured. One limitation of their method, however, was that there was no consideration of prehospital variables that could influence the outcome. Respiratory complications were also not included as a major determinant of survival.

A source of retrospective data that has been used to assess the extent of geriatric trauma is death certificates. Fife (1987) reviewed death certificate data and identified that death certificates also tend to underestimate the role of injury in deaths of older adults. Death certificates may list pneumonia or other complications versus trauma as the cause of death.

Champion et al. (1989) reported results of the Major Trauma Outcome Study conducted between 1982 and 1986. In this study data from more than 100 trauma centers in both the United States and Canada was pooled. Although data from more than 46,000 subjects was collected, older adults comprised only about 3800 of the total sample. Champion compared the older adult group, aged 65 and older, to the younger adult group, under age 65. Champion et al., identified that mortality and complications related to trauma were significantly higher in the older adult group versus the younger adult group. The complications, related to trauma, that had the highest mortality for the older adult were pulmonary complications.

Finelli, Jonsson, Champion, Morelli and Fouty (1988) analyzed age as a univariate factor in survival and compared elderly trauma patients (> 65 years) to a similarly injured group of younger patients. Overall mortality for older patients was found to be 89% greater than that of younger patients. Health care providers were also more likely to underestimate the seriousness of any given injury in the older adult.

More recently, DeKeyser, Carolan, and Trask (1995), conducted a fairly large retrospective review of 766 subjects transported to a suburban trauma center. Older subjects, aged 65 years and above, were compared to two groups of younger subjects,
one group aged 35-45 years and a second group, aged 55 to 64 years. Falls and motor vehicle accidents were the most common mechanism of injury identified. Older adults had greater physiologic compromise and longer hospital stays with lower levels of injury than the other groups. In contrast to Finelli, et al. (1988), older adults had a lower mortality in this study. One possible reason for the lower mortality in this sample may be the lower proportion of subjects with severe trauma. If the nature of the injuries is less severe, mortality is less likely.

Demaria, Pardon, Merriam, Cassanova and Gann (1987) also examined survival after trauma in older adults. Of the 63 survivors of trauma that were retrospectively reviewed, the highest percentage of complications (33%) were pulmonary related with 11% of the survivors requiring long term assisted ventilation.

Horst, Obeid, Sorenson and Bivens (1989) examined factors predictive of survival in the older adult who had sustained injury. One of the factors that was identified was oxygen uptake. They noted that, in nonsurvivors, the primary organ/system to fail was the pulmonary system and recommended further research to improve support of respiratory status.

Wetle (1987), has identified age as a factor that may influence the nature and type of interventions provided for older adults. Frequently, older adults are not provided with the same aggressive interventions that are used for younger adults to enhance survival. Older adults are less likely to be transported to trauma centers where patient outcomes have demonstrated lower mortality and a decrease in complications (Smith, Martin, & Young, 1990). In the study conducted by Smith et al., 14 of 16 deaths that occurred in nontrauma centers, were in older adults greater than 70 years of age.

Only one study could be identified that specifically examined trauma in older adults from a prehospital perspective. Spaite, Criss, Valenzuela, Merslin and Ross (1990)
attempted to review prehospital patterns related to demographics, mechanism of injury and utilization of services. They found the mortality rate to be higher in older adults for injuries that were determined to be less severe in a younger population. This was in contrast to the findings of Dekeyser et al. (1995), who noted a lower mortality rate. Spaite et al., also noted that, in the prehospital records they reviewed, older adults comprised approximately 22% of the emergency services runs devoted to trauma-related injuries. This represents a relatively high percentage since older adults comprise approximately 12.7% of the population (Day, 1996)

Few interventional studies to improve survival and outcomes related to trauma have been conducted in relation to the older adult. Scalea et al. (1990) did attempt an interventional study for older adults who had sustained blunt trauma. The intervention instituted by Scalea, et al. (1990) was early invasive monitoring, which included use of arterial lines and Swan Ganz catheters. Scalea concluded that survival was enhanced with early institution of invasive monitoring. The advantage of early invasive monitoring was the identification of subtle changes associated with potential complications related to trauma. No interventions were developed, however, to prevent these complications in the immediate period following the injury. Overall, there is a paucity of research related to injury in the older population. The majority of studies that have been conducted were retrospective and focused on identification of risk factors for injury, mechanism of injury and outcomes.

**Spinal Immobilization**

No studies could be identified in the literature which specifically examined the initial care provided for the older adult in the prehospital setting. According to Beaver (1990), 24% of all trauma deaths are preventable if appropriate care is provided within the first hour of injury. One of the most important aspects of prehospital care is spinal
immobilization. The older adult is at higher risk for cervical spine injury due to the higher incidence of osteoarthritic changes in this population (Bryson, Warren, Schwedhlem, Mumford & Lenaghan, 1987). In a prospective study of 174 individuals with a mean age of 61 years who had sustained trauma, 92% had signs and symptoms which may indicate the potential for cervical spine injury (Bryson, Warren, Schwedhlem, Mumford, & Lenaghan, 1987). No studies could be identified in the literature, however, which specifically examined methods or effects of spinal immobilization on the elderly.

Herzenberger, Hensiger, Dedrick, and Philips (1989) did investigate spinal immobilization of young children with cervical spine injuries. A variety of clinical, radiographic and anthropometric methods were used to determine the most appropriate method for placing a child on a backboard. Herzenberger et. al., recommended modifying the traditional wooden backboard by making an adjustable cut out in the board or adding a double mattress pad to raise the chest in order to prevent undesirable cervical flexion. No attempt was made to determine the effects of these modifications on the respiratory status of the child.

Schafermeyer, Ribbeck, and Gaskins (1991), however, did attempt to examine the effects of standard spinal immobilization on healthy children. Forced vital capacity was measured prior to being placed on the backboard and while they were immobilized on the backboard. Results indicated that there was a mean reduction in forced vital capacity that was 20% lower than the baseline value.

Several studies have been conducted on adults to determine the effectiveness of cervical spine immobilization methods and devices. Podolsky, Baraff, Simon, Hoffman, Larmon, and Ablon (1983) compared the efficacy of six different immobilization methods/devices on 25 healthy volunteers, aged 18 to 57 years. The methods evaluated included the use of the soft cervical collar, hard cervical collar, extrication cervical collar,
Philadelphia collar, the use of bilateral sandbags joined with three inch cloth tape across the forehead, and a combination method, consisting of sandbags, tape and the Philadelphia collar. Neck movements were recorded using a hand held goniometer in the supine position with the subjects placed on a rigid emergency department resuscitation table. The use of sandbags and tape as a method of spinal immobilization was found to be significantly better than any other single device ($p < .005$). Current recommendations made by the Committee on Trauma of the American College of Surgeons, however, have advocated against use of sandbags due to possible shifting and moving of the contents which could produce localized lateral pressure against the cervical spine (McSwain, 1990).

Cline, Scheidel and Bigsby (1985) compared seven methods of cervical immobilization used in the prehospital setting. Two of the methods, the Philadelphia collar and the cervical extrication collar, were identical to those evaluated by Podolsky et al. (1983). The other methods evaluated included use of an additional type of cervical collar, and combinations of the various types of collars with use of the short spinal immobilization board. The short board technique was found to be superior to the cervical collars. The use of the collars did not provide any additional improvement in immobilization compared to the use of the short board alone. Ninety-seven healthy volunteers were used for the study, ranging in age from 18 to 54 years. Radiographic evidence was used to evaluate the effectiveness of the various methods. No attempt was made in this study to use the long spinal immobilization board since all data was collected with the subjects in a sitting position.

Graziano, et al. (1987) also attempted to compare prehospital cervical immobilization methods. Three different devices, one of which was a stiff collar and two short board factory-fabricated extrication devices, were compared to use of the short spine board
technique. Radiography was used to measure cervical movement in the sagittal, frontal and horizontal planes. The short board technique was found to be consistently superior in all planes of cervical spine motion. The major difficulty with this study is that all data was collected in a sitting position.

Few studies could be identified in which the effectiveness of the long spinal immobilization board was examined. One study, conducted by McGuire, Neville, Green and Watts (1987), evaluated three techniques used in the prehospital environment: use of the log roll maneuver, the stability offered the spine by a traditional wooden backboard, and use of the Ferno-Washington scoop style stretcher. Three subjects were used for the study: a cadaver in which spinal instability at the first and second lumbar vertebra was created and then documented via radiographs; a healthy, young female adult volunteer; and a 38 year old male with a recent T_{12}-L_{1} fracture dislocation. The log roll maneuver was used for all three subjects but only the cadaver was placed on the long spinal board. Use of the scoop stretcher was also limited to the cadaver. Radiographs were obtained for each of the subjects in the supine position and before/after the log rolling maneuver. Radiographs were also obtained of the cadaver after immobilization on the long spinal board and after immobilization on the scoop stretcher. Analysis of the radiographs demonstrated that the anteroposterior displacement which had been created on the cadaver was fully corrected when the cadaver was immobilized on the long spinal backboard. Use of the log-roll maneuver, however, produced lateral and rotational displacement. The study was limited in that only three subjects were used, but it does provide some support relative to the efficacy of the traditional wooden backboard as a method of spinal immobilization.

Chan, Goldberg, Tascone, Harmon and Chan (1994) studied the effects of spinal immobilization on healthy volunteers. The primary purpose of this study was to
determine the effects of the backboard on subjective perceptions of pain and discomfort. The sample size in this study was also limited, consisting of 21 subjects ranging in age from 10 to 43 (mean age = 23.6 years). None of the subjects had a history of chronic back pain or had taken analgesics within 24 hours of their participation in the study. The subjects were placed on a backboard for a 30 minute period. The methodology was very questionable in this study since the subjects were asked to respond to only one question after they were released from the board. The question was "How do you feel?" If they reported pain they were asked to grade the pain as mild, moderate or severe. All of the subjects reported pain while on the backboard, with 55% reporting moderate to severe pain. The occipital and sacral areas were identified as the two most common sites for experiencing pain. Although this study had many limitations, it does demonstrate that there are side effects associated with the process of immobilizing a person on a backboard.

Another side effect associated with spinal immobilization on the backboard is an alteration in skin integrity. Linares, Mawson, Suarez, and Biundo (1987) conducted a retrospective study which examined the relationship between the development of pressure sores and immobilization following spinal injury. Development of pressure sores was found to be associated with reports of prolonged immobilization on the backboard from time of injury to admission on the unit in the hospital. The study, however, had several major limitations. Self-report by the patients was used to determine an estimate of time spent on the board and not being turned. Perceptions of patients with spinal cord injury regarding time could have been influenced by the amount of pain they were experiencing while on the board. The study also failed to consider other factors, such as nutritional status, which could have contributed to the development of pressure ulcers in these patients.
A prospective study was later conducted by Mawson, et al. (1988) which confirmed the earlier retrospective findings of Linares et al. (1987). The authors followed 39 patients consecutively admitted with spinal injury and compared time spent on the backboard to the development of pressure ulcers. Ambulance reports, emergency room records and nursing notes were used as the primary sources of data to confirm time spent on the board. Of the 39 patients with spinal cord injury, 23 (59%) developed a pressure ulcer within 30 days of admission. The amount of time the person was immobilized on the backboard was found to be significantly related to the development of pressure ulcers within the first eight days after injury (p = .04). Those with pressure ulcers were immobilized 1.6 times longer on the board than those who did not develop pressure ulcers. The authors recommended a change in design of the backboard to reduce this complication.

A recent study by Cordell, Hollingsworth, Olinger, Stroman and Nelson (1995), addressed both the pain and pressure side effects of spinal immobilization. The size of the sample was again small (N = 20) but the methodology was much improved over earlier studies. A visual analogue scale was used to assess pain. The Talley-Scimedics Pressure Evaluator MK II (Talley Medical Group), which uses an electropneumatic sensor, was used to measure the tissue interface pressures. Two methods of spine immobilization were compared: the wooden backboard and the backboard with a commercially available low-pressure, low-volume air mattress used as an overlay on the board. A crossover experimental design was used. Results showed a significant difference (p = .0001) in mean pain scores on the backboard (37.5 mm) versus the backboard with the overlay (9.7 mm). The tissue interface pressures, measured at the occiput, sacrum, and heel, were all significantly less (p = .001) with the overlay versus the backboard alone. Although the authors recommend the use of an air mattress overlay,
it would increase time needed in the field to inflate and apply the overlay to the board. Additional space would be needed to store these in the emergency vehicle. Performance of the air mattress in adverse weather conditions has also not been determined. Finally, the overlay is not puncture resistant which could render it useless if broken glass is present at the scene. Durability and ease of maintenance was not evaluated by the authors.

Although pain and tissue pressure are reasonable considerations in spinal immobilization, support of respiratory function is of primary importance. Only one study could be identified that attempted to examine the effects of spinal immobilization on respiratory function in the adult. Bauer and Kowalski (1988) studied the effect of spinal immobilization devices on pulmonary function in the healthy nonsmoking male. Fifteen volunteers, aged 23 to 28 years old, were placed on two different spinal immobilization devices: the long spinal board and the Zee Extrication Device (Zee Medical Products). Four pulmonary function parameters were measured at baseline and after being strapped to the device. A significant difference was noted in three of the four pulmonary function parameters when subjects were placed on the long spinal board when compared to baseline values: forced vital capacity (p = .0079), forced expiratory volume in one second (p = .001), and forced mid-expiratory flow (p = .0022). The findings were similar for the Zee Extrication Device. The decreases noted in all of these parameters were consistent with a marked pulmonary restrictive effect. The authors conclude that the process of spinal immobilization may contribute to respiratory compromise in the injured adult. There were several limitations, however, of this study. Small sample size and possible gender bias, since only males were used, could affect the results. The major threat to this study, however, was that no baseline data were collected in the supine position prior to
being placed on either device. Baseline data was collected on the devices prior to and after being strapped to the devices. Changes in pulmonary function, therefore, are more related to the process of strapping the person to the device rather than the device itself.

Few studies could be identified which evaluated the efficacy of the vacuum splint mattress, although it has been used extensively in the United States, Sweden and Europe. Johnson, Hauswald and Stockhoff (1996) compared the vacuum splint device to the long spinal board in relation to comfort and efficacy of spinal immobilization. A convenience sample of 30 emergency medical technician students was used for the study and the subjects were placed on each device for 30 minutes. The amount of time it took to apply the device was measured as well as parameters related to comfort and measures to determine immobilization. The vacuum splint device was determined to be significantly more comfortable than the spinal board ($p < .001$) and was faster to apply ($131.6 \pm 24.3$ seconds versus $154.6 \pm 22.2$ seconds). The vacuum immobilizer splint was also found to provide better immobilization of the torso with less slippage when the device was gradually tilted in a lateral direction ($p < .001$). The authors conclude that "the vacuum splint seems to be a reasonable alternative to traditional spinal immobilization using a rigid backboard" (p. 372).

In summary, studies related to spinal immobilization have compared the efficacy of different devices and have primarily examined the effects of spinal immobilization on the skin and comfort level for the person. Little consideration has been given to determining the effect that this procedure has on respiratory function. The sample sizes for the majority of studies reviewed has also been small with older adults not represented. Methodological problems exist which may affect the credibility of some studies. No studies could be found that examined the effects of the vacuum immobilizer device on respiratory function.
Effects of the Supine Position on Respiration

When a person is placed on either the wooden backboard or the vacuum splint mattress the supine position is used. Change in body position from sitting to supine changes the external forces which affect the lung. In the supine position there is less of a gravitational effect, resulting in the weight of the abdominal contents being transmitted through the diaphragm to the lungs. Inspiratory capacity, however, may increase in the supine position since the resting position of the diaphragm is elevated. The supine position, therefore, may actually increase the efficiency of the diaphragm (Coonan and Hope, 1983).

Hess, Agarwal, and Meyers (1992) calculated the hydrostatic pressure produced by the abdominal contents. A hydrostatic column created by the abdominal contents was found to produce a pressure of 20 cm at the lowest point. Although there may be increased efficiency of the diaphragm in the supine position, the decreased hydrostatic pressure may result in a lower pressure gradient and decreased ventilation for dependent areas of the lung.

Body position also affects the distribution of ventilation. In normal healthy subjects, in a supine position, the intrapleural pressure gradient between the apex and the base of the lungs is less than in an upright position (Ng & McCormick, 1982). Ventilation, therefore, is more uniform in the supine position but it is still better in the base of the lung.

Perfusion of the lung is also affected by body position. In the supine position perfusion throughout the lung becomes more even, mainly due to changes in the hydrostatic pressure gradients (Ng & McCormick, 1982). Blood flow to the apex and
base of the lungs is therefore, more uniform but blood flow to the posterior regions is still
greater than to the anterior regions (Von Reuden and Harris (1995).

One of the primary effects of the supine position is a reduction in all lung volumes, except $V_t$ (Tyler, 1984). Blair and Hickman (1955) studied the effects of changes in body position on lung volumes in adults. Residual volume (RV) was found to be decreased in the supine position compared to the standing position. Functional residual capacity (FRC) was also decreased, with a mean FRC of 2.69 liters in the supine position compared to 3.79 liters in the standing position. Coonan and Hope (1983) report a decrease in FRC of 24% for the conscious person in a supine position compared to the sitting position, with an average decrease of 800 ml. This decrease in FRC in the supine position may be partially attributed to the weight of the abdominal contents on the diaphragm (Von Reuden and Harris (1995).

There was less of a difference in the total lung capacity (TLC) reported by Blair and Hickman (1955) with a mean TLC of 6.22 liters in the supine position compared to 6.77 liters in the standing position. Von Rueden and Harris (1995), however, report a 7% decrease in lung capacity in the supine position. Other lung volumes that decrease in the supine position include the expiratory reserve volume (5%) and the closing volume (10%) (Von Reuden And Harris (1995).

In addition to lung volumes, the effect of position on physiologic dead space was also examined by Blair and Hickman (1955). Physiologic dead space was found to be decreased in the supine versus standing position. A decrease in dead space should increase the surface area for gas exchange. This is one effect of aging that should contribute to improved pulmonary function in the supine position.

Changes in body position have also been associated with changes in the rate of ventilation (Blair and Hickman, 1955). Higher respiratory rates were noted in the upright
position compared to lower rates in the supine position. Diminished respiratory muscle
contraction has also been noted in the supine position (Bynum, Wilson & Pierce, 1976).

The supine position also has an effect on removal of mucus from the lung. In the
supine position the bronchioles are horizontal as opposed to vertical when in the upright
position. The horizontal direction of the bronchioles allows mucus to pool on the floor of
the bronchioles. As secretions pool they begin to interfere with the function of the cilia.
The cilia are essential in the removal of mucus from the lung since the ciliary action
moves the mucus up and out of the bronchiole and into the larger airways where it can be
expelled. As the mucus collects in the floor of the bronchioles it thickens, in contrast to
the mucus on the anterior surface of the bronchiole which is reduced. This causes the
cilia to dry out since they are exposed to air. Remaining in the supine position for an
extended period of time may ultimately contribute to atelectasis (Von Reuden and Harris,
1995).

Rabow, Dwayne and Don (1972), examined the effect of position on PaO2 for post-op
cardiac patients. Although there was no significant difference between sitting and supine,
the patients stated that they could breathe easier and were more comfortable in the sitting
position. Norton and Conforti (1985) used their critical review of research related to the
effects of body position on oxygenation to develop a body positioning protocol to
enhance and support respiratory function. The protocol included a listing of specific uses
of prone, lateral and sitting positions. Specific uses of the supine position, however,
were not included.

Many of the effects on respiratory function that have been described for the supine
position may actually increase the risk for pulmonary complications for older adults who
are injured. The effects of the supine position on respiratory function may also be further modified by the effects of aging on the respiratory system.

**Changes in the Respiratory System Associated with Aging**

The respiratory status of the older adult who has sustained trauma may be compromised not only by injury but also by the physiologic changes associated with aging which reduce the adaptive capacity of the respiratory system.

One change that occurs is a progressive decline in alveolar surface area. Beginning at the age of 30 alveoli decline by approximately 4% per decade. The alveoli themselves actually become flatter and shallower which decreases the lung parenchyma available for gas exchange (Allen, 1992).

Structural support for the alveoli in the lungs is provided by elastin. Although total pulmonary elastin content increases with age, there is a loss of elastin fibers in the walls of the alveoli and alveolar ducts (Pierce & Ebert, 1965). Contrary to this loss, there is an increase in elastin in the pleura, interlobular septa, and possibly the bronchi and blood vessels (Krumpe, et al., 1985). A study by Andreotti, Bussotti and Cammelli (1983), did find that, when the concentration of elastin was expressed as mg/cm³, there was no change with age, but when elastin was measured as a percentage of dry weight, there was an increase of 8.3% in the amount of elastin. Compliance changes with aging have been proposed as being related to shifts in elastin content (Krumpe, et al., 1985).

Another component of connective tissue in the lung is collagen. Collagen is the primary protein in the lung, comprising approximately 10-20% of dry weight of the lung (Krumpe, et al., 1985). Lung collagen can be further subdivided into at least five genetically distinct types of collagen with more than 40 cell types (Krumpe, et al., 1985). Analysis of collagen content in the aging lung has been limited due to methodological difficulties. Studies of collagen content, therefore, have demonstrated conflicting
results, (Andreotti, Bussotti, & Cammelli, 1983; Briscoe, Loring & McClement, 1959). Studies of physical properties of lung collagen, however, have demonstrated more consistent results (Butler, 1976; Szemenyei, Balint & Havanghy, 1968). Aging changes identified include an increased temperature needed to induce shrinking of the collagen and increased resistance of collagen to proteolysis. These changes may affect the distensibility of the collagen fibers and are theorized to also contribute to decreased compliance with age (Levitzky, 1984). Since the purpose of elastin and collagen is to help support the lung, they also assist in maintaining patency of the small airways at low lung volumes during expiration.

Kauder and Schwab (1990) have summarized the studies on collagen and elastin and they conclude that "there is no decrease in the amount or type of collagen or elastin fibers in the lung parenchyma" (p. 218). Qualitative changes, however, may occur. Functional changes seen in pulmonary elasticity may not necessarily be the result of structural changes in elastin and collagen so this area remains controversial.

A functional change that is altered with aging is increased airway resistance. Niewoehner and Kleinerman (1972) examined lungs of older adults postmortem. They observed a decrease in the diameter of the membranous bronchioles after the age of 40. As bronchioles decrease in size, the resistance to airflow increases. This may make it more difficult to maintain a patent airway in the older adult.

Another functional change associated with aging is a loss of elastic recoil in the lung. Knudson and Kaltenborn (1981) used exponential curve analysis to calculate elastic lung recoil. Loss of elastic lung recoil was found to be greatest at high lung volumes. The resultant curve produced, therefore, was curvilinear rather than a direct linear decline. Because of these changes, increased lung volumes are required to close small airways.
Airway closure tends to occur in dependent areas of the lungs (Von Reuden & Harris, 1995). Older adults who are immobilized on the backboard, therefore, are more likely to develop atelectasis in the posterior sections of the lung.

A decrease in maximal expiratory flow also occurs with aging, but this function is better preserved than other age related respiratory parameters. In a study by Knudson, Clark, and Kennedy (1977) 51 normal, nonsmoking, adults aged 25 to 75 years were compared in relation to the mechanical properties of lung function. Maximum expiratory flow declined very little until lung volumes reached 70 per cent of the expired vital capacity. During the last 30 per cent of the expired vital capacity, the decrease in maximal expiratory flow finally became statistically significant (p < .05).

Although total lung capacity is relatively unchanged with age, one volume that is altered is the residual volume (RV) (Levitzky, 1984). The RV represents the amount of air which remains in the lungs after a maximal exhalation. Residual volume increases from approximately 25% of lung capacity in the young adult to 40% or greater at the age of 70 (Godar, 1986). The RV results from a balance of chest wall compliance and lung compliance. Although static pulmonary compliance may increase with age, chest wall compliance decreases with age, contributing to an increase in the RV (Levitzky, 1984). Dynamic pulmonary compliance also decreases with age (Levitzky, 1984). Since total lung capacity remains relatively constant with age, the increase in residual volume is associated with a reduction in vital capacity (Tockman, 1990).

Jammes and Auran (1979) reported that older adults have VMIN that are similar to younger subjects but tidal volumes tend to be smaller. Older adults also tend to have higher FREQ. The increased FREQ, helps to adjust for the slightly lower Vt, producing an adequate VMIN. Mahler, Rosiello and Loke (1986) suggest that this represents an attempt to compensate for the decreased compliance and airway closure.
Pressures as well as volumes are affected by aging. In an early, yet comprehensive study, Rinquist (1966) measured the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) in 106 men and 94 woman ranging in age from 18 to 83 years of age. When comparing the older and younger subjects Rinquist noted that the MIP decreased linearly with age and the MEP decreased in a curvilinear fashion. These parameters declined by about 15% between 20 and 65 years of age. In addition to the decline in MIP and MEP, elastic recoil pressure also decreased in subjects over 50 years of age. These findings suggest that lung pressures as well as volume decrease with age. Tockman (1990) has summarized the changes in pulmonary function associated with aging of the respiratory system. The average loss of function for nonsmoking males is 14 to 30cc/year of functional vital capacity. Nonsmoking females demonstrate less loss of function with 15 to 24 cc/year of functional vital capacity.

The changes in spinal curvature associated with kyphoscoliosis may also result in reduction of lung volumes (Mezon, West, Israels & Kryger, 1980). In addition to altering lung volumes, the presence of kyphoscoliosis may affect positioning required for spinal immobilization. The spine should be maintained in a neutral position without flexion, extension or rotation. This may be more difficult in the presence of kyphoscoliosis.

Other thoracic structures also change with aging. Decalcification occurs in the ribs and vertebrae while simultaneously, there is an increase in calcification of the costal cartilages (Levitzky, 1984). This increased chest wall stiffness, along with a decrease in strength of the skeletal muscles in the thorax, may contribute to a reduction in the ability of the older adult to generate an effective cough (Krumpe, Knudson, Parsons and Reiser, 1985).
The presence of osteoporosis further complicates the normal changes associated with aging. Edge, Millard and Reed (1964) reported that 68% of subjects over 75 years of age, in their study, had osteoporosis of the spine with associated kyphoscoliosis. These findings occur more frequently in women since the incidence of osteoporosis is higher among post-menopausal women. Edge, et al.'s (1964) study was an early study. Increased health education efforts, as well as improved treatments for osteoporosis, would probably result in a reduction in that percentage for older adults today.

The increased chest wall stiffness in the older adult may also contribute to increased use of abdominal and diaphragmatic breathing. Rizzato and Marazzini (1970) reported on a decrease in the strength of respiratory muscles in older men. Arora and Rochester (1982), however, noted that, based on body weight, the mass of the diaphragm was similar for older subjects when compared to younger subjects; the implication being that if muscle mass of the diaphragm is stable then muscle strength should not decline.

Tolep and Kelsen (1991), however, provide evidence that does not support this conclusion. They assessed the effects of aging on the diaphragm strength through the measurement of maximum static transdiaphragmatic pressures (Pdi_{max}). Ten healthy older adults, aged 65 to 74 years were compared to 9 healthy younger subjects, aged 18-32 years. Pdi_{max} was found to be significantly lower in the older adults (128 ± SE cm H_2O) versus the younger adults (171± 8 SE cm H_2O) (p<0.003). Based on these changes and similar changes in the Pdi, the authors concluded that diaphragmatic strength tends to be 20 to 25% less in older adults when compared to younger adults. Decrease in diaphragmatic strength may also contribute to a reduction in the ability of the older adult to generate an effective cough.

Type II muscle fibers have also been shown to decrease with age. Type II muscle fibers have larger glycogen stores and are utilized with moderate respiratory loading.
(Tolup & Kelson, 1993); however, these fibers fatigue quickly. Age-related decreases may contribute to earlier muscle fatigue when an extra load, such as occurs with trauma, is placed on the respiratory muscles. Demands can rapidly exceed supply leading to increased potential for pulmonary complications.

Another outcome of the effects of aging on the function of the respiratory system is the changes which occur in oxygen tension. Sorbini, Brassi and Solinas (1968) noted a progressive decline in PaO2 when subjects ranging from age 20 to 80 were evaluated in the upright position. The reduction in mean PaO2 is believed to be due to the development of zones within the lung that have a reduced ventilation/perfusion ratio as a result of premature closure of the small airways (Godar, 1986).

Finally, mucociliary transport is also altered. The mucosa and mucus secreting glands in the nose begin to atrophy with aging. Puchelle, Zachm and Bertrand (1979) compared mucociliary transport in older versus young adults. Radioactive particles were aerosoled and then inhaled in order to track mucociliary efficiency. The rate at which these particles were cleared from the airway was then measured. Clearance of the radioactive particles was reported as significantly slower for older adults versus young adults. A decrease in the ability of the older adult to expel foreign material from the nose and airway may contribute to increased potential for aspiration.

Kronenburg and Drage (1973) compared the responses of healthy older men and healthy younger men to transient hypoxia and found that the ventilatory response of healthy older adults was reduced by half in the older population compared to the younger population. When injury has been superimposed, the ventilatory response to hypoxia may be even further impaired. All of the structural and functional changes associated with aging affect the ability of the older adult to adapt to a traumatic physiologic insult.
Summary

This review of the literature suggests that investigation of the effects of trauma on the older adult has been limited in scope. The epidemiological aspects of trauma have been well addressed but interventions to reduce morbidity and mortality for the older adult have been lacking. Spinal immobilization represents one intervention that helps to prevent further injury in the immediate post-injury phase. Studies related to spinal immobilization methods have primarily been conducted with small samples and several have had significant methodological flaws. Difficulties were encountered in measuring the effectiveness of specific spinal immobilization devices. Investigation of effects of this procedure, however, has been limited to considerations of comfort and skin integrity. Only one study was conducted that examined the effects of spinal immobilization on pulmonary function (Bauer & Kowalski, 1988). No studies were identified that evaluated any effects of spinal immobilization on the older adult. The process of spinal immobilization involves placing the person in a supine position. The physiologic effects of lying in this position can potentially reduce pulmonary function. The normal effects of aging on the respiratory system, combined with the effects of lying in a supine position, plus the physiologic insult of trauma, place the older adult at high risk for pulmonary compromise. The paucity of literature in this area suggests that evaluation of methods to support respiratory function in the presence of injury are needed.
CHAPTER 4

METHODOLOGY

Research Design

The classic Latin square or counterbalanced design was used for this study. The design involves randomly assigning the subjects to two groups which differ in the order of treatment (Beck, 1989; Brown, 1980). Both groups in this study received both treatments but the order in which the treatments were given was different for each group. Figure 2 presents a graphic portrayal of the research design using Campbell and Stanley’s (1963) notation.

\[
\begin{array}{cccc}
\text{GROUP A} & \text{R} & O_1 & X_1O_2 & X_2O_3 \\
\text{GROUP B} & \text{R} & O_4 & X_2O_5 & X_1O_6 \\
\end{array}
\]

R = random assignment  
O = Observation  
\(X_1\) = standard wooden backboard  
\(X_2\) = vacuum immobilizer device

\textbf{Figure 2}: Counterbalanced Design
In this design the independent variable is the method of spinal immobilization, with two levels. The first level is the standard backboard and the second level is the vacuum immobilizer apparatus. The dependent variable is respiratory effort.

Major advantages of the counterbalanced design, as identified by Beck (1989), are: increased control of variance and decreased requirements of sample size. The primary external validity threat is the potential for carry-over effects from one treatment to the next (Brown, 1980). Carry-over can be minimized by allowing adequate time for the effects of one treatment to dissipate before administering the other (Louis, Lavori, Bailar & Polansky, 1984). Counterbalancing, however, distributes the carry-over effects equally across all the conditions of the study, assuming that the carry-over effect is essentially the same for either treatment (Burns & Grove, 1987).

Setting

The study was conducted on the General Clinical Research Center located in The Ohio State University Hospital.

Sample

The sample consisted of noninstitutionalized older adult volunteers in the central Ohio area aged 65-75. The most common cause of accidental death in this subgroup is motor vehicle-related accidents (Baker, Ginsburg & Li, 1992). This subpopulation, therefore, is more likely to be placed on a backboard for transport in the prehospital setting.

Criteria for exclusion were: (a) age under 65 or over 75, (b) presence of a cognitive deficit such that instructions for the study could not be comprehended, (c) presence of a physical impairment which would limit mobility to the extent that the person would be unable to lie in the supine position, (d) smokers, (e) need for supplemental oxygen by the subjects, and (f) subjects who have had injuries requiring hospitalization within three months of the study. Subjects with trauma were excluded from this initial study due to
the difficulty in controlling for extraneous variables related to the nature and extent of injuries. Future studies will need to be conducted which extend this research to the older adult who has sustained trauma.

Determination of the sample size was based on a power analysis for a two-tailed test with alpha equal to .05, desired power of 80, and a medium effect size, as established by Cohen (1988). Based on these parameters, the required sample size would be 64 per group with independent samples. Since the observations are correlated however, the required number of subjects would be less. Estimate sample requirements on the Cohen table were interpolated, yielding an estimate of 39 per group or 78 total. The power analysis was done in consultation with Dr. Knapp, a statistical consultant with The Ohio State University College of Nursing.

The actual sample size, however, was 60. As data collection proceeded, a definite trend was noted in the data. Data collection was stopped to determine if significance could be established based on the available data. Additional subjects, therefore, were not required to answer the research question. Since there were 78 cards in the original deck, 18 cards remained at the end of the data collection period. This resulted in the two order groups having unequal size.

A convenience sample was recruited from volunteers in senior citizens centers in the central Ohio area which encompasses the Standard Metropolitan Statistical Area (SMSA) of Franklin, Delaware, Licking and Fairfield counties. The purpose was to ensure a sample of older adults who were active and in the community. No gender or racial limitations were imposed. All persons who met the criteria for inclusion in the study and voluntarily agree to participate could enter the study.

Several methods were used to secure participants. Posters describing the purpose and nature of the study were distributed to the senior citizens' centers in the designated
inclusion in the study. Potential participants who met the criteria were invited to leave their name and phone number with a designated contact person at the center. Announcements explaining the project and criteria for admission into the study were also included in newsletters sent by the designated senior citizens' centers to the older adults in the community served by the center. Finally, opportunities were provided by the senior centers for the researcher to present the project personally to older adults who were participating in exercise classes or other activities at the center. This provided an informal mechanism to answer questions or concerns about the project for potential subjects.

**Ethical Review**

Participation in the study was voluntary and all subjects signed a written consent for participation in the study. A copy of the consent form is contained in Appendix A. The consent was obtained by the investigator. No subject's name was identified with the data. Confidentiality of the data was maintained through use of a coding system. All subjects were assigned a code, with the first three letters representing the senior citizens' center, the next two numbers representing their age, and the last two numbers indicating their entry into the study.

The proposal was submitted to the Human Subjects Review Committee of Ohio State University in accordance with the Human Subject Program Guidelines of The Ohio State University (1992). Approval of the Human Subjects Review Committee is contained in Appendix B.

**Procedures to Protect Against and Minimize Potential Risks**

The study did not involve any direct physical harm or risk to the subjects. Minor discomfort was encountered by some participants associated with lying on a firm surface during the study. The measuring devices used for the study were noninvasive and did
not create any risk or harm for the participants. All procedures occurred under nursing supervision on the General Clinical Research Center at the Ohio State University Hospital.

**Possible Benefits for Subjects/Society**

The primary benefit for participation in the study was the contribution that the person would make toward improving the care of the older adult who has been injured in an accident.

**Duration of Subject Participation**

The duration of the subject's participation was approximately two hours and fifteen minutes. Twenty minutes was devoted to explanation of the study and obtaining consent. Thirty minutes was required for calibration, placement of the transducers for measurement of respiratory effort and to obtain baseline data. Each subject then spent 30 minutes on each device with a ten minute break provided before being placed on the second device for 30 minutes. An additional fifteen minutes was needed to remove the transducers and to allow the subjects time to recover from the experience.

**Exit From the Study**

Exit from the study occurred by two methods. The subject could voluntarily leave the study at any time or exit from the study could occur when the data collection period was completed.

**Instrumentation**

**Respiratory Inductance Plethysmography**

Respiratory effort was measured by respiratory inductance plethysmography (RIP) (Tobin, Chadha, Jenouri, Birch, et al., 1983). The American Thoracic Society has formally stated that "there is no doubt that the instrument (RIP) can be used in a
qualitative or semiquantitative fashion to monitor...respiratory effort” (American Thoracic Society, 1989, p. 564).

Respiratory inductance plethysmography is a noninvasive method for evaluating respiratory effort. The method consists of the placement of two coils of wire that are sewn into bands that can be placed across the chest and abdomen. As the subject breathes the wires either expand or contract which produces changes in an oscillator that are demodulated to produce output voltage signals. Parameters related to respiratory effort which can be obtained through RIP include: respiratory rate (FREQ), tidal volume (TV) or average volume per breath, minute ventilation (VMIN), inspiratory time (T₁), inspiratory flow (TV/T₁), and total compartmental displacement volume/tidal volume (TCDV)/VT), which is a ratio that expresses the total excursion of the rib cage and abdominal compartments during inspiration divided by the VT (Watson, 1998). Other methods to determine respiratory effort, such as use of spirometry for pulmonary function tests, and pneumotachograph, were determined to be inappropriate for this study since, in these methods, a mouthpiece must be used which has been shown to increase VT and decrease FREQ compared to natural breathing (Tobin, et al., 1983). In addition, spirometry values are usually obtained in the sitting position versus the supine position. The specific instrument that was used for measurement of respiratory inductance plethysmography was the Respigraph (Non-Invasive Monitoring Systems, Inc.). The Respigraph consists of two transducers sewn inside elastic bands 10 cm in width. The bands are placed across the chest and abdomen. The rib cage band is placed on the upper chest above the nipple line in female subjects and at the nipple line in male subjects. The abdominal band is placed at the level of the umbilicus above the iliac crest (Krieger, 1990).
The transducers, located within the bands, are connected to an oscillator which produces a sine wave of approximately 20 mV amplitude at a frequency of 300 kHz. As the rib cage and abdominal compartment move with respiration, changes in the cross sectional area occur. These changes alter the orientation of the wire coils which, in turn, change the oscillatory frequencies as a function of changes in self-inductance (Krieger, 1990). A Z80A-based microprocessor then demodulates, amplifies and converts the frequencies to an analog display.

Tobin et al., (1983) compared data obtained from RIP, using the Respigraph, to that obtained from spirometry. Less than ten per cent deviation of the tidal volume from that obtained from spirometry was identified.

The Respigraph has also been shown to be a reliable device for use in the older population (Krieger, Ershowsky, Spivack, Thortenson, & Sackner, 1988). Krieger et al. (1988), evaluated the use of RIP versus intensive care monitoring of Medicare patients who required long term ventilatory support. RIP was accurate within 20% of spirometry values for the older adult with chronic respiratory failure.

RIP has also been used to compare respiratory drive and timing in healthy older (range 60-81 years old) versus younger (range 21-50 years old) adults (Tobin, Mador, Guenther, Lodato & Sackner, 1988). Subjects were placed in a supine position for a minimum of ten minutes, followed by a recording of the subjects breathing pattern for fifteen minutes (approximately 250 breaths). Older subjects had a greater breath-to-breath variability versus the younger subjects. To adjust for this difference, calculations of respiratory parameters should be made based on a larger number of breaths versus isolated "representative" breaths. Accuracy of the RIP was also established through the
simultaneous use of spirometry. The $V_t$ coefficients of variation were significantly correlated ($p < .001$) and were within one per cent of each other.

A potential source of error in use of RIP with the older adult population is variations in cross sectional area of the rib cage due to the presence of kyphoscoliosis or chronic lung disease. Changes in the cross sectional area could potentially influence the validity of the measurements obtained. Watson, Poole and Sackner (1985), however, did evaluate the accuracy of RIP in the presence of deformities of shape. To evaluate the effects of changes in cross-sectional area, the standard RIP transducer band was stretched around wooden dowels placed in holes on a peg board, which formed a grid. A variety of physiologic shapes were simulated in this manner. The relationship between output voltage and change in cross-sectional area was found to be linear for the range of physiologic shapes associated with breathing. Reliability of the RIP was also demonstrated by less than a 2.5 mv base-line drift over a twelve hour observation period.

A variety of methods have been identified for calibration of the Respigraph. These include the two posture least squares method (LSQ) (Chadha, et al., 1982), the simultaneous equation method (SEQ) (Sackner, Nixon, Davis, Atkins & Sackner, 1980), the isovolume maneuver calibration (ISOCAL) (Konno & Mead, 1967; Loveridge, West, Anthonisen & Kryger, 1983), and the qualitative diagnostic calibration method (QDC) (Sackner, et al., 1989).

The two posture LSQ method (Chadha, et al., 1982) involves changing the position of the subjects so that the sum of the changes of rib cage and abdominal compartment volume are scaled to be equivalent to $V_t$ measured with spirometry. This is accomplished using a least squares graphic solution. Using ten subjects, Chadha et al., reported 93% of values obtained by the LSQ method to be within +/- 10% of spirometry values. The
LSQ method, however, was found to give lesser values for the rib cage contribution in the supine position when compared to the ISOCAL method.

The SEQ method (Sackner, et al., 1980) is similar to the LSQ method in that two body postures, most frequently supine and standing are required for calibration. In the SEQ method, however, two simultaneous equations with two unknowns are set up to solve for the scaling factors. Once the rib cage and abdominal signals are correctly scaled, their sums are added together to equal the spirometry volume. Using this method, Sackner et al. (1980), reported that 85.6% of breaths during bicycle exercise and 87% of breaths during treadmill exercise on six male subjects were within +/- 20% of tidal volumes measured by spirometry. The most unreliable periods of the breath for measurement with the SEQ method were at the end of inspiration and at the end of expiration.

The ISOCAL method involves a special breathing maneuver in which the subject voluntarily shifts the volume between the rib cage and abdominal compartments while the airway openings are occluded. After this is accomplished, the subject then breathes using a spirometer or pneumotachograph. The signals are then multiplied by a constant to make the sum of the rib cage and abdominal compartment equal to Vt recorded by spirometry. This calibration method may be unsuitable for the older adult population since it requires a specialized respiratory maneuver which may be difficult for untrained subjects to perform.

The QDC method is a single-posture method which is carried out during a five minute period of natural breathing. No mask or mouthpiece is required. The QDC method uses equations similar to that of the ISOCAL method. In the QDC method, however, K approximates the ratio of standard deviations of the uncalibrated changes of abdominal to rib cage volume deflections. Validity of calibration by this method has been established by analysis of RIP waveforms during an isovolume maneuver and comparison with
spirometry (Sackner, et al., 1989). No significant differences (p>0.05) were reported between the QDC method and other methods of calibration when this method was used on a sample of ten male subjects, aged 23-54 years. The QDC method was found, however, to be most accurate, in comparison to spirometry, when the supine position was used. One hundred per cent of absolute values of Vt (RIP) were found to be within 10% of values obtained by spirometry in the supine position versus only 50-60% of values in the upright posture. The QDC method was used with spirometry for calibration in this study since it was relatively easy to perform, it was less stressful for the subjects, and it was accurate in the supine position. Calibration was performed by this method until differences of 10% or less were obtained between the spirometry values and the Respigraph values. Use of the QDC method with spirometry provides a semi-quantitative method for calibration.

The VRS 2000 dry rolling seal spirometer (S &M Instrument Company, Doyelstown, PA) was used for calibration of the Respigraph. The VRS 2000 has a capacity of 10 liters and a sensitivity of 10 mm/L. The spirometer was calibrated with a three liter syringe (Gould) prior to data collection from each subject. Since the spirometric test results are expressed under ambient temperature, pressure, saturation with water vapor conditions (ATPS), a correction factor was entered into the Respigraph to correct to body temperature, pressure, saturation with water vapor conditions (BTPS).

Visual Analog Scale for Subjective Measurement of Respiratory Effort

To provide a subjective measure of respiratory effort a 100 mm visual vertical analogue scale (VAS) was administered before the subject was placed on the spinal immobilization device, at the end of 15 minutes, and at the completion of the 30 minute period on the device (Appendix C). According to Ho, Spence and Murphy (1996), the VAS is more reliable when the instrument is used to measure changes in a sensation over
time versus at a single instance. The anchors that were used for the scale were "no
difficulty breathing" as the lower anchor and at the upper end of the scale, "difficulty
breathing as bad as it can be". The subject was asked to mark a point on the scale that
indicates the amount of respiratory effort they were currently experiencing. Perpendicular
anchor lines were used at the top and bottom of the scale. The scale was also enclosed in a
box to help the subjects focus on the scale (Cline, Herman, Shaw & Morton, 1992). The
dergee of respiratory effort was scored by using a transparent grid overlay made up of one
millimeter boxes. This was placed over the VAS to measure the millimeters from the low
end of the scale to the subject's mark.

A vertically oriented scale was selected because it has been shown to be more sensitive,
produce higher scores and is easier to use than a horizontal scale (Gift, 1989). A horizontal
scale would be more difficult for the subjects to use due to the narrowed visual field
produced by the spinal immobilization. Detailed verbal instruction in use of the VAS was
provided for the participants.

Validity has been established for the VAS in relation to pain, dyspnea, and other
subjective sensations (Gift, Plaut & Jacox, 1986; Lee & Kieckhefer, 1989; Price,
McGrath, Rafii, & Buckingham, 1983). Concurrent validity of a vertical analogue scale to
measure dyspnea was demonstrated by Gift (1989) who reported an $r = 0.97$ between a
vertical and a horizontal VAS for dyspnea intensity and an $r = 0.85$ between the vertical
VAS and peak expiratory flow rates. Gift also reported construct validity for the vertical
VAS using the contrasted-groups approach with repeated measures ($p < .01$).

Convergent validity for respiratory effort was established by Muza, Silverman,
Gilmore, Hellerstein and Kelsen (1990) who compared intensity of perceived sense of
effort in breathing using both a modified Borg scale and a VAS. No significant difference
was noted in the coefficient of variation for the VAS and the modified Borg
scale. Correlation of the modified Borg scale with the VAS was 0.71. When the scores were converted to Z scores, the VAS was noted to be almost twice as sensitive to changes in respiratory status as the modified Borg scale (slope of the relationship of VAS to Borg = 1.90). Although, Muza, et al. have established convergent validity for respiratory effort, construct validity has not been clearly established for respiratory effort since the domain of the construct has not been clearly defined (Bouley, Froman & Shah, 1992). The construct of respiratory effort is multidimensional and Wewers and Lowe (1990) have criticized use of the VAS as a unidimensional tool to measure a multidimensional construct. This study attempts to measure the construct in healthy older adults exposed to two forms of intervention that may affect respiratory effort.

According to Price, Bush, Long & Harkins (1994), validity of the VAS may also be influenced by the type of instruction provided for the subjects regarding the use of the instrument. If subjects are unclear as to how they are to complete the instrument, results may be inconsistent and/or difficult to score. For this reason, subjects in this study were given an opportunity to practice completing the VAS prior to being placed on the apparatus.

Reliability has not been established for use of the VAS to measure respiratory effort. Reliability of the VAS has been demonstrated using the test-retest method for subjective measurement of mood (Luria, 1979). Wewers and Lowe (1990) and Wewers, Rachfal and Ahijevych (1990), however, have questioned the use of the test-retest method as a measure of reliability due to difficulties associated with attempting to quantify the dynamic nature of a subjective phenomenon.

Other limitations of the single item VAS include difficulties associated with subjects conceptual understanding of the scale; inability to use traditional techniques, such as
internal consistency, to assess reliability of the instrument; and scoring difficulties associated with the instrument (Wewers & Lowe, 1990).

Due to the limitations associated with use of the VAS, subjects were also asked to simultaneously rate their perception of respiratory effort, using an arbitrary verbal scale of one to ten. The subjects were asked to rate their respiratory effort while on each device at the same time the VAS was administered. The verbal scale ranged from one, representing no effort and 10, representing maximum effort. Price et al. (1994) compared the use of simple numeric rating scales with a mechanical VAS in the measurement of pain. Both scales provided an indication of pain intensity and unpleasantness but the numeric ratings were higher than the mechanical VAS ratings ($F = 54.27, p < .0001$). The mechanical VAS was a slide algometer divided into ten units with numeric subdivisions identified at two millimeter increments. The numeric scale used was a 0-10 scale. The use of prespecified units on the VAS has been criticized by Gift (1989) for increasing complexity and reducing sensitivity of the scale. The VAS used in this study, therefore, had no intermediate marks or gradations.

**Procedure**

Upon arrival to the General Clinical Research Center, informed consent was obtained from the subjects (Appendix A). Subjects were randomly assigned to either Order BV (standard wooden backboard followed by vacuum technology device) or Order VB (vacuum technology device followed by standard wooden backboard). Random assignment was made using 4 X 4 cards with the treatment order specified on the card with half of the sample having $X_1X_2$ on the cards and the remaining half of the sample having $X_2X_1$ on the cards. The cards were then shuffled and one card at a time was drawn from the deck to determine the treatment order for each subject. Subjects with $X_1X_2$ received the standard backboard device followed by the vacuum technology device.
and subjects with $X_2X_1$ received the same treatments but in reverse order. Once a card was selected from the deck it was not replaced. This procedure was repeated until a total of 60 cards were drawn from the deck.

Once subjects were assigned to Order BV or Order VB, a questionnaire was administered to ensure that subjects met the criteria for inclusion in the study and to obtain a brief self-report of their health status (Appendix D). If subjects completed the section on prescription medications they were verbally questioned about the nature of their medical condition. Vital signs were then taken and recorded. An opportunity was provided for subjects to practice completing the VAS.

After calibration with a three liter syringe, the VRS 2000 spirometer was connected to the Respigraph. Respibands were applied to the subject while in a standing position. One Respiband was applied to the chest, over the skin, below the axillae and above the nipple line. The second Respiband was applied to the abdomen over the umbilicus. After application of the Respibands, the subjects were placed in a supine position in bed and connected to the Respigraph. Placement of Respibands was checked for proper location and fit.

A two stage procedure was used to calibrate the Respigraph. In the first stage, data collection for a five minute period of natural breathing, with the subject in a supine position, was done with the Respigraph in the QDC calibration mode. After the five minute period, noseclips were applied and the subject was asked to take seven deep breaths from the spirometer. An additional seven breaths from the spirometer was used to validate the values obtained from the spirometer and the Respigraph. The noseclips were removed after calibration. If a difference of 10% or less between the spirometer and Respigraph was obtained, then data collection commenced.
Baseline data (FREQ, TV, VMIN, T1, VT/TL, %RC/Vt, and TCDV) with no apparatus was obtained for a five minute period with the subject in a supine position. The subject was asked not to talk during the baseline data collection period. The VAS was also administered at this time.

Following the baseline data collection period, the subject was placed in a cervical collar (Stiffneck™, Laerdal, New York, NY). Depending on randomization order, the subject was put on the backboard or the vacuum immobilizer device. Straps were applied to secure the subject to the device. The VAS score was administered as soon as the subject was secured to the device. The subject was instructed not to talk during the data collection period. Six, five minute segments of data referred to as "epochs" were collected during the 30 minutes the subjects spent on each device. The VAS was administered after 15 minutes on the apparatus and at the completion of 30 minutes on the apparatus.

Once the 30 minute period on the apparatus was completed, the subject was removed from the apparatus and given a ten minute rest period. The subject was also asked to share his/her perceptions about the device. The subject was then placed on the alternate apparatus and the procedure was repeated. After removal from the second apparatus the subject was again asked to share his/her perceptions about the device. Subjects were assessed for any visible evidence of physical harm from the apparatus and then permitted to leave.

Data Management

Respiratory Inductive Plethysmography

Data obtained from RIP was displayed as an analog waveform and was collected in five minute epochs. For purposes of calibration, each breath was considered as two deltas, with the inspiratory component equivalent to one delta and the expiratory
component equivalent to one delta. Initial calibration, using the QDC semi-quantitative method, was made using a minimum of 500 deltas (250 breaths) or five minutes, whichever was exceeded first.

Figure three presents a diagram of a tracing for a "normal" breath obtained from the Respigraph in which there is synchronous motion between the rib cage and abdominal compartments. The waveform for the rib cage (RC) contribution to the breath is located at the top of the tracing. The waveform for the abdominal component (AB) is located at

Figure 3. RIP tracing showing rib cage, abdominal waveforms and tidal volume waveform (Krieger, 1990).
the middle of the tracing. At the lower end of the tracing is the $V_t$ waveform, which represents the sum of the RC and AB. Tidal volume is determined by measuring the height differential between the peak of the $V_t$ waveform and the trough of the $V_t$ waveform. This is equivalent to the electrical sum of the RC and AB components of the breath ($RC + AB = V_t$) (Krieger, 1990).

The shaded areas under the RC and AB waveforms denote the area during inspiration which, when added together, are the total compartment displacement volume (TCDV). This is compared to the shaded area under the $V_t$ waveform. To obtain this value, the absolute values of the derivatives of the entire waveform of the RC, AB and $V_t$ displacements were integrated on a breath by breath basis. The integrals of RC and AB were then summed to provide the TCDV. This value was then divided by the $V_t$ to obtain a ratio which reflects the overall phasic relationship between the RC and AB excursions (Sackner, Watson, Belsito, Feinerman, et al., 1989). When the RC and AB signals are in phase, the ratio of TCDV/$V_t$ is equivalent to 1.00. When either the RC or AB excursions move out of phase with each other, the value may be less than or greater than 1.00, depending on their contribution to $V_t$.

Data for all physiologic indices of respiratory effort was collected in five minute epochs. The analog breath waveforms were reduced to a compound plot envelope (ENV) for purposes of data collection. Figure four presents an example of an ENV from one subject. Each vertical bar on the plot corresponds to one breath as represented by the $V_t$ signal in the analog breath waveform.

With each epoch, the numerical means of FREQ, $V_t$, VMIN, $T_I$, $V_t/T_I$, TCDV/$V_t$ and %RC/$V_t$ were calculated by the Respigraph and listed as absolute values. These values were marked on an ENV at the termination of each epoch. The coefficient of variation for breath by breath FREQ and $V_t$ was also calculated. One epoch of data were collected
with the subject in a supine position, without being placed on either device, to serve as a baseline. A total of six additional epochs of data were collected from the subjects for each of the spinal immobilization apparatus.

To ensure accurate calibration during data collection the QDC value was updated for each epoch. The QDC value was obtained by comparing the last 500 measured deltas to the original baseline calibration. The value obtained is the standard deviation of RC deflections divided by the standard deviation of the AB deflections. If the gain settings

![Figure 4. Example of compound plot envelope for five minute period of data collection](image_url)

on the RC and AB compartment remain constant, the QDC value approximates 1.00 (Sackner, 1989).

To determine if movement artifact had a significant impact on results obtained from the Respigraph, $V_t$ waveforms from 30 epochs containing artifact were hand calculated.
The $V_t$ signal was calculated with the artifact removed from the tracing and then compared with the $V_t$ calculated from the Respigraph. Less than 10% error was noted between the hand calculations versus the Respigraph.

**Visual Analogue Scale**

Subjective evaluation of respiratory effort, as measured by the VAS, was determined by using a transparent grid overlay that was superimposed on the scale (Cline, Herman, Shaw & Morton, 1992). The grid consisted of one millimeter boxes. To score the VAS the grid was placed over the subject's VAS and aligned using the reference points of the perpendicular anchor lines, as well as the box that was used to frame the VAS. If the X drawn by the subject did not cross the reference line on the VAS the grid was used to determine the most probable point of intersection of the X with the vertical line of the scale. Possible range of scores was 0 to 100.

All data from both the Respigraph and the VAS was then coded and entered into a PC computer using Epi Info. EpiInfo, BMDP and SAS were used as the statistical packages for data analysis. All data was kept confidential and no subject's name was identified with the data. The initial raw data that was collected was stored in a locked fireproof file cabinet. Only the investigator had access to the data. The signed informed consents were stored in a separate area from the raw data.

**Pilot Test of Methodology**

Before the study was begun, a pilot test was conducted with four subjects. Their feedback regarding the presentation of the VAS and procedural aspects of the study were incorporated into the final methodology.

**Data Analysis**

A statistical consult with Dr. Moeschberger, a statistician with the School of Public Health at The Ohio State University, was obtained to ensure the most appropriate
statistical analysis for the data. Statistical analyses were performed using standard statistical computer packages (BMDP, Epi Info, SAS). Demographic data obtained from the subjects was analyzed using descriptive statistics. Demographic data for each order group (BV and VB) was analyzed using Chi Square analysis. McNemar’s test was used to assess the presence of a specific confounding variable, sleep-wake status. The Wilcoxon Signed Rank Test was used to compare the subject's ranking of difficulty breathing on the backboard versus the vacuum immobilizer.

ANCOVA-RM, controlling for baseline values of respiratory indices, was used to compare respiratory effort on the backboard versus the vacuum immobilizer device over the six time periods. In addition, baseline values of all indices of the dependent variables were entered into the model to control for possible carry-over effects associated with the order of treatment. The two confounding variables identified through analysis of demographic data were also used as covariates in the analysis. The level of significance was set at \( p < .05 \).

The Greenhouse-Geisser correction was applied for degrees of freedom adjustment for the effect of time and interactions of time with order and apparatus because of heterogenous variance-covariance matrices. For those repeated measures correlated over time, the Greenhouse-Geisser adjusted probability is reported.
CHAPTER 5

RESULTS

Description of the Sample

The sample consisted of 60 older adult volunteers, aged 65-75. The subjects were randomized to the order in which they were placed on the apparatus. Three subjects were excluded from data analysis because they exceeded the age limit for the study. One subject was excluded from the analysis of physiologic data due to equipment malfunction. Six subjects did not remain on the backboard for the full 30 minutes. Two of these subjects requested that the experiment be stopped after 15 minutes on the backboard. Three subjects requested that the experiment be stopped after 20 minutes on the backboard and the remaining subject asked that the experiment be stopped after 25 minutes on the backboard. Only one subject requested that the experiment be stopped after 15 minutes on the vacuum immobilizer. Thus, 50 participants completed all components of the study.

Sample demographics are presented in Table 1. The mean age of the sample was 70.88 years (SD ± 3.601). Chi Square analysis revealed no significant differences in gender, race or age between subjects assigned to Order BV or Order VB (p ≥ .325).

The ratio of females to males in Order BV and Order VB closely approximates the 1.5:1 ratio of women to men that is identified in U.S. census data (Day, 1996). There was a low percentage (1.75%) of African-Americans in the sample.
Table 1: Sample demographics of Order BV and Order VB groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Order BV</th>
<th></th>
<th>Order VB</th>
<th></th>
<th>(\chi^2)</th>
<th>p</th>
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<td></td>
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<td>Percentage</td>
<td>n</td>
<td>Percentage</td>
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</tr>
<tr>
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<td>20</td>
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</table>
Table 2 presents a description of the self-reported medical history of the sample. Medical conditions with the highest percentage in both groups included the presence of coronary artery disease and/or hypertension (66.66%), arthritis (40.35%), sinus problems (28.08%), and breathing problems (26.32%). Of the total sample, 84.22% (n = 48) reported that they were taking prescription medicines for their health problems. Chi Square analysis revealed no significant differences between subjects receiving Order BV versus subjects receiving Orde VB for all reported medical conditions, except for breathing problems.

The confounding variable that was identified in the sample was the presence of breathing problems. Of the total sample, 19.37% of subjects assigned to Order BV versus 7.02% of subjects assigned to Order VB, reported having breathing problems. Types of breathing problems identified by the subjects included asthma (n = 4), allergies (n = 2), COPD (n = 2), chronic bronchitis (n = 2), and other (n = 5). Chi Square analysis revealed a marginally significant difference between Order BV and Order VB for breathing problems (p = .061). The presence of a higher proportion of breathing problems in Order BV could potentially influence responses on the dependant variable. To control for these potential effects, breathing problem was used as a covariate in the repeated measures analysis.

Another confounding variable was the change in sleep/wake status. Some subjects, when placed on the backboard or vacuum immobilizer fell sleep over time while on the apparatus. To assess the change in their sleep/wake status the McNemar Test (exact binomial) was used. Results indicated that none of the subjects who were placed on the vacuum immobilizer apparatus first, followed by the backboard, fell asleep on the backboard. Sixty-eight percent (n = 35) of the subjects did not fall asleep on either device.
<table>
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<tr>
<th>Medical Condition</th>
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<th>n</th>
<th>Percentage</th>
<th>$\chi^2$</th>
<th>p</th>
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(table continues)

Table 2: Self-report of medical history
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<th>n</th>
<th>Percentage</th>
<th>( \chi^2 )</th>
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<td>27</td>
<td>47.37</td>
<td>0.006</td>
<td>0.94</td>
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</tbody>
</table>
Approximately 27% (n = 14) of subjects who did not fall asleep when placed on the backboard, did fall asleep when placed on the vacuum immobilizer device. Only two subjects (3.92%) fell asleep on both devices. Results of McNemar's Test indicated that significantly more subjects fell asleep after being placed on the vacuum immobilizer apparatus versus the backboard (p = .0001). Due to the changes noted in the sleep/wake status, sleep was used as a covariate in the repeated measures analysis.
Perception of Difficulty Breathing

Rank Order of Breathing Difficulty

The Wilcoxon Signed Rank Test was used to compare the difference between the subject's ranking of difficulty breathing on the backboard and the vacuum immobilizer apparatus. The ranking ranged from 1 = no difficulty breathing to 10 = breathing as difficult as it can be. Difficulty breathing was measured at three different times: (a) time one - initial ranking after being placed on the apparatus, (b) time three - ranking after 15 minutes on the apparatus, and (c) time six - ranking after 30 minutes on the apparatus. Three separate Wilcoxon Signed Rank Tests were conducted for time one, time three, and time six (one for the total group, one for Order BV and one for Order VB). In each test the difference between the verbal ranking of difficulty breathing on the two apparatus was obtained by subtracting the rank for difficulty breathing on the vacuum immobilizer from the rank for difficulty breathing on the backboard.

Table 3 presents the results of the Wilcoxon Signed Rank Tests. At time one, the mean rank of the difference in difficulty breathing on the backboard versus the vacuum immobilizer was not significant. At both time three and time six, the mean rank of the differences in difficulty breathing on the backboard versus the vacuum immobilizer apparatus was significant ($p < .0001$). This was significant irregardless of which order of treatment was used. At time six, the number of subjects did decrease since two of the subjects in Order BV and four subjects in Order VB requested that the experiment be stopped.

Figure 5 displays the mean rank of the differences in difficulty breathing on the backboard versus the vacuum immobilizer at time one, time three, and time six. The mean value increased over time, reflecting a difference in the two apparatus. Appendix E
<table>
<thead>
<tr>
<th>Time</th>
<th>Order BV</th>
<th>Order VB</th>
<th>Total Group</th>
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<td></td>
<td>n</td>
<td>Mean Difference</td>
<td>Std. Mean</td>
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<td>57</td>
<td>0.1754</td>
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Table 3: Wilcoxon signed rank tests for difficulty breathing on backboard versus vacuum immobilizer.
Figure 5: Mean difference by order and by total group for difficulty breathing on backboard versus vacuum immobilizer

B = Backboard
V = Vacuum Immobilizer
contains the absolute values of the ranking for difficulty breathing on the backboard and vacuum immobilizer for time one, time three, and time six.
Visual Analogue Scale

The VAS was used to determine the subject's perception of respiratory effort. The three data collection times for each apparatus were (a) time one - immediately after being placed on the apparatus, (b) time three - 15 minutes after lying on the apparatus, and (c) time six - at the completion of the 30 minute period on the apparatus.

Baseline VAS was used as a covariate in the analysis to control for potential differences between the two order groups. A square root transformation of the VAS scores was also required since the distribution of the scores was positively skewed. Table 4 presents the results of the ANCOVA-RM for the VAS. The main effect of apparatus on the mean square root of the VAS score was statistically significant ($p = .0000$), adjusting for baseline mean square root VAS score as a covariate. The main effect of time was also statistically significant ($p = .0000$). The interaction that was statistically significant was between apparatus and time ($p = .0000$). No significant effect of the baseline mean square root of the VAS score on the order of treatment was noted ($p = .1315$), and no other interactions were significant, as can be seen in Table 4. There was no change in level of significance when breathing problem or sleep/wake status were used as covariates. The interaction between apparatus and time remained significant across models.
### Repeated measures analysis of covariance results between order, apparatus and T₁-T₆ on the visual analogue scale controlling for baseline visual analogue scale.

<table>
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<tr>
<td>Order</td>
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<td>125.8730</td>
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<tr>
<td>T₁-T₆ (Time)</td>
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<td>2</td>
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<td>1.4116</td>
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<td>0.5630</td>
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<tr>
<td>Apparatus X Time</td>
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<td>0.2524</td>
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<tr>
<td>Apparatus X Time X Order</td>
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<td>2</td>
<td>0.4067</td>
<td>0.49</td>
<td>0.6121</td>
<td>0.5820</td>
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</tbody>
</table>
Figure 6 displays the plot of the mean square root of the VAS score for subjects on the backboard versus the vacuum immobilizer apparatus. The mean square root of the VAS score was consistently higher for the backboard versus the vacuum immobilizer regardless of the order of treatment. There is also more variability in the SEM for the backboard apparatus versus the vacuum immobilizer.

Figure 7 displays the plot of the adjusted mean square root of the VAS score for the backboard and vacuum immobilizer, using the baseline mean square root of the VAS as a covariate. For both Order BV and Order VB, there is an increase in the adjusted mean square root of the VAS score for the backboard versus the vacuum immobilizer.
BLVAS = Baseline Mean Square Root of VAS Score
VAS = Visual Analogue Scale
B = Backboard
V = Vacuum Immobilizer

Figure 6: Plot of mean square root of visual analogue score for subjects on backboard apparatus versus vacuum immobilizer apparatus from time 1 to time 6.
VAS = Visual Analogue Scale  
B = Backboard  
V = Vacuum Immobilizer  

**Figure 7:** Plot of adjusted mean square root of visual analogue scores from time 1 to time 6 for order BV versus order VB using baseline mean square root of visual analogue score as a covariate.
Changes in Respiratory Rate

Baseline FREQ was used as a covariate in the analysis to control for potential differences in the two order groups. Adjusting for baseline FREQ (p = .0176), the main effect of apparatus was statistically significant (p = .0000). The main effects of order of treatment and time were not statistically significant (p > .05). No interaction effect was identified since the interactions of apparatus X order, apparatus X time, time X order, and apparatus X time X order, were not statistically significant as can be seen in Table 5.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
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<th>Greenhouse-Geisser Probability</th>
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<td>Baseline Respiratory Rate</td>
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<td>815.8364</td>
<td>6.06</td>
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<td>Order</td>
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<td>260.0866</td>
<td>1.93</td>
<td>0.1711</td>
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<td>611.7153</td>
<td>57.94</td>
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<td></td>
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<td>T1-T6 (Time)</td>
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<td>4.2005</td>
<td>1.34</td>
<td>0.2462</td>
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</tr>
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<td>2.3634</td>
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<td>1.04</td>
<td>0.3945</td>
<td>0.3888</td>
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<td>Time X Order</td>
<td>20.2171</td>
<td>5</td>
<td>4.0434</td>
<td>1.29</td>
<td>0.2669</td>
<td>0.2728</td>
</tr>
<tr>
<td>Apparatus X Time X Order</td>
<td>21.1150</td>
<td>5</td>
<td>4.2230</td>
<td>1.79</td>
<td>0.1154</td>
<td>0.1296</td>
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</table>

Table 5: Repeated measures analysis of covariance results between order, apparatus and T1-T6 on respiratory rate controlling for baseline respiratory rate.
The effects of breathing problem on respiratory rate was also examined since the self-report of breathing problem did reflect a marginal difference between Order BV and Order VB. Breathing problem, when entered as a covariate, was not statistically significant ($F = 1.33$, $p = .2542$), after controlling for baseline FREQ. The main effect of apparatus remained statistically significant ($p = .0000$). The interaction of apparatus X time remained nonsignificant.

Since sleep/wake status was identified as an additional confounding variable, sleep/wake status was also used as a covariate in the analysis. Sleep/wake status, when entered as a covariate, was not statistically significant ($F = 0.16$, $p = .6891$), after controlling for baseline FREQ. The main effect of the apparatus again remained statistically significant ($F = 29.6$, $p = .0000$). The interaction of apparatus X time remained nonsignificant. In short, apparatus was consistently significant across models, adjusting for baseline FREQ, breathing problems and sleep/wake status.

Figure 8 displays the plot of mean FREQ for subjects on the backboard apparatus versus the vacuum immobilizer apparatus. Mean FREQ was higher on the backboard apparatus versus the vacuum immobilizer for each of the six time periods. Compared to the mean FREQ of 17.014 (SEM = 0.344), the mean FREQ on both apparatus was lower. The variation in $n$ reflects missing data from subjects who requested that the experiment be stopped.

Figure 9 displays the plot of adjusted mean FREQ for Order BV versus Order VB from time one to time six, using baseline FREQ as a covariate. For both groups, the adjusted mean FREQ was higher for subjects on the backboard versus the vacuum immobilizer apparatus.
\textbf{Figure 8:} Plot of mean respiratory rate per minute for subjects on backboard apparatus versus vacuum immobilizer from time 1 to time 6.

B = Backboard
V = Vacuum Immobilizer
Figure 9: Plot of adjusted mean respiratory rate from time 1 to time 6 for order BV versus order VB using baseline respiratory rate as a covariate.
Changes in Tidal Volume

Baseline Vt was used as a covariate in the analysis to control for potential differences between the two order groups. Results of the ANCOVA-RM between order, apparatus and time on Vt, after adjustment for the baseline Vt as a covariate, are presented in Table 6.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>Greenhouse-Geisser Probability</th>
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<tbody>
<tr>
<td>Baseline Tidal Volume</td>
<td>3038398.2657</td>
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<td>3038398.2657</td>
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<td>235597.8308</td>
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<tr>
<td>Apparatus</td>
<td>251233.7248</td>
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<td>251233.7248</td>
<td>18.35</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>T₁-T₆ (Time)</td>
<td>48016.8079</td>
<td>5</td>
<td>9603.3616</td>
<td>3.61</td>
<td>0.0036</td>
<td>0.0109</td>
</tr>
<tr>
<td>Apparatus X Order</td>
<td>42628.3114</td>
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<td>42628.3114</td>
<td>3.11</td>
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<td>Apparatus X Time</td>
<td>20974.7280</td>
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<td>4194.9456</td>
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<tr>
<td>Time X Order</td>
<td>8729.6479</td>
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<td>1745.9296</td>
<td>0.66</td>
<td>0.6573</td>
<td>0.6010</td>
</tr>
<tr>
<td>Apparatus X Time X Order</td>
<td>8607.3814</td>
<td>5</td>
<td>1721.4763</td>
<td>1.17</td>
<td>0.3238</td>
<td>0.3247</td>
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</table>

Table 6: Repeated measures analysis of covariance results between order, apparatus and T₁-T₆ on tidal volume, controlling for baseline tidal volume.
Adjusting for baseline $V_t$ ($F = 73.77, p = .0000$), the main effects of order ($p = .0208$), apparatus ($p = .0001$), and time ($p = .0036$), were all statistically significant. More importantly, the interaction that was statistically significant was the interaction between apparatus and time ($p = .0159$). Other interactions between apparatus, time, and order were not significant, as can be seen in Table 6.

The effect of breathing problem on $V_t$ was also examined since the self-report of breathing problem did reflect a marginally significant difference between Order BV and Order VB. Breathing problem, when entered as a covariate, was not statistically significant ($F = 8.4, p = .3628$), after controlling for baseline $V_t$. Adjusting for breathing problem, the main effect of apparatus ($F = 18.35, p = .001$) and time ($F = 3.61, p = .0036$) remained significant. The interaction between apparatus and time also remained significant ($F = 2.85, p = .0269$).

Likewise, when sleep/wake status was entered as a covariate, no significant effect of breathing problem was identified ($F = 2.98, p = .0909$). Adjusting for sleep/wake status, the main effect of apparatus ($F = 18.04, p = .0001$) and time ($F = 4.36, p = .0035$) remained significant, as well as the interaction between apparatus and time ($F = 2.58, p = .0405$). In summary, apparatus and time were consistently significant across models, adjusting for baseline $V_t$, breathing problem and sleep/wake status. Interaction between apparatus and time also remained significant across models.

Figure 10 displays the plot of mean $V_t$ for subjects on the backboard apparatus versus the vacuum immobilizer from time one to time six. The mean $V_t$ is higher on the backboard apparatus versus the vacuum immobilizer apparatus. The variation in $n$ reflects missing data from subjects who requested that the experiment be stopped.
**Figure 10:** Plot of mean tidal volume for subjects on backboard apparatus versus vacuum immobilizer from time 1 to time 6.

BLV<sub>t</sub> = Baseline Mean Tidal Volume  
V<sub>t</sub> = Tidal Volume  
B = Backboard  
V = Vacuum Immobilizer
Figure 11 displays the plot of adjusted mean $V_t$ for subjects on each apparatus by order, using the baseline $V_t$ as the covariate. Order BV had a higher mean $V_t$ for both the backboard and the vacuum immobilizer apparatus than Order VB. Both Order BV and Order VB had a higher mean $V_t$ on the backboard apparatus versus the vacuum immobilizer apparatus.
$V_t = \text{Tidal Volume}$

B = Backboard

V = Vacuum Immobilizer

**Figure 11:** Plot of adjusted mean tidal volume for subjects on each apparatus by order from time 1 to time 6, using baseline tidal volume as a covariate.
Changes in Minute Ventilation

To control for potential differences in minute ventilation (VMIN) between the two order groups, baseline VMIN was used as a covariate in the analysis. Table 7 presents the results of the ANCOVA-RM between order, apparatus, and time on VMIN, adjusting for differences in baseline VMIN between Order BV and Order VB.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
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<th>F</th>
<th>P</th>
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<td>Baseline VMIN</td>
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<td>Apparatus</td>
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<td>0.0000</td>
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</tr>
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<td>Time X Order</td>
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<td>1.06462</td>
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</tr>
<tr>
<td>Apparatus X Time X Order</td>
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<td>1.96</td>
<td>0.0847</td>
<td>0.1113</td>
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Table 7: Repeated measures analysis of covariance results between order, apparatus and T₁-T₆ on minute ventilation controlling for baseline minute ventilation.
Adjusting for differences in baseline VMIN between Order BV and Order VB ($F = 29.05, p = .0000$), the main effects of apparatus ($p = .0000$) and time ($p = .0000$) were statistically significant. Order of treatment, however, was not statistically significant ($p = .2586$). No interaction effect was identified since none of the interactions were statistically significant, as can be seen in Table 7.

Breathing problem, when entered as a covariate, was not statistically significant ($F = 0.15, p = .6986$), after adjusting for baseline VMIN. The main effect of apparatus ($F = 72.02, p = .0000$) and time ($F = 6.15, p = .0001$) remained significant. The apparatus X time interaction remained nonsignificant.

Since sleep/wake status was also identified as a confounding variable, sleep was used a covariate. Sleep/wake status, when entered as a covariate, was not statistically significant ($F = 1.52, p = .2235$), after adjusting for baseline VMIN. The main effect of apparatus ($F = 45.57, p = .0000$) and time ($F = 5.38, p = .0004$) remained significant. The interaction between apparatus and time remained nonsignificant. In summary, apparatus and time were consistently significant across models, adjusting for baseline VMIN, breathing problems, and sleep/wake status.

Figure 12 displays the plot of mean VMIN for subjects on the backboard versus the vacuum immobilizer apparatus. Mean VMIN was higher on the backboard apparatus versus the vacuum immobilizer apparatus. The mean VMIN on the vacuum immobilizer is closer to baseline values when compared to the mean VMIN on the backboard apparatus. The SEM has a wider variation for the backboard versus the vacuum immobilizer device. The variation in $n$ reflects missing data from subjects who requested that the experiment be stopped.
BLMV = Baseline Minute Ventilation
B = Backboard
V = Vacuum Immobilizer

Figure 12: Plot of mean minute ventilation for subjects on backboard apparatus versus vacuum immobilizer apparatus from time 1 to time 6
Figure 13 displays the plot of adjusted mean VMIN from time one to time six for Order BV versus Order VB, using baseline VMIN as a covariate. For both order groups, the adjusted mean VMIN was higher for the backboard versus the vacuum immobilizer apparatus.
VMIN = Minute Ventilation
B = Backboard
V = Vacuum Immobilizer

Figure 13: Plot of adjusted mean minute ventilation from time 1 to time 6 for order BV versus order VB, using baseline minute ventilation as a covariate.
Changes in Inspiratory Time

Baseline inspiratory time (T_1) was used as a covariate in the analysis to control for potential differences between the two order groups. Table 8 presents the results of the ANCOVA-RM between order, apparatus, and time on T_1, adjusting for differences in baseline T_i, between Order BV and Order VB.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
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<th>F</th>
<th>p</th>
<th>Greenhouse-Geisser Probability</th>
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<td>T_1-T_6 (Time)</td>
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</tr>
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<td>0.0374</td>
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<td>0.2740</td>
<td>0.2838</td>
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</table>

Table 8: Repeated measures analysis of covariance results between order, apparatus, and T_1-T_6 on inspiratory time, controlling for baseline inspiratory time.
Adjusting for differences in baseline TI between the two order groups ($F = 10.13, \ p = .0026$), the main effect of apparatus was statistically significant ($p = .0129$). Order of treatment ($p = .3987$) and time ($p = .1919$) were not statistically significant. No interaction effect was identified since none of the interactions were statistically significant, as can be seen in Table 8.

Breathing problem, when entered as a covariate, was not statistically significant ($F = 2.73, \ p = .1052$), after adjusting for baseline TI. The main effect of apparatus remained significant ($F = 6.67, \ p = .0129$). The apparatus X time interaction remained nonsignificant.

Sleep/wake status, when entered as a covariate, was not statistically significant ($F = 3.02, \ p = .0888$) after adjusting for baseline TI. The main effect of apparatus remained significant ($F = 3.99, \ p = .0471$). The apparatus X time interaction was nonsignificant.

Figure 14 displays the plot of mean TI for subjects on the backboard apparatus versus the vacuum immobilizer from time one to time six. Minimal variation is seen in the total group mean TI, but mean TI is slightly shorter for the backboard versus the vacuum immobilizer. The variation in TI reflects missing data from subjects who requested that the experiment be stopped.

Figure 15 displays the plot of adjusted mean TI by order for subjects on each apparatus, using the baseline TI as a covariate. Order BV had slightly higher mean inspiratory times than Order VB. Mean TI is somewhat shorter for the backboard versus the vacuum immobilizer apparatus.
$T_t =$ Inspiratory Time  
BLT$_t =$ Baseline Mean Inspiratory Time  
B = Backboard  
V = Vacuum Immobilizer

Figure 14: Plot of mean inspiratory times for subjects on each apparatus from time 1 to time 6.
Figure 15: Plot of adjusted mean inspiratory time for order BV versus order VB from time 1 to time 6.

Ti = Inspiratory Time
B = Backboard
V = Vacuum Immobilizer
Changes in Percent Rib Cage Contribution to Tidal Volume

Baseline mean percent rib cage contribution to tidal volume (\%RC/V_t) was used as a covariate in the analysis to control for potential differences between the two order groups. Table 9 presents the results of the ANCOVA-RM between order, apparatus, and time, adjusting for differences in baseline \%RC/V_t between Order BV and Order VB.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
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<th>F</th>
<th>p</th>
<th>Greenhouse-Geisser Probability</th>
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</thead>
<tbody>
<tr>
<td>Baseline % RC</td>
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<tr>
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</tr>
<tr>
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<td>6369.26970</td>
<td>18.07</td>
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<td></td>
</tr>
<tr>
<td>T_1-T_6 (Time)</td>
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</tr>
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<td>9.17870</td>
<td>0.27</td>
<td>0.9297</td>
<td>0.8871</td>
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Table 9: Repeated measures analysis of covariance results between order, apparatus and T_1-T_6 on percent rib cage contribution to tidal volume, controlling for baseline percent rib cage contribution.
Adjusting for differences in baseline mean %RC/Vt between the two order groups (F = 85.63, p = .0000), the main effects of apparatus (p = .0001) and time (p = .0070) were statistically significant. Order of treatment was not statistically significant (p = .2811). The only interaction that was statistically significant was the interaction between time and order (p = .0242). No other significant interactions were identified. There was no change in level of significance.

Breathing problem, when entered as a covariate, was statistically significant (F = 6.68, p = .0129). The main effects of apparatus (F = 18.07, p = .0001) and time (F = 3.27, p = .0160) remained significant, after adjustment for breathing problem. The interaction of time X order also remained significant (F = 3.00, p = .0242), after adjustment for breathing problem. No other interactions were significant.

Sleep/wake status, when entered as a covariate, was not statistically significant (F = .01, p = .9079), after controlling for baseline %RC/Vt. The main effects of apparatus (F = 12.76, p = .0008) and time (F = 3.29, p = .0157) remained significant, after adjusting for sleep/wake status. The interaction of time X order also remained significant (F = 3.02, p = .0234). No other interactions were significant.

Figure 16 displays the plot of mean %RC/Vt for subjects on the backboard versus the vacuum immobilizer apparatus from time one to time six. The mean %RC/Vt was lower for subjects on the backboard versus the vacuum immobilizer device. The variation in n reflects missing data from subjects who requested that the experiment be stopped.

Figure 17 displays the plot of adjusted mean %RC/Vt for Order BV versus Order VB from time one to time six, using baseline %RC/Vt as a covariate. For both order groups, mean %RC/Vt was lower on the backboard versus the vacuum immobilizer apparatus.
%RC = Percent Rib Cage Contribution
BL%RC = Baseline Mean Percent Rib Cage Contribution
Vt = Tidal Volume
B = Backboard
V = Vacuum Immobilizer

Figure 16: Plot of mean percent rib cage contribution to tidal volume for subjects on each apparatus from time 1 to time 6.
%RC = Percent Rib Cage Contribution
Vt = Tidal Volume
B = Backboard
V = Vacuum Immobilizer

Figure 17: Plot of adjusted mean percent rib cage contribution to tidal volume from time 1 to time 6 for order BV versus order VB, using baseline percent rib cage contribution as a covariate.
Changes in Total Compartment Displacement Volume / Tidal Volume Ratio

The baseline total compartment displacement volume/tidal volume ratio (TCDV/Vt) was used as a covariate in the analysis to control for potential differences between the two order groups. A log transformation of the data was also required due to failure to meet the assumptions of ANCOVA-RM. The distribution of the data was positively skewed. Table 10 presents the results of the ANCOVA-RM between order, apparatus, and time, controlling for baseline TCDV/Vt.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>Greenhouse-Geisser Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline TCDV</td>
<td>0.0943</td>
<td>1</td>
<td>0.09430</td>
<td>1.99</td>
<td>0.1654</td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td>0.0054</td>
<td>1</td>
<td>0.00540</td>
<td>0.11</td>
<td>0.7384</td>
<td></td>
</tr>
<tr>
<td>Apparatus</td>
<td>0.0756</td>
<td>1</td>
<td>0.07560</td>
<td>7.94</td>
<td>0.0070</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;-T&lt;sub&gt;6&lt;/sub&gt; (Time)</td>
<td>0.0406</td>
<td>5</td>
<td>0.00810</td>
<td>2.52</td>
<td>0.0303</td>
<td>0.0473</td>
</tr>
<tr>
<td>Apparatus X Order</td>
<td>0.0027</td>
<td>1</td>
<td>0.00270</td>
<td>0.28</td>
<td>0.5970</td>
<td></td>
</tr>
<tr>
<td>Apparatus X Time</td>
<td>0.0228</td>
<td>5</td>
<td>0.00460</td>
<td>1.47</td>
<td>0.2001</td>
<td>0.2152</td>
</tr>
<tr>
<td>Time X Order</td>
<td>0.0061</td>
<td>5</td>
<td>0.00120</td>
<td>0.38</td>
<td>0.8655</td>
<td>0.8120</td>
</tr>
<tr>
<td>Apparatus X Time X Order</td>
<td>0.0062</td>
<td>5</td>
<td>0.00120</td>
<td>0.40</td>
<td>0.8476</td>
<td>0.7977</td>
</tr>
</tbody>
</table>

Table 10. Repeated measures analysis of covariance results between order, apparatus, and T<sub>1</sub>-T<sub>6</sub> on total compartment displacement volume controlling for baseline total compartment displacement volume ratio.
Adjusting for differences in baseline TCDV/Vt that were present but not significant (\(F = 1.99, p = .1654\)), the main effects of apparatus (\(p = .0070\)) and time (\(p = .0473\)) were statistically significant. None of the interactions were significant, as can be seen in Table 10.

When breathing problems were used as a covariate, the main effects of apparatus (\(F = 7.94, p = .0070\)) and time (\(F = 2.52, p = .0473\)) remained significant. No interactions were statistically significant.

There was a marginally significant difference between Order BV and Order VB in the effect of sleep/wake status on TCDV/Vt (\(F = 3.74, p = .0592\)), but when sleep/wake status was controlled, the main effect of apparatus remained significant (\(F = 6.24, p = .0160\)).

In summary, apparatus was consistently significant across models, adjusting for baseline TCDV/Vt, breathing problems, and sleep/wake status. Interaction between apparatus and time remained significant across all models, except for sleep/wake status.

Figure 18 displays the log of the mean TCDV/Vt for subjects on the backboard apparatus versus the vacuum immobilizer from time one to time six. The log of the mean TCDV/Vt was higher for subjects on the backboard versus the vacuum immobilizer apparatus. The variation in \(n\) reflects missing data from subjects who requested that the experiment be stopped.

Figure 19 displays the log of the adjusted mean TCDV/Vt for Order BV versus Order VB from time one to time six, using baseline TCDV/Vt as a covariate. The log of the adjusted mean TCDV/Vt was higher for subjects on the backboard versus the vacuum immobilizer apparatus.
Figure 18: Mean of log of total compartment displacement volume ratio for subjects on backboard apparatus versus vacuum immobilizer from time 1 to time 6.
$TCD/V_t = \text{Total Compartment Displacement Volume Ratio}$

$B = \text{Backboard}$

$V = \text{Vacuum Immobilizer}$

**Figure 19:** Adjusted mean of log of total compartment displacement volume ratio for subjects on backboard apparatus versus vacuum immobilizer from time 1 to time 6.
Changes in Inspiratory Flow

Baseline mean inspiratory flow (Vt/T1) was used as a covariate in the analysis to control for potential differences between the two order groups. Table 11 presents the results of the ANCOVA-RM between order, apparatus and time, adjusting for baseline mean Vt/T1.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>Greenhouse-Geisser Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Vt/T1</td>
<td>1689542.3762</td>
<td>1</td>
<td>1689542.3762</td>
<td>29.30</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td>197281.6300</td>
<td>1</td>
<td>197281.6300</td>
<td>3.42</td>
<td>0.0707</td>
<td></td>
</tr>
<tr>
<td>Apparatus</td>
<td>405648.0020</td>
<td>1</td>
<td>405648.0020</td>
<td>37.84</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>T1-T6 (Time)</td>
<td>132688.8835</td>
<td>5</td>
<td>26537.7777</td>
<td>9.36</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Apparatus X Order</td>
<td>22048.9220</td>
<td>1</td>
<td>22048.9220</td>
<td>2.06</td>
<td>0.1580</td>
<td></td>
</tr>
<tr>
<td>Apparatus X Time</td>
<td>30121.9487</td>
<td>5</td>
<td>6024.3895</td>
<td>2.26</td>
<td>0.0496</td>
<td>0.0611</td>
</tr>
<tr>
<td>Time X Order</td>
<td>7830.0301</td>
<td>5</td>
<td>1566.0060</td>
<td>0.55</td>
<td>0.7364</td>
<td>0.7069</td>
</tr>
<tr>
<td>Apparatus X Time X Order</td>
<td>17699.1077</td>
<td>5</td>
<td>3539.8215</td>
<td>1.33</td>
<td>0.2539</td>
<td>0.2603</td>
</tr>
</tbody>
</table>

Table 11: Repeated measures analysis of covariance results between order, apparatus and T1-T6 on mean inspiratory flow, controlling for baseline mean inspiratory flow.
Adjusting for differences in the baseline mean $V_t/T_I$, ($F = 29.30, p = .0000$), the main effects of apparatus ($p = .0000$) and time ($p = .0000$) were statistically significant. Order was not statistically significant ($p = .0707$). There were no interactions that were statistically significant.

Breathing problem, when entered as a covariate, was not statistically significant ($F = 0.54, p = .4679$). The main effect of apparatus ($F = 37.84, p = .0000$) and time ($F = 9.36, p = .0000$) remained significant, adjusting for baseline $V_t/T_I$. Interaction of apparatus X time was marginally significant ($F = 2.26, p = .0611$). No other interactions were statistically significant.

Sleep/wake status, when entered as a covariate, was statistically significant ($F = 5.38, p = .0247$). Adjusting for sleep/wake status, the main effect of apparatus ($F = 34.31, p = .0000$) and time ($F = 8.80, p = .0000$), was statistically significant. Interaction of apparatus X time was significant ($F = 2.39, p = .0492$). No other interactions were significant.

Figure 20 displays the plot of mean $V_t/T_I$ for subjects on the backboard versus the vacuum immobilizer apparatus from time one to time six. The mean $V_t/T_I$ was higher for subjects on the backboard versus the vacuum immobilizer apparatus. The variation in $n$ reflects missing data from subjects who requested that the experiment be stopped.

Figure 21 displays the plot of the adjusted mean $V_t/T_I$ for Order BV versus Order VB from time one to time six, using the baseline adjusted mean $V_t/T_I$ as a covariate. The mean inspiratory flow was higher for subjects on the backboard versus the vacuum immobilizer apparatus.
Figure 20: Plot of mean inspiratory flow for subjects on the backboard versus the vacuum immobilizer device.
$V_{I}/T_{I} =$ Inspiratory Flow  
$B =$ Backboard  
$V =$ Vacuum Immobilizer Device  

**Figure 21:** Plot of adjusted mean inspiratory flow for Order BV versus Order VB from time 1 to time 6, using baseline mean inspiratory flow as a covariate.
CHAPTER 6
DISCUSSION

Discussion of Results

This study demonstrates that there is a significant difference between the backboard and the vacuum immobilizer device in their effect on respiratory effort. The main effect of apparatus was consistently significant across both subjective and physiologic indices of respiratory effort. The order in which the subjects were placed on the apparatus had no significant effect on indices of respiratory effort, except for tidal volume. Although order did have a significant effect on tidal volume, tidal volume remained higher on the backboard versus the vacuum immobilizer apparatus. Significant interactions were primarily related to time. Mean values for respiratory indices tended to increase over time for the backboard, suggesting that the longer the subject remained on the backboard, the more respiratory effort was required to breathe.

Subjective indices of respiratory effort suggest that subjects had increased difficulty breathing on the backboard versus the vacuum immobilizer apparatus. Visual analogue scores and rank order of difficulty breathing were both higher for the backboard than the vacuum immobilizer apparatus.

Physiologic indices of respiratory effort included volume, time and flow components. The volume component is reflected in the $V_t$, VMIN, $\%RC/V_t$ and TCDV. There was a significant difference between the two devices for each of these indices. Mean $V_t$ and VMIN were higher for the backboard versus the vacuum immobilizer device. The higher mean $V_t$ and VMIN for the backboard could be related to several factors.
One factor that may contribute to the increase in $V_t$ and VMIN is increased impedance to the action of the respiratory muscles. The hard surface of the backboard does not conform to the body contour. This may increase impedance for the respiratory muscles, especially the intercostals, which are in direct contact with the board. According to Killian and Jones (1988), impedance opposing the action of the respiratory muscles is one mechanism that may affect respiratory effort. Increased impedance may result in increased work of breathing.

Another factor that may contribute to the increase in $V_t$ and VMIN is the presence of discomfort or pain. Comments made by subjects, such as, "It's very uncomfortable" and "My hips are killing me!" indicate that the backboard was uncomfortable. This is consistent with earlier findings by Chan et al. (1994), in which all of the subjects reported the presence of pain after spending 30 minutes on the backboard. Chan et al., also used healthy volunteers, although no older adults were included in his sample. The development of pain related to the device may lead to increased anxiety which stimulates the sympathetic nervous system. Increased discharge from the sympathetic nervous system contributes to increased oxygen demand, thereby increasing respiratory effort.

Several subjects in this study were also noted to have gaps, as large as 7 cm, between the cervical or lumbar area and the spine board. One subject commented, "I feel a lot of pressure on my back and I have to work harder to breathe on this thing [backboard]." Inability of the backboard to conform to body contour, therefore, may increase the work of breathing. In contrast, no gaps were noted between the subject's body and the vacuum immobilizer device. One subject commented, "I like the way this [vacuum immobilizer] conforms to my body. It seems as if I can breathe easier on this thing."
The percent that the rib cage contributes to tidal volume or \( \% RC/V_t \) is an additional indice that can be used to assess the volume component of respiratory effort. There was a significant difference between the two devices in \( \% RC/V_t \) (\( p = 0.0001 \)). For both order groups the mean \( \% RC/V_t \) was lower on the backboard versus the vacuum immobilizer. The lower \( \% RC/V_t \) suggests that subjects tend to have less rib cage movement and more abdominal breathing on the backboard versus the vacuum immobilizer. Again, this may be related to increased impedance to the intercostal muscles. Since the abdominal muscles are not in direct contact with the board there is less impedance to the action of these muscles. The findings are also consistent with Goldman (1982) who studied the action of thoracoabdominal muscles during breathing. He noted an increase in the contribution of abdominal muscles, as opposed to the rib cage, when subjects were placed in a supine position.

Total compartment displacement volume/tidal volume ratio or TCD/Vt, is the final indice that was used to assess the volume component of respiratory effort. There was a significant difference between the TCD/Vt for subjects on the backboard versus the vacuum immobilizer apparatus. The mean TCD/Vt was higher for subjects on the backboard versus the vacuum immobilizer device. TCD/Vt is a ratio that expresses the total excursion of the rib cage and abdominal compartments divided by the tidal volume. In this study both the \( V_t \) and TCDV were increased for subjects on the backboard. These findings suggest that subjects on the backboard had larger volumes and increased respiratory effort than the subjects on the vacuum immobilizer device. Two possible explanations can be offered. One is that subjects on the backboard were expending increased respiratory effort which, in turn, contributed to increased volumes. Another possible explanation is that subjects on the backboard were actually breathing more effectively which, in turn, increased the volumes. The second explanation is less likely,
however, in lieu of comments made by the subjects about their ability to breathe on the two devices. Subjects reported decreased difficulty breathing on the vacuum immobilizer and increased difficulty breathing on the backboard.

In addition to volume, indicators of the time component of respiratory effort include FREQ and Tᵢ. There was a significant (p = .0000) difference between the respiratory rate of subjects when they were placed on the backboard versus the vacuum immobilizer apparatus. The mean FREQ was higher for subjects on the backboard versus the vacuum immobilizer apparatus. This was consistent with the increases in Vₑ and VMIN that were seen in this study. The higher FREQ identified with subjects on the backboard, however, is in contrast to the findings of Blair and Hickman (1955), who noted a decrease in FREQ when subjects were placed in a supine position. They studied the effects of changes in position on lung volumes and intrapulmonary gas mixing in normal subjects. The increase in respiratory rate, therefore, is more likely to be associated with the effects of the device versus the position of the subjects. According to Capps and Schade (1988), increased FREQ is directly associated with increased work of breathing since the amount of work performed by the respiratory muscles per unit of time increases as the FREQ increases. Although the FREQ was higher on the backboard than the vacuum immobilizer, it was actually decreased by approximately one per minute from the baseline value. The lower rates noted on the vacuum immobilizer may reflect less respiratory effort than what was required on the backboard.

Inspiratory time or Tᵢ is another parameter associated with the time component of respiratory effort. Once again, there was a significant difference (p = .0129) between subjects on the backboard and the vacuum immobilizer. Mean inspiratory times were slightly shorter for subjects on the backboard versus the vacuum immobilizer.
Differences in mean values between the two devices was so small, however, that, although there was statistical significance, it is doubtful that these would be clinically significant.

The flow component of respiratory effort is reflected by the $V_t/T_I$. Results indicate that there was a significant difference between the two devices. Mean $V_t/T_I$ was higher for the subjects on the backboard versus the vacuum immobilizer device. The higher flow rates noted on the backboard are consistent with the increases seen in volume and rate that were discussed earlier. Capps and Schade (1988) identify flow as an indicator of the mechanical work of breathing. Increased flow reflects increased work of breathing. Increased work of breathing, in turn, reflects increased respiratory effort.

Not all subjects were able to remain on the apparatus for the entire 30 minute period. Five subjects (8.7%) requested that the experiment be stopped while they were on the backboard. Comments from subjects who were unable to stay on the backboard included, "This is torture"; "I can't breathe because of all the sinus drainage; I feel like I'm choking to death!"; "I can't stand it anymore; I have a headache, my back is in spasm and I'm having tingling down my legs"; and "My whole leg is getting numb, I have to get off this thing right now!". All of the subjects who requested that the experiment be stopped reported having either sinus problems, arthritis or both. Subjects with sinus problems had more complaints of increased sinus drainage and difficulty breathing when placed on the backboard versus the vacuum immobilizer. Subjects with arthritis had more complaints of pain on the backboard.

Only one subject requested that the experiment be stopped while on the vacuum immobilizer apparatus. This subject initially stated that he was getting "dizzy, hot, sweaty and short of breath". Further discussion with the subject, after being removed from the apparatus, indicated that the subject reported having claustrophobia. One other
subject also reported having a temporary feeling of claustrophobia but, once they "relaxed", the feeling seemed to pass. The vacuum immobilizer device does have design features that may contribute to this sensation. It encloses the body more fully than the backboard. When subjects are placed on the vacuum immobilizer the sides of the device are brought up around the person's head to help immobilize the head and neck. This restricts visual fields as well as movement. The development of claustrophobia on the vacuum immobilizer device has never been reported and was not anticipated for this study.

Another unanticipated finding was the effect of the vacuum immobilizer on sleep/wake status. Six of the subjects (11%) fell asleep on the vacuum immobilizer and only one subject fell asleep on the backboard. Two of the subjects who fell sleep were noted to have sleep apnea and were referred to their physician for further evaluation. Stern and Tuck (1990) report that "as much as 30 to 60% of the elderly population manifests some of the sleep-related breathing disorders." (p. 201). Only two (4%) of the subjects in this study manifested sleep apnea. Other sleep-related breathing disorders may be present in this sample but were not identified.

The ease with which subjects fell asleep on the vacuum immobilizer apparatus can most likely be attributed to the comfort of the device. Johnson, Hauswald, and Stockhoff (1996), in their comparison of the vacuum immobilizer device with the backboard, concluded that "a vacuum splint device is significantly more comfortable than a rigid, wooden backboard" (p.371). Delbridge, Auble and Garrison (1993) also reported increased comfort levels with use of the vacuum splint device. In this study, 40 subjects (70%), stated that the vacuum immobilizer device was comfortable. These subjects were not asked to comment on the comfort of the device and the comments were unsolicited.
One subject remarked, "I can't believe that anything that rigid could be so comfortable!"

A serendipitous finding in this study was the presence of skin alterations. One third of the subjects, when placed on the backboard, developed reddened areas on their lower back, shoulders, sacrum or coccyx after being on the backboard for 30 minutes. Size of reddened areas ranged from 3 cm to 12.5 cm. No skin alterations, however, were seen after subjects were on the vacuum immobilizer for 30 minutes. This finding is in agreement with Mawson, et al. (1988) who noted a relationship between time spent on the backboard and the development of pressure ulcers within eight days of admission for a spinal injury. Cordell, et al. (1995) noted increased tissue - interface pressures for the occiput, sacrum and heel when subjects were placed on a backboard. Although tissue-interface pressures were recorded, there was no indication if areas of actual redness or skin breakdown occurred on the backboard.

Other comments made by the subjects suggest that the vacuum immobilizer was warmer than the backboard. This may be an important consideration for older adults who are at higher risk of hypothermia due to alterations in temperature regulation associated with the aging process.

**Limitations of the Study**

The generalizability of the findings of this study is limited by several factors. First, normal volunteers who had not sustained any trauma were used for the sample. The results obtained in this study could be affected by the nature and type of injuries sustained. Pulmonary injuries, for example, could produce a different response than abdominal injuries.

Second, the composition of the sample was limited in relation to race and cultural considerations. The majority of the sample was Caucasian. There was a lower percentage of African-Americans in both order groups inspite of active efforts to recruit
from this population. Recruitment was attempted in senior citizen centers with a high proportion of African-Americans. Volunteers were obtained but, often did not meet the criteria for inclusion in the study. African-Americans in these senior citizen centers tended to have a greater number and severity of health problems that precluded their ability to participate in the study.

Third, the study was limited to one subgroup of older adults. The sample was confined to older adults, aged 65-75. The study, therefore, cannot be generalized to all adults over 65 years of age. There are distinct differences between the subgroups of older adults. An adult who is 95 years old may react differently to the devices than a person who is 65 years old.

Fourth, the study was conducted in a controlled laboratory setting. The effects seen in the laboratory may not necessarily be duplicated in a field setting. The amount of time needed to immobilize the person was not measured and the subjects were not exposed to the effects of movement associated with transport in an emergency medical services vehicle or helicopter.

Potential sources of error could have also affected the results. Only ten minutes was provided between placement on the different devices. This may not have permitted sufficient time to eliminate carryover effects from the first treatment. Statistical analysis, however, indicated that the order of treatment was not significant.

The instrumentation also had several limitations. Respiratory plethysmography, as measured by the Respigraph (NDM Corp.), provides only a semi-quantitative method for determining respiratory effort. Direct measurement of these indices with endotracheal intubation of the subject, would provide a more direct measurement of these parameters.
Endotracheal intubation of normal older adults was not feasible since the risk and discomfort of the procedure precluded its use in this study.

The VAS also had several limitations. One subject was blind and could not complete the instrument. Other vision problems, such as the presence of cataracts, tended to produce distortion of the scale and altered the placement of the subject's X on the VAS. Several subjects were not able to get the center of the X to cross the vertical line of the VAS. Scoring of the VAS in these situations was more difficult. One subject who was placed on the backboard first, followed by the vacuum immobilizer, regretted that she had not rated the VAS higher while she was on the backboard. She asked if she could go back and change the VAS. It was only after she was on the vacuum immobilizer that she realized how much harder it had been for her to breathe on the backboard. In this case order did affect the response of the subject.

Another limitation of the VAS in this study is the inability of the instrument to capture a multidimensional construct. The VAS is a unidimensional instrument but the construct of respiratory effort is multidimensional. In order to capture the various aspects of this construct, multiple VASs would be required which may lead to subject fatigue and decreased validity. Wewers and Lowe (1990) have also recognized this as a limitation of the instrument.

Implications for Nursing Practice

Immobilization of the spine is a procedure commonly performed in the prehospital setting. Older adults who are injured are commonly placed on the backboard as part of the process of spinal immobilization. Nurses who practice in the prehospital setting and who care for injured older adults need to consider the effects that this procedure has on the respiratory status of the injured person. Use of the backboard has been a standard
practice that has been accepted without considering the impact that this procedure may have on the effort expended by the person to breathe.

When performing an assessment of the older adult who has been injured, the nurse, should consider immobilization on the backboard as one factor that may contribute to respiratory dysfunction. It may be difficult for the nurse to differentiate effects of injury from the trauma induced from placing the older adult on a backboard. Increased respiratory rate, for example, may be partly due to immobilization on a backboard and it may also be due to pulmonary trauma.

The effects of aging and body position will also be superimposed on the injury sustained in the accident. An attempt should be made to evaluate the response of the older adult to the spinal immobilization procedure. Nurses caring for older adults in the prehospital setting should document the respiratory status prior to and after the immobilization process. Pulmonary function of older adults who are immobilized on the backboard should be closely monitored. Other effects of the procedure, such as discomfort and skin alterations, should be noted.

Older adults, if they are on a backboard and are admitted to the emergency department, should be removed from the device as soon as possible. The time spent on the backboard may contribute to negative effects. Unnecessary delays in removing the older adult from the backboard may contribute to respiratory dysfunction. The development of emergency department protocols for spinal immobilization may help to decrease the amount of time spent on the backboard.

Alternatives to the backboard also need to be considered. Spinal immobilization devices should not only provide adequate stabilization of the spine, they should also be designed to support the respiratory and other body systems. Use of the vacuum immobilizer device for older adults represents one alternative to the backboard. The
findings from this study suggest that the vacuum immobilizer device may decrease respiratory effort when compared to the backboard. The vacuum immobilizer device may also minimize discomfort and prevent skin alterations related to spinal immobilization. Nurses in the prehospital setting should consider use of the vacuum immobilizer as the preferred device for spinal immobilization in older adults.

In an era when health care costs are escalating, providing support for the respiratory system by using the vacuum immobilizer in the prehospital setting may help to reduce pulmonary complications and costs related to trauma. The cost of the vacuum immobilizer device is somewhat higher than the backboard, approximately $500 versus $100.00 for the backboard. The vacuum immobilizer device, however, is guaranteed for ten years. When the cost is prorated over the life of the device, the cost per year is approximately $50.00. This financial cost is easily offset through the reduction in physiologic and health care costs that may occur by maximizing respiratory support and reducing complications related to spinal immobilization.

**Recommendations for Further Research**

Additional research is needed to validate the findings of this study in a field situation. The controlled nature of the laboratory setting could have influenced the results obtained. Testing of the devices with older adults who have sustained a variety of injuries may help to determine if there are specific injuries for which these devices may be more appropriate than others; for example, is the vacuum immobilizer device more effective in supporting respiratory effort for pulmonary versus abdominal injuries?

The effect of pre-existing chronic conditions may also influence the results of this chronic disease in some subjects, none of the subjects in this study had significant limitations. A comparison of these devices using subjects with chronic disease who have limitations, such as emphysema with limited pulmonary reserve, is needed.
This study was done using a sample that had limited racial, ethnic and cultural composition. The study would need to be replicated with adequate representation from other racial, ethnic and cultural groups. Cultural variations must also be considered when designing the instruments; Hispanics, for example, may need to have the anchors for the VAS presented in Spanish versus English.

The study needs to be replicated with other subgroups of older adults. The devices should be evaluated with the 75-85 year old subgroup and the 85+ subgroup of the aged. Findings could be influenced by age related changes in the pulmonary and other systems. This study represents a preliminary study that may contribute to improved care in a prehospital field situation. Replication of the study with a larger sample is indicated to further validate the results obtained in this study.

Additional studies to determine validity and reliability of the VAS for respiratory effort are needed. Studies to determine the most reliable method for scoring the VAS are also needed.

Research to further explore and evaluate the construct of respiratory effort is needed. Respiratory effort is a multidimensional construct with time, volume and flow components. Further testing of this construct is needed to evaluate these components and to determine if there are other aspects of this construct that have not yet been identified.
CHAPTER 7

SUMMARY

The purpose of this study was to determine the effects of two methods of spinal immobilization on respiratory effort in older adults, aged 65 to 75 years of age. The two methods of spinal immobilization evaluated were the standard wooden backboard and a vacuum immobilizer apparatus. Haddon's Model of Injury served as the theoretical framework for this study, with spinal immobilization representing an external factor in the post-injury event phase.

A counterbalanced research design was used for this investigation. Each subject served as her/his own control since all subjects received both treatments. The sample consisted of 57 older adults aged 65-75 years of age who were recruited primarily from senior citizens centers in the central Ohio area. Subjects in the sample were randomly assigned to one of two order groups. The groups were Order BV, backboard followed by vacuum immobilizer, and Order VB, vacuum immobilizer followed by backboard.

Instruments used for data collection included the VAS, rank ordering of difficulty breathing, and respiratory plethysmography. The VAS and rank order of difficulty breathing were used to obtain subjective perceptions of respiratory effort. Respiratory plethysmography was used to evaluate the following physiologic indices of respiratory effort: respiratory rate, V_t, V_MIN, V_T/V_t, TCD/V_T, and %RC/V_T.

Baseline values for subjects were obtained for respiratory effort prior to being placed on either apparatus. A cervical collar was placed on each subject and then the subject
was put on either the backboard or vacuum immobilizer, depending on randomization order. Each subject remained on the device for 30 minutes. Six subjects, however, were unable to remain on the backboard for the entire 30 minutes. Only one subject was unable to remain on the vacuum immobilizer.

Data for physiologic indices of respiratory effort was collected by the Respigraph (NDM Corporation). A continuous analog display of the physiologic data was obtained via the Respigraph, with data averaged in five minute increments, referred to as an epoch. Subjective perceptions of respiratory effort were obtained immediately after being placed on the apparatus, 15 minutes after lying on the apparatus, and at the end of the 30 minute period on the apparatus. Subjects were then given a ten minute rest period between each device to minimize carry-over effects from one device to the other.

Chi square analysis was used to compare demographic data between the two order groups. The Wilcoxon Signed Rank Test was used to analyze the subjective perceptions of rank order in difficulty breathing. McNemar's test was used to determine sleep/wake status as a confounding variable. Another confounding variable that was identified was the presence of breathing problems, identified by self-report. To control for these confounding variables, repeated measures ANCOVA was used to compare the mean values for respiratory effort between the two order groups.

Significant differences were identified between subjects placed on the backboard versus the vacuum immobilizer. The order in which subjects were placed on the devices did not significantly influence the responses of the subjects, except for tidal volume. Significant differences were seen for both subjective as well as physiologic indices of respiratory effort. When baseline values for indices of respiratory effort, breathing problems, and sleep/wake status were used as covariates, the differences remained significant. Mean values for all indices of respiratory effort were increased for subjects
on the backboard versus the vacuum immobilizer device. The increases seen in the 
indices of respiratory effort suggest that breathing on the backboard required more 
respiratory effort than breathing on the vacuum immobilizer.

Qualitative responses, reflected in comments made by the subjects, indicated that they had 
a more difficult time breathing on the backboard. Subjects reported that they could 
breathe easier on the vacuum immobilizer and it was described as being more 
comfortable. Redness of the skin over pressure areas on the backboard was noted on one 
third of the subjects. No redness was noted when subjects were placed on the 
backboard.

The findings of this investigation suggest that the vacuum immobilizer may support 
respiratory effort more effectively than the backboard for older adults. When air is 
withdrawn from the device, the vacuum immobilizer conforms to the body contour. 
Pressure is then inverted inward into the device rather than being applied to the patient. 
The polystyrene beads provide a rigid yet comfortable support for spinal immobilization. 
This may contribute to more efficient use of the respiratory muscles which decreases the 
effort expended to breathe. Nurses who care for older adults who are transported on a 
backboard need to carefully monitor pulmonary function. The backboard has been the 
standard method for spinal immobilization but other methods, such as the vacuum 
immobilizer, may provide better support of pulmonary function in the older adult.


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Krumpe, P., Knudson, R., Parsons, G. & Reiser, K. (1985). The aging respiratory system. Clinics in Geriatric Medicine, **1** (1), 143-175.


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APPENDIX A

Consent Form
CONSENT TO INVESTIGATIONAL TREATMENT OR PROCEDURE

I, _______________________________________________, hereby authorize or direct Dr. Kathleen Stone, associates or assistants of her choosing, to perform the following treatment or procedure: on one occasion to (1) apply a stiff plastic neck collar (2) place me in a flat position, with my back straight, on two different types of equipment that provide a firm support for the back; (3) place two bands around the outside of my chest and stomach to measure my respiratory effort; (4) measure my respiratory effort while lying flat in a bed and while lying in a flat position on each of two types of equipment that provide firm support for the back and (5) determine my perception of respiratory effort while lying flat in a bed and while lying in a flat position on each of two types of equipment that provide firm support for the back upon

( myself or name of subject)

The experimental (research) portion of the procedure is: (1) completion of a questionnaire on my medical history; (2) measurement of my respiratory effort, using two bands placed around the outside of my chest and stomach, while lying flat in bed and for a 30 minute period while lying on each of two different types of equipment that provide firm support for the back (total of 60 minutes) and (2) describing the respiratory effort that I am experiencing by making a mark on a line between least and most effort making on a mark on a line describing my respiratory effort will be completed a total of seven times (while lying flat in bed; three times while lying on one type of equipment that provides firm support for the back and three times while lying on the other type of equipment that provides firm support for the back). This is done as part of an investigation entitled: "A Comparison of the Effects of Two Methods of Spinal Immobilization on Respiratory Effort in the Older Adult".

1. Purpose of the procedure or treatment: to determine the effect of two different types of equipment that provide firm support for the back, on respiratory effort in older adults aged 65 to 75.

2. Possible appropriate alternative procedure or treatment: not to participate.

3. Discomforts and risks reasonably to be expected: there is a possibility of back and/or neck discomfort which may occur while lying on a hard surface.

4. Possible benefits for subjects/society: improving the care of the older adult who has been injured; the subjects may also win a weekend at an Ohio State Park Lodge.
5. Anticipated duration of subject's participation (including number of visits): Approximately one hour and forty minutes on one occasion.

I hereby acknowledge that __________________________ has provided information about the procedure described above, about my rights as a subject, and he/she answered all questions to my satisfaction. I understand that I may contact him/her at Phone No. ___________ should I have additional questions. He/She has explained the risks described above and I understand them; he/she has also offered to explain all possible risks or complications.

I understand that, where appropriate, the U.S. Food and Drug Administration may inspect records pertaining to this study, I understand further that records obtained during my participation in this study that may contain my name or other personal identifiers may be made available to the sponsor of this study. Beyond this, I understand that my participation will remain confidential.

I understand that I am free to withdraw my consent and participation in this project at any time after notifying the project director without prejudicing future care. No guarantee has been given to me regarding this treatment or procedure.

I understand that in signing this form that, beyond giving consent, I am not waiving any legal rights that I might otherwise have, and I am not releasing the investigator, the sponsor, the institution, or its agents from any legal liability for damages that they might otherwise have.

In the event of injury resulting from participation in this study, I also understand that the costs of such treatment is available at University Hospitals of The Ohio State University and that the costs of such treatment will be at my expense; financial compensation beyond that required by law is not available. Questions about this should be directed to the Office of Research Risks at 292-5958.

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: __________ Time __________ PM Signed: ________________________________

(Signature of Project Director or his/her Authorized Representative)

Witness (es) ____________________________ (Person Authorized to Consent for Subject if Required)

If Required ____________________________

I certify that I have personally completed all blanks on this form and explained them to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Date: ___________ Signed: ________________________________

(Signature of Project Director or his/her Authorized Representative)

HS-028A (Rev. 7/93)
APPENDIX B

Human Subjects Review Committee Approval
BIOMEDICAL SCIENCES
HUMAN SUBJECTS REVIEW COMMITTEE
THE OHIO STATE UNIVERSITY

Meeting Date: April 14, 1994

RESEARCH PROTOCOL:

AMENDMENT

94H0107 A COMPARISON OF THE EFFECTS OF TWO METHODS OF SPINAL
IMMOBILIZATION ON RESPIRATORY EFFORT IN THE OLDER ADULT,
Kathleen Stone, Diane Jedlicka, Adult Health & Illness

presented for review by the Biomedical Sciences, Human Subjects Review Committee to
ensure the proper protection of rights and welfare of the individuals involved with
consideration of the methods used to obtain informed consent and the justification of risks in
terms of potential benefits to be gained. The Committee action was:

Protocol was unanimously APPROVED WITH THE FOLLOWING
STIPULATION:

1. Revise the consent form as follows and forward a copy to the
Committee:
   a. Use lay terms throughout the consent (e.g. "cervical collar",
      "immobilize", "back support devices" "abdomen", "marking a
      visual scale").
   b. Include PI's phone number in space provided on 2nd page, 1st
      paragraph.

Your approval is contingent upon your agreement to comply with the above stipulations.
Please SIGN this form in the space(s) provided and RETURN WITH ANY ADDITIONAL
INFORMATION REQUESTED TO THE HUMAN SUBJECTS REVIEW DESK, 300
RESEARCH FOUNDATION, 1960 KENNY ROAD, CAMPUS, within one week. Upon such
compliance, the approval form will be mailed to you. In the case of a deferred protocol, please
submit the requested information at your earliest convenience.

Date ___________________________ Signature(s) ___________________________

Principal Investigator(s)

HS-105 (2/91)
Stipulations/Comments

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ACTION OF THE REVIEW COMMITTEE

With regard to the employment of human subjects in the proposed research:

94H0107 A COMPARISON OF THE EFFECTS OF TWO METHODS OF SPINAL IMMOBILIZATION ON RESPIRATORY EFFORT IN THE OLDER ADULT, Kathleen Stone, Diane Jedlicka, Adult Health & Illness

APPROVED

Stipulations stated by the Committee have been met by the investigator and, therefore, the protocol is APPROVED.

It is the responsibility of the principal investigator to retain a copy of each signed consent form for at least three (3) years beyond the termination of the subject’s participation in the proposed activity. Should the principal investigator leave the University, signed consent forms are to be transferred to the Human Subjects Committee for the required retention period. This application has been approved for the period of one year. You are reminded that you must promptly report any problems to the Review Committee, and that no procedural changes may be made without prior review and approval. You are also reminded that the identity of the research participants must be kept confidential.

Date: April 14, 1994

Signed

Chairperson
APPENDIX C

Visual Analogue Scale
Directions: Make an X across the point on the line that best indicates the amount of difficulty you are having in breathing at this time. Be sure the center of the X crosses the line.
APPENDIX D

Questionnaire
Code No. ______

QUESTIONNAIRE

NAME_______________________________________

ADDRESS____________________________________

CITY____________________ ZIP CODE___________

TELEPHONE______________

AGE_____________________

1. HAVE YOU BEEN ADMITTED TO THE HOSPITAL FOR ANY INJURIES DURING THE LAST THREE MONTHS?
   YES________________ NO____________________

2. DO YOU SMOKE?
   YES________________ NO____________________

3. DO YOU HAVE ANY BREATHING PROBLEMS?
   YES________________ NO____________________
4. IF YOU ANSWERED YES TO THE PREVIOUS QUESTION PLEASE INDICATE THE NATURE OF YOUR BREATHING PROBLEM?

________________________________________
________________________________________
________________________________________

5. DO YOU NEED TO USE ANY OXYGEN AT HOME TO HELP YOU BREATHE?

YES __________________ NO ____________________

6. ARE YOU CURRENTLY TAKING ANY MEDICATIONS THAT WERE PRESCRIBED BY YOUR DOCTOR?

YES __________________ NO ____________________

7. IF YOU ANSWERED YES TO THE PREVIOUS QUESTION, PLEASE INDICATE WHAT MEDICATIONS YOU ARE CURRENTLY TAKING.

________________________________________
________________________________________
________________________________________

8. DO YOU HAVE ANY PROBLEMS WITH MOBILITY THAT WOULD MAKE IT DIFFICULT FOR YOU TOLie FLAT? YES __________________ NO ____________________
APPENDIX E

Absolute Values for Rank Order of Difficulty Breathing
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APPENDIX F

Copyright Permission
Dear Ms. Barcus,

I am writing to request copyright permission for a figure that was published in Respiratory Care. The name of the article was "Ventilatory Pattern Monitoring: Instrumentations and Applications". The article was written by Bruce Krieger and was published in Volume 35, number 7, July, 1990. The figure that I am requesting copyright permission for is Figure 5 on page 701. The figure is an RIP tracing showing rib cage, abdominal waveforms and tidal volume waveform. The copyright permission is requested for use in a dissertation for completion of Ph.D. degree requirements at The Ohio State University. The title of the dissertation is, "A Comparison of the Effects of Two Methods of Spinal Immobilization on Respiratory Effort in the Older Adult" by Diane Jedlicka. Thank you very much.

Sincerely,

Diane Jedlicka,
Doctoral Candidate
The Ohio State University
Fax (614) 823-7453

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May 1, 1997