THE EFFECTS OF POSTURAL DRAINAGE, MANUAL PERCUSSION AND VIBRATION VERSUS POSTURAL DRAINAGE AND MECHANICAL VIBRATION ON MAXIMAL EXPIRATORY FLOWS

by

Marilyn Burke Hartsell

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Grief has its rhythm--first the wild
swift tide of dark despair,
The time of bleak aloneness
When even God's not there,

And then the slow receding
Till quiet calms the sea,
And bare, washed sand is everywhere
Where castles used to be

(Helen Marshall)

This thesis is lovingly dedicated to the memory of

CAPTAIN JAMES B. COSGRAVE, U.S.A.F.
(1945-1977)
ACKNOWLEDGMENTS

The author wishes to express her appreciation to the following:

"It is when you give of yourself that you truly give."  
(K. Gibran)

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"Gratitude is a memory of the heart."  
(Massieu)

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"Your friend is your needs answered, for you come to him with your hunger, and you seek him for peace."  
(K. Gibran)

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"If he is indeed wise he does not bid you enter the house of his wisdom, but rather leads you to the threshold of your own mind."  
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"What is a truthful life? A life with deliberateness, a good, strong life. It is the path traveled with Heart."

(The Teachings of Don Juan)

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ABSTRACT

Cystic fibrosis and bronchiectasis are two chronic pulmonary diseases that are characterized by the production of large amounts of thick, tenacious mucus which can obstruct air flow and interfere with adequate ventilation. Postural drainage with percussion and vibration is an effective treatment regimen as it helps to clear mucus from peripheral and central airways. However, postural drainage with percussion and vibration is a time-consuming procedure, requires a trained individual to administer, and does not allow independence in self-care.

Mechanical vibrators have recently been used in the older patients with cystic fibrosis and bronchiectasis to provide them with some measure of independence and self-treatment. Little was previously known of the efficacy of this treatment alternative, however. Thus, the purpose of the study was to compare maximal expiratory flow changes following treatment with the standard postural drainage with manual percussion and vibration to changes in flows following postural drainage and mechanical vibration.

Maximal expiratory flow volume curves were obtained from a sample of nine subjects, six with cystic fibrosis and three with bronchiectasis unrelated to cystic fibrosis. The MEFV curves were obtained pre-drainage, and at 60
minutes post-drainage for both treatments. At 60 minutes post-drainage, there was a significant increase in forced vital capacity and isovolume flow rates near 25 per cent and 50 per cent of FVC for both treatments. Peak expiratory flow rates did not change with either treatment. There was no significant difference in flows between the two treatments.

Since there was no significant difference by lung mechanics in the efficacy of the two treatments, it would seem that mechanical vibration with postural drainage is an effective treatment alternative for those patients desiring more independence in their own care.
CHAPTER 1

INTRODUCTION

The production of mucus within the bronchopulmonary system of man is considered to be one of the normal self-cleaning protective mechanisms of the body which aids in the elimination of particles, whether organic or inorganic, that might be present in the respiratory tract. Two other cleaning and protective mechanisms are: (1) the presence of ciliated columnar epithelial cells that line the respiratory tract from the trachea to the respiratory bronchioles, and (2) the cough mechanism which further mobilizes the mucus blanket by producing high velocity airflows (Guyton, 1976). Normally, approximately 100 milliliters (mls) of mucus are produced every 24 hours and form the thin transparent film of mucus that covers the epithelial lining of the respiratory system (Murray, 1976). However, in the diseased state, excessive mucus production or loss of ciliated epithelial tissue can overwhelm the normal protective mechanisms of the lung. Cystic fibrosis and bronchiectasis are two such disease conditions.

Cystic fibrosis, an inherited autosomal recessive disorder of the exocrine glands, thought to occur in one of every 2,000 live births, is now considered the most common
cause of chronic incapacitating respiratory disease in children and adolescents (Landau and Phelan, 1973). It is a disease characterized by hypertrophy of bronchial glands, goblet cell metaplasia, and the production of copious amounts of thick, tenacious mucus which results in the obstruction of various organ ducts, bronchi, and bronchioles. Much of the morbidity and mortality of pulmonary dysfunction results from the thick and viscous bronchial mucus produced, and from the resulting impairment of the mucociliary transport system. As a result, there is stasis of mucus, plugging of peripheral airways, inflammation, infection, atelectasis, and the inevitable sequelae of respiratory insufficiency (Wood, Boat, and Doershuk, 1976).

Bronchiectasis in the adult is often due to recurrent infections and pneumonitis. The result is excessive mucus production, dilation of the airways, and destruction of ciliated epithelial cells. The mucociliary transport system becomes impaired and atelectasis, respiratory insufficiency, and cor pulmonale often result (Baum, 1974: p. 397).

Although there is no known cure for cystic fibrosis or chronic bronchiectasis, there is an effective medical and nursing care regimen that has helped increase the life span of these patients (Wood et al., 1976). One aspect of the regimen has been the use of postural drainage with percussion and vibration to aid in the clearance of bronchial
secretions. However, postural drainage with percussion and vibration poses a problem. It is a time-consuming treatment; requires a trained individual to administer; and is not amenable to patient self-treatment. Thus, where it may have increased a patient's life span, it has not increased the patient's ability to control his/her life. The treatment described has not allowed these patients to assume a more independent lifestyle. Rather, as survival has increased, as in the case of the patient with cystic fibrosis, this treatment has prolonged the patient's dependency state on parents and relatives. Therefore, understanding the normal developmental needs of the adolescent and adult, and in an effort to increase the independence of patients with cystic fibrosis and chronic bronchiectasis, some patients are learning to use mechanical vibrators with postural drainage instead of the usual postural drainage with manual percussion and vibration. Little is known, however, of the efficacy of this treatment modification in the treatment of cystic fibrosis or chronic bronchiectasis.

Manual percussion and vibration has been part of the treatment regimen for patients with chronic bronchitis, chronic bronchiectasis, and cystic fibrosis for some time now. It is a modification of the "catsup bottle" theory so commonly employed at the local hamburger stand. Here the bottle is turned upside down (postural drainage) and then it is pounded on (percussion) and then shaken (vibration)
(Traver, 1977). However, there have been few studies, until recently, that have shown the efficacy of this theory. One of these studies, done by Feldman (1976), showed significant beneficial effects from postural drainage with percussion and vibration on forced expiratory flows at 50 and 25 percent of the vital capacity (\( \dot{V}_{\text{max}} 50 \) and \( \dot{V}_{\text{max}} 25 \)) at 45 minutes following the treatment. Whether these same beneficial effects can be demonstrated with mechanical vibration and postural drainage has yet to be shown.

**Statement of the Problem**

The present study compared the efficacy of postural drainage with manual percussion and vibration vs. postural drainage with mechanical vibration, as measured by changes in maximal expiratory flows at 60 minutes posttreatment, in patients with cystic fibrosis or chronic bronchiectasis.

**Purpose of the Study**

Postural drainage with manual percussion and vibration is a time-consuming process and one that requires the aid of another individual. As the life span of patients with cystic fibrosis is increased, the normal developmental processes and needs for independence must also be considered. For the adolescent, especially in today's world, these factors are of particular importance. According to Erikson, adolescence is a time of various social demands and role changes. It is a time when
the adolescent is no longer a child but is not yet an adult. It is a time essential for meeting the challenges of coming adulthood (Hjelle and Ziegler, 1976). If adolescents are to successfully complete this phase of their development, they must establish a positive ego identity. Independence and an accrued confidence in self help establish this sense of ego identity.

Adolescence is also a time of psychological stresses between parent and child, even in families free of illness. It is a time when the child starts to assert himself. It is a time of "pulling up roots," in preparation for leaving the family (Sheehy, 1974:260). In the family with a chronically ill child, these same psychological stresses are apparent. The consequences of this rebellion against their parents, however, can often result in the life-threatening abandonment of treatment regimens. Mechanical vibrators, therefore, can help offset this problem by giving these patients that needed sense of independence.

For the adult with chronic bronchiectasis, postural drainage with manual percussion and vibration can lead to feelings of dependency and resulting internal tensions within the patient and the family. Such added stresses for the chronically ill should be avoided for as long as possible. Thus, the purpose of this study was to determine if mechanical vibrators were as effective as postural drainage with manual percussion and vibration in aiding the removal
of mucus from the bronchopulmonary tree in patients with chronic and excessive mucus production.

**Definition of Terms**

Postural drainage: gravitational clearance of airways and lung parenchyma by the assumption of six different positions for five minutes. Each position corresponded to a specific segment of the lung to be drained (see Figure 1). In this study postural drainage also included the following:

1. Manual percussion: the chest wall (ribs only) over the area to be drained was percussed or clapped for one minute. The hands were cupped and held rigid as the wrists moved to clap the draining area.

2. Vibration: during the period of three prolonged exhalations through pursed lips a downward vibrating pressure by the flat part of the hand was applied over each area to be drained. It was accomplished by rigid extension of the elbows, with a fine vibrational tremor, originating in the shoulders.

Mechanical vibration: application of an Oster hand massager, Model 103-01 Stim-u-lax, to the chest wall over each area to be drained for a period of two minutes. The same six positions described for postural drainage were used (see Figure 2).
Figure 1. Postural Drainage Positions — from Feldman (1976:7), used with written permission.
Figure 2. Schematic Drawing of Mechanical Vibrator
Composite curve: refers to the best flow rates, vital capacity and peak expiratory flows taken from three maximum expiratory flow volume curves.

Cystic fibrosis: an inherited autosomal recessive disease of the exocrine glands which primarily involves the lungs, gastrointestinal tract, and skin. Mucus production is thick, tenacious, and excessive. The normal mucociliary clearing mechanism becomes impaired and a vicious cycle of stasis, inflammation, and infection with further impairment of function results (Cherniak, Cherniak, and Naimark, 1972).

Bronchiectasis: an acquired disease of the pulmonary system and related to frequent infections and pneumonitis. Dilated airways and an impaired ciliary transport system make adequate clearance of mucus difficult. Stasis, inflammation, and infection further complicate the pulmonary status of the patient with each acute exacerbation (Cherniak et al., 1972).

**Hypotheses**

1. There will be a significant increase in FVC, PEFR, and \( \dot{V} \) max 50 and \( \dot{V} \) max 25 at the 0.05 level from baseline 60 minutes postpostural drainage with manual percussion and vibration.

2. There will be a significant increase in FVC, PEFR, and \( \dot{V} \) max 50 and \( \dot{V} \) max 25 at the 0.05 level from
baseline at 60 minutes postmechanical vibration with postural drainage.

3. There will be no significant difference in the increase in FVC, PEFR, \( V_{\text{max} 50} \), or \( V_{\text{max} 25} \) at 60 minutes posttreatment between the two treatments.

**Conceptual Framework**

Cystic fibrosis and chronic bronchiectasis are diseases which are characterized by the production of large amounts of very viscid mucus (Boat and Petty, 1977). In addition, the mucociliary transport system is impaired due to loss of ciliated epithelium and the difficulty in moving viscid secretions along the airway. The result is an accumulation of mucus, airway obstruction, and increased resistance to airflow (Matthews et al., 1973:332; Wanner, 1977). If the use of postural drainage with manual percussion and vibration facilitates mucus transport and clearance, resistance to airflow should decrease and maximal expiratory flow volume (MEFV) measurements should improve. If mechanical vibration with postural drainage is also effective, the same MEFV measurements should improve. Therefore, a summary of the physiology of mucus transport and how it is affected by postural drainage and a discussion of measurements for flow and airway resistance principles is presented.
In the normal pulmonary system, ciliated epithelial cells line the mucociliary escalator system from the larynx to the respiratory bronchioles (Wanner, 1977). These cilia beat rhythmically to move the mucus sheet toward the upper airway. There are two distinct layers comprising the sheet: (1) the overlying viscoelastic layer which acts as a transport layer, as the beating tips of the cilia propel this layer toward the mouth; and (2) the underlying serous layer, which acts as a medium in which the cilia move and upon which the overlying viscoelastic layer moves (Parks et al., 1971). However, in cystic fibrosis and chronic bronchiectasis, this normal clearance mechanism is impaired by too thick and large a viscoelastic layer (Waring, 1973:682; Matthews et al., 1973:305).

Postural drainage with manual percussion and vibration, according to Egan (1973), can help establish adequate airway clearance along the tracheobronchial escalator by literally "shaking loose secretions" and by the natural forces of gravity (Petty, 1974:92-93). Vibration is also helpful in removing secretions, as well as aiding in the dislodging of mucus plugs (Foss, 1973:668-669). In fact, it has been reported that during bronchoscopy, "vibrations given on expiration squeeze the secretions from the bronchioles into the larger bronchi" (Thacker, 1971:20; Denton, 1962:41). From this level, then, secretions can be more easily removed via coughing or suctioning.
In studies done by Sanchis et al. (1973a, 1973b), no dysfunction of the mucociliary transport mechanism in large proximal airways was shown in subjects with cystic fibrosis or chronic bronchitis. In bronchiectasis the dysfunction can involve the bronchi or bronchioles (Cherniak et al., 1972). However, the dysfunction may be either focal or discontinuous. An adequate cough transport system is therefore essential in helping clear the airways.

For an adequate cough to mobilize airway secretions effectively, there must be sufficient velocity of air flow. Velocity, in and of itself, is a measure of the distance per unit time of the gas molecules and is determined by (1) airflow rates, and (2) the cross-sectional area (Macklem 1974). In the lung, the cross-sectional area of the lung becomes even greater with each succeeding bronchial generation until finally terminating in the alveoli. Velocities are, therefore, greater in the proximal airways because the cross-sectional area is less. Thus, coughing is more effective in clearing the large proximal airways than the smaller peripheral airways (Macklem, 1974).

Another physiologic mechanism that assists in the clearance of mucus from the proximal airways, and which works in concert with the cough mechanism, is the phenomenon of dynamic compression. Dynamic compression is a narrowing of the airway lumen during maximal expiratory airflows, such
as in a cough (Burrows, Knudson, and Kettel, 1975). An explanation of how the phenomenon occurs follows.

During normal quiet breathing, expiration is passive and is a function of lung recoil. Since chest wall elasticity and lung recoil oppose one another, the pleural pressure \( P_{pl} \) remains negative. During a forced expiration, however, such as a cough, the expiratory muscles are brought into play and help generate forces that compress the lung. Alveolar pressure \( P_{alv} \) increases, and since alveolar pressure equals the sum of the elastic recoil pressure \( P_{st} \) and \( P_{pl} \), it is greater than the pleural pressure. Thus, as air flows from the alveoli toward the mouth, the pressure gradient decreases and becomes equal to or less than the pleural pressure. The point at which the pressure within the airway is equal to \( P_{pl} \) is called the equal pressure point (EPP) (Burrows et al., 1975). Points along the airway where the \( P_{pl} \) exceeds the airway pressure are subject to dynamic compression. Since the EPP is movable along the airway, as it is a function of lung volume, the length of the dynamically compressed segment will vary, depending on its location. At high lung volume, the EPP is located in the central airways, such as the segmental bronchi, while at low lung volumes it is located more peripherally (Burrows et al., 1975). Thus, airways downstream from the EPP (toward the mouth) are dynamically compressed, and airways upstream from the EPP (toward the
alveoli) are distended. As the dynamically compressed segment of airway has its lumen reduced, the air flow within the airway is greatly increased. The resulting blast of expelled air causes a shearing effect on secretions within the airway. Mucus transport, airway clearance, and cough efficacy are, therefore, greatly improved (Macklem, 1974: 761).

In assessing the effectiveness of the clearance mechanisms and treatments attempting to reduce the airway resistance that accompanies excessive mucus retention, the maximal expiratory flow curve (MEFV) provides an objective data-base when used on patients who are their own control (Green et al., 1973:35s). An analysis of the MEFV curve also provides for an understanding of the physiological basis for volume-flow relationships. When maximal expiratory flows (\( V_{\text{max}} \)) are plotted against lung volumes during forced vital capacity maneuvers, air flow quickly rises to a peak level and then declines over the remaining portion of the forced vital capacity (FVC) (Motoyama, 1973:335) (see Figure 3).

The determinants of \( V_{\text{max}} \) are the elastic recoil pressure (\( P_{\text{st1}} \)) at corresponding lung volumes for \( V_{\text{max}} \), and the resistance of the airways on the alveolar (upstream) side of the equal pressure point (\( R_{\text{us}} \)); such that \( V_{\text{max}} = P_{\text{st1}}/R_{\text{us}} \) (Motoyama, 1973:366). The elastic recoil pressure is also equal to the driving pressure from the alveoli to
Figure 3. Maximal Expiratory Flow Volume Curve
the equal pressure point (EPP) (Mead et al., 1967:95), and depends on the lung elastic recoil force. In a study by Landau and Phelan (1973:593), the $P_{st \ l}$ was shown to be normal in patients with cystic fibrosis. Thus, any changes in $V_{max}$ following postural drainage with manual percussion and vibration, or postural drainage with mechanical vibration would reflect a change in the resistance of the airways on the alveolar or upstream side of the point in the airways where the intraluminal pressure equals pleural pressure (Motoyama, 1973:336). In the case of patients with chronic bronchiectasis, the $P_{st \ l}$ has been shown to be abnormally decreased when emphysematous changes are present (Bates, Macklem, and Christie, 1971:35, 177).

Possible reasons for changes in resistance of the upstream segment to air flow are (1) increased tone of the smooth muscles in the airways, (2) edema of the ciliary mucosa in the airway, and (3) the presence of excessive sputum which can narrow the airways (Knudson, 1972:10). When any of the aforementioned occurs, the calibre of the airways is reduced and resistance to air flow increases. For example, when the radius of a tube is decreased by half, the resistance increases 16-fold (West, 1974:102-103). Thus, if adequate airway calibre is to be maintained, so that resistance to air flow is not increased, secretions must be removed. Maximal expiratory flow volume curves can help measure the adequacy of this removal of secretions by
assessing increased airflow and $V_{max}$ changes at various lung volumes.

During postural drainage with manual percussion and vibration, it is thought that sputum is moved from the lung periphery into larger central airways, so that the mucociliary transport system can help clear the bronchial tree. Such a situation would cause an initial increase in airflow resistance, since sputum "shaken loose" from the peripheral airways would move into the more central airways and increase resistance to flow. However, as sputum is expectorated, following the treatments, there will be a decrease in airflow resistance and a corresponding increase in $V_{max}$ (Foss, 1973:668).

**Assumptions**

1. The presence of sputum in the airways increases resistance to airflow.

2. Lung elastic recoil pressure ($P_{st}$) will not change during the short duration of this study.

3. Changes in maximal expiratory flow rates (MEFR) at $V_{max}$ 50 and $V_{max}$ 25 on the MEFV curve will reflect changes in airflow resistance.

4. Total lung capacity (TLC) will not change during the study.
Limitations

1. Generalizations can only be extended to the sample.
2. Maximal expiratory flow volume (MEFV) curves measure changes in resistance to air flow indirectly and can be affected by lung elastic recoil.
CHAPTER 2

REVIEW OF THE LITERATURE

Literature pertaining to the lung clearance of sputum by postural drainage with manual percussion and vibration was reviewed, as well as material on the use of maximal expiratory flow volume (MEFV) curves as a measurement of airway obstruction to air flow. Limited material was found on the use of the mechanical vibrator with postural drainage as a means of airway clearance.

Postural Drainage and Airway Clearance

The theoretical basis for the use of postural drainage as a facilitator of airway clearance has already been discussed in the previous chapter. However, in terms of adequate research into the actual theories, there has been little in the way of controlled studies. In fact, there has been little to validate or disprove the common theoretical and clinical assumptions regarding the use of postural drainage with manual percussion and vibration.

In a study by Feldman (1976), a positive relationship between postural drainage and an increase in $V_{\text{max}} 50$ and $V_{\text{max}} 25$ was demonstrated. Nineteen patients with either cystic fibrosis or chronic bronchitis were studied using MEFV curves before and at 5, 15, and 45 minutes.
posttreatment. While there was an immediate reduction in the peak expiratory flow rates in these patients following postural drainage, all had a significant increase in their MEFV and isovolume flow rates 45 minutes posttreatment. Thus, postural drainage with manual percussion and vibration was shown to be a valuable aspect in the treatment of those patients with excessive mucus production, decreased air flows, and increased airway resistance.

In another study done by Sanchis et al. (1973a), the mucociliary function of a group of 19 patients with chronic bronchitis or emphysema was assessed. The rate of removal of an inhaled radioactive aerosol from diseased lungs was compared against clearance rates of nine non-smoking adults. Sanchis et al. (1973b) also did another study with 13 cystic fibrosis patients and compared the rates of removal of an inhaled radioactive aerosol from their lungs to that of nine normal adults. In both studies, clearance rates from the diseased lungs were found to be close to or faster than clearance rates from the normal lungs. However, it was found that, in the diseased groups, the radioactive aerosol was deposited centrally in the proximal airways, while in the normal lungs a more peripheral distribution was achieved. Thus, because of the more central deposition of the aerosol in the diseased lungs, it was cleared at a comparable or faster rate than that of the more peripheral distribution in the normal lung. Also, because of the
proximal deposition of the aerosol in the diseased lungs, a
greater proportion of it was removed by the proximal portion
of the mucociliary escalator and thus resulted in an equal
or faster clearance rate than the normal lungs.

Also in the Sanchis et al. (1973b) study, using the
cystic fibrosis group, no correlation was found between the
clinical severity of the disease and the difference in
clearance rates. The more frequent coughing spells of the
more severely ill children, as compared to children with a
milder form of the disease, were thought to be the reason
for these results. Thus, cough plays an important part in
helping the mucociliary system clear secretions from the
bronchial airways.

A number of other studies have attempted to assess
the usefulness of postural drainage with manual percussion
and vibration in cystic fibrosis and chronic bronchitis
patients by using various physiological parameters, such as
pulmonary function tests, arterial oxygen, arterial carbon
dioxide determinations, sputum volume, and rheology. In a
study done by Anthonisen, Reis, and Anderson (1964), these
same parameters were examined in 63 patients with an acute
exacerbation of their chronic bronchitis. After dividing
these patients randomly into two groups, the treatment group
which received chest physiotherapy and the control group
which did not, no significant difference in the number of
days in which the patients' temperatures remained elevated was shown.

In a study done by March (1971), sputum volume and forced expiratory spiromograms in 20 patients with chronic obstructive pulmonary disease (COPD) were examined before and after postural drainage. However, this study did not include percussion or vibration with the postural drainage maneuvers, and there was no significant improvement in pulmonary function as well as no correlation between the amount of sputum produced and changes in lung function.

Motoyama (1973) looked at the effect of postural drainage on airway obstruction in a study measuring MEFV curves before, five minutes after, and 45 minutes after postural drainage in 10 patients with cystic fibrosis. It was found that there was a significant increase in $\dot{V}$ max 50 and $\dot{V}$ max 25 at the 0.05 level, when compared with pretreatment values. It also was found that there were no significant increases in vital capacity (VC), peak expiratory flow rates (PEFR), $\dot{V}$ max 50, and $\dot{V}$ max 25 at 45 minutes post-postural drainage.

Tecklin and Holsclaw (1975) conducted a study using 26 subjects with a diagnosis of cystic fibrosis. Here spirometry was done before and five minutes after postural drainage, percussion, and vibration. Results of the study showed a statistically significant increase in PEFR, FVC, expiratory reserve volume (ERV), and inspiratory capacity
(IC) at five minutes posttreatment. Changes in FEV\textsubscript{1} and maximal mid-expiratory flow rate (MMEFR) were not observed.

**Vibration and Lung Clearance**

There have been few studies on the effectiveness of mechanical vibrators to clear bronchial secretions. One such study was that of Pavia, Thomson, and Phillipaks (1976), which attempted to study the effect of a vibrating pad on bronchial clearance on 10 patients with obstructive lung disease. The rate of clearance was measured using an inhaled radioactive aerosol. Subjects were tested twice, once during a control period in which the subjects lay for an hour at a 45 degree angle, and once during the treatment period in which the patient lay for an hour in the same position with a vibrating pad placed between the patient's back and the table. Subjects had pretreatment pulmonary function tests but they were not repeated posttreatment. Rather, the investigators looked at the volume of sputum produced during both treatments. Although the mean rate for all subjects was slightly higher with vibration, previous studies already mentioned have demonstrated that sputum expectoration and lung function changes are not necessarily correlated. It was also concluded that there was no significant effect of vibration on the rate of clearance or on the production of expectoration or sputum as against the control treatment.
In another study done by Buchberg and Goldbarb (1972), the use of a mechanical percussion and vibration vest was shown to produce increased sputum in 11 patients with chronic bronchitis, bronchiectasis, and emphysema. However, information on the subjects' posttreatment lung function was not reported.

The use of mechanical hand vibrator with shoulder strap modification and a slant board was reported in the literature by Plumstead (1972:50) (see Figure 2). It was shown to be effective in easing the clearance of mucus from the airways as well as increasing patient independence, but adequate lung function measurements were not obtained to substantiate the results reported (Plumstead, 1972).

The Maximum Expiratory Flow Volume Curve

Today, through the efforts of many researchers, the MEFV curve is regarded as a valuable test in the evaluation of airway obstruction and in the measurement of the efficacy of different forms of treatment. One of the first studies done on the clinical usefulness of the MEFV curve was done by Fry et al. (1954). Here the isovolume pressure flow curve and the aerodynamic behavior of the lungs were introduced. Also, the study showed that expiratory flows experience autoregulation; that is, as the driving pressure is increased, the expiratory flow rates also increase to a
maximum beyond which a further increase in pressure did not increase flows.

In a study done by Landau and Phelan (1973), various pulmonary function tests were conducted on 46 cystic fibrosis patients in an attempt to correlate test results with clinical severity. These tests included: spirometry, MEFV curves, respiratory conductance, conductance of the upstream segment, and frequency dependence of dynamic compliance. The results suggested that the initial airway obstruction in cystic fibrosis is in the small airways.

In Motoyama's (1973) study, $V_{\text{max}}$ was shown to be significantly decreased in children with cystic fibrosis, particularly at low lung volumes. This finding was interpreted as a reflection of increased resistance in small airways since $P_{\text{st}}$ is normal in children with cystic fibrosis.

In 1973, Green and associates examined the extent and normal variability within the MEFV curve by comparing their findings with the MEFV curve and other lung function parameters. It was found that measurements of $V_{\text{max}}$ 50 varied considerably more than those of vital capacity (VC) and forced expiratory value in one second (FEV$_1$). However, both $V_{\text{max}}$ 50 and FEV$_1$ include effort dependent parts of the curve and may account for the variations. Further work by Green, Mead, and Turner (1974) demonstrated variations of the MEFV curve at low lung volumes within each individual.
Results of their study suggested, therefore, that variability of the curves are due to resistance to flow rather than the driving force of the flow. Thus, differences in airway and lung structure within individuals would prevent the definition of normals for the curve. However, it was postulated that the curve could still be useful as a measurement of lung function when subjects act as their own control.

Differences in MEFV curves were also found in "normal" individuals by Hyatt and Block (1973). Here it was postulated that differences may be a reflection of non-identical mechanical properties in many lung regions.

In a recent article by Mead (1978), the non-identical mechanical properties of the lung, as identified by Hyatt and Block (1973), were further explored. Mead (1978) attempted to demonstrate slow ratio-volume relationships in the healthy (homogeneous) lung and the non-healthy (non-homogeneous) lung. What was demonstrated was that in the non-homogeneous lung there are different areas in the lung that empty at different rates, as well as having different closing volumes. Therefore, flows at high lung volume represent the faster phase emptying of less diseased airways; while flows at low lung volumes represent the slower phase emptying of more diseased, or obstructed, airways. Thus, improvements in flows at low lung volumes
would indicate a decrease in the number of slow or obstructed spaces.
CHAPTER 3

METHODOLOGY

Research Design

An experimental research design was chosen to study the effects of postural drainage with manual percussion and vibration vs. postural drainage and the use of a mechanical vibrator on MEFV curves. Since respiratory illness is a labile process, and because of the variability between subjects, each subject acted as his own control. Each subject experienced both treatments and the treatment order was randomly assigned. Treatment sessions were scheduled at the same time of day and were three to five days apart. An MEFV curve, as a measurement of baseline pulmonary function, was obtained before each treatment as a control value for each subject in the study. Posttreatment MEFV curves were obtained at 60 minutes. The data obtained were then analyzed in terms of change from baseline.

The research proposal and the Subject Consent Form (see Appendix A) were submitted to the Human Subjects Committee and the physicians in authority of the clinics where the data were collected. Letters of approval appear in Appendices B through D.
The Sample

The sample consisted of nine patients from a southwestern chest clinic. Six subjects had a diagnosis of cystic fibrosis and three had bronchiectasis, unrelated to cystic fibrosis. The subjects who agreed to participate in the study and met the following criteria were included in the study. The criteria were that the patients:

1. had a diagnosis of either cystic fibrosis or bronchiectasis unrelated to cystic fibrosis;
2. were able to speak English and follow directions;
3. were physically able to tolerate postural drainage and pulmonary function tests;
4. were willing to abstain from postural drainage for at least six hours prior to each experimental treatment session;
5. were in a stable condition during the experimental period;
6. had not received intermittent positive pressure breathing treatments, bland aerosol, or aerosolized bronchodilators for at least four hours prior to the treatments; and
7. had previously done a forced expiratory vital capacity maneuver.

The purpose of the study was explained to those meeting the above criteria, and they were asked if they
would like to participate. Individuals consenting to participate were then informed of what their participation would involve and were asked to sign the Subject Consent Form. If the subject was a minor, he was asked to sign as well as his parents.

**Treatment Protocol**

Postural Drainage with Manual Percussion and Vibration

The anterior and posterior apical, as well as the anterior, posterior, right, and left lateral positions designed to drain the basal lung segments were used (see Figure 1). The subjects assumed each position for five minutes, making a total of 30 minutes per treatment. Each subject was required to assume each position for two minutes prior to the onset of percussion. After one minute of percussion, the subject was instructed to inhale deeply, followed by prolonged exhalation and repeated for three consecutive breaths. During exhalation, the investigator vibrated the area to be drained. The subject was then allowed to rest for the remainder of the five minutes while still in the postural drainage position. Immediate before each position change, the subject was instructed to cough if he had not done so spontaneously.
Postural Drainage with Mechanical Vibration

The same six positions as used in the above treatment protocol were used (see Figure 1). The subjects also were asked to assume the positions for the same time intervals as in the above. However, before beginning the treatment regimen, the subjects were instructed in the operation and treatment protocol for the mechanical vibrator. The subject was allowed to assume the postural drainage position for two minutes prior to the onset of mechanical vibration. The subject then used the mechanical vibrator for two minutes (see Figure 2). Subjects were allowed to rest for the remaining time before moving to the next position. The investigator did not do the treatment itself but was only present to supervise the subjects and use of the equipment. Coughing again was encouraged following each position if the subject had not done so spontaneously.

**Measurements**

Maximal Expiratory Flow Volume Curves

The subjects were instructed in the forced expiratory vital capacity maneuver and were asked to perform the maneuver three times before each treatment. The maneuver was also repeated three times at 60 minutes after each treatment. A composite of the three curves at each time interval was then determined and used as the final
measurement. This composite curve was used to reduce intra-individual variability. The MEFV curve was measured on a Fleisch #4 pneumotachograph with a differential pressure transducer (Statham PM-283TC) and storage oscilloscope. Flows were converted to a volume signal via electronic integration. The investigator then traced the curves from the oscilloscope using an oscillotracer.

Calculations of FVC, PEFR, $V_{\text{max}}$ 50, and $V_{\text{max}}$ 25 were then made from the composite curves obtained before each treatment. Volume measurements were subtracted from total lung capacity (TLC) on the posttreatment curves and isovolume points were determined. Assuming total lung capacity did not change significantly, posttreatment curves were standardized to the baseline vital capacity so that the isovolume flow, measured down from TLC, and near 50 per cent and 25 per cent of the vital capacity could be obtained.

**Data Analysis**

The data collected were analyzed in terms of absolute change from the subject's baseline values. Because the number of subjects was too small to split into subgroups, the total group was used in analyzing the data via the following tests.

The Wilcoxon matched pairs signed rank two-tailed test (Hollander and Wolfe, 1973:27-33) was used to determine whether baseline values for FVC, PEFR, $V_{\text{max}}$ 50, and $V_{\text{max}}$
were different on either day of the experiments or for either treatment protocol. The Wilcoxon matched pairs signed rank one-tailed test was used to analyze for improvements between the pretreatment baseline values and the post-treatment measurements for FVC, PEFR, \( \dot{V} \) max 50, and \( \dot{V} \) max 25 (Hollander and Wolfe, 1973:27-33).

The two-tailed student T test (Dunn and Clark, 1974:138) was then used to examine all subjects' responses to the two treatment protocols and to see if there was any difference between the two therapies. The same test was used to test for differences between the two therapies and the amount of sputum expectorated with either protocol.

Sputum

The total volume of sputum obtained during each treatment, and for one hour after each treatment, was collected in a sputum cup. The color and consistency of the sputum were recorded on the data collection sheet (see Appendix F). Sputum volume was measured by using a 10 cc syringe.

Data Collection

Pertinent data from the subjects' charts were obtained and placed on the history sheets (see Appendix E). Data collected during the treatments also were placed on the coded data collection sheets, as above. Following the
completion of both treatment sessions, subjects were asked to fill out a subjective questionnaire regarding their feelings about any side effects or benefits from the two treatments (see Appendix G).
CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

Characteristics of the Sample

The sample consisted of nine subjects, six with a diagnosis of cystic fibrosis and three with a diagnosis of bronchiectasis unrelated to cystic fibrosis. In the cystic fibrosis group, there were four females and two males. The age range was seven to 35 years of age, with a mean age of 23.6 years. At the time of the study, all subjects were stable in their disease and none were hospitalized for an acute exacerbation. Four of the six subjects were on antibiotic therapy and none were on bronchodilator therapy.

All subjects in the cystic fibrosis group were given a clinical score for cystic fibrosis, based on the National Institute of Health's scoring system for cystic fibrosis, as developed by Taussig et al. (1973). The scores ranged from a high of 92 to a low of 49, with a mean of 77.8. A score of 100 indicates a normal healthy state, while a decreasing score indicates increasing evidence of clinical disease. Thus, the above scores indicate a clinical severity range from mild to severe (see Table 1).
Table 1. Characteristics of the Subjects: Diagnosis, Age, Sex, Height, Weight, Clinical Score, Antibiotic, and Bronchodilator Therapy

<table>
<thead>
<tr>
<th>Subject</th>
<th>Diagnosis</th>
<th>Age in years</th>
<th>Sex</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Clinical score</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CF</td>
<td>21</td>
<td>M</td>
<td>160.5</td>
<td>53.2</td>
<td>85</td>
<td>Antibiotics</td>
</tr>
<tr>
<td>2</td>
<td>CF</td>
<td>35</td>
<td>F</td>
<td>158</td>
<td>50.4</td>
<td>90</td>
<td>Antibiotics</td>
</tr>
<tr>
<td>3</td>
<td>CF</td>
<td>26</td>
<td>F</td>
<td>158.5</td>
<td>48.5</td>
<td>88</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>CF</td>
<td>7</td>
<td>F</td>
<td>123</td>
<td>19.3</td>
<td>63</td>
<td>Antibiotics</td>
</tr>
<tr>
<td>5</td>
<td>CF</td>
<td>31</td>
<td>F</td>
<td>158.2</td>
<td>45</td>
<td>49</td>
<td>Antibiotics</td>
</tr>
<tr>
<td>6</td>
<td>CF</td>
<td>22</td>
<td>M</td>
<td>165.2</td>
<td>53</td>
<td>92</td>
<td>--</td>
</tr>
<tr>
<td>7</td>
<td>B</td>
<td>41</td>
<td>F</td>
<td>157.4</td>
<td>45.9</td>
<td>NA</td>
<td>Bronchodilators</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>60</td>
<td>F</td>
<td>161.2</td>
<td>44.4</td>
<td>NA</td>
<td>Bronchodilators</td>
</tr>
<tr>
<td>9</td>
<td>B</td>
<td>71</td>
<td>F</td>
<td>157</td>
<td>50</td>
<td>NA</td>
<td>Antibiotics</td>
</tr>
</tbody>
</table>
The group of subjects with a diagnosis of bronchiectasis consisted of three females, ranging in age from 41 to 71 years of age. The mean age was 57.3 years. Two of the three subjects were on oral bronchodilators at the time of the present study and one was on oral antibiotic therapy. All medications were held constant during each experimental protocol in the study (see Table 1). One subject was hospitalized in a stable condition for postural drainage treatments and routine care because of an unstable family situation.

**Analysis of the MEFV Curves**

A composite of three flow volume curves was recorded pretreatment and at 60 minutes posttreatment for each experimental treatment session. Baseline calculations of forced vital capacity (FVC), peak expiratory flow rate (PEFR), $\dot{V}$ max 50 and $\dot{V}$ max 25, at 50 per cent and 25 per cent of FVC respectively, were then determined from each composite pretreatment flow volume curve. Following postural drainage, manual percussion and vibration, or postural drainage with mechanical vibration, posttreatment composite flow volume curves were obtained and the data were compared with the baseline measurements. Isovolume flow rates were calculated on the post-drainage curves in the following manner. Using the pretreatment MEFV curve, measurements were made of the volume down from total lung capacity (TLC) to 50 per cent
(volume 1) and 25 per cent (volume 2) of the baseline FVC. Volume 1 and 2 were the points at which \( \dot{V} \text{ max } 50 \) and \( \dot{V} \text{ max } 25 \) were measured. The same volumes (volume 1 and volume 2) were then subtracted from TLC on the posttreatment curves and were considered to be the isovolume points. The flow rates at these points on the curve were then measured and reported as the isovolume flows near 50 per cent of FVC and 25 per cent of FVC (see Figure 4). Individual subjects' flow data, which were collected during the treatment protocols, can be found in Appendices H and I.

The absolute range and mean differences from baseline for FVC at 50 minutes post-mechanical vibration and the standard percussion and vibration treatment are presented in Figure 5. For mechanical vibration, the range was +.16 liters to +.70 liters from baseline with all nine subjects demonstrating an increase. The mean difference was +.36 liters from baseline.

For the standard percussion and vibration treatment, the range was -.08 to +.20 liters from baseline with eight subjects demonstrating an increase in FVC and one with no change from baseline. The mean difference was +.15 liters from baseline.

The absolute range and mean differences from baseline for PEFR at 60 minutes post-mechanical vibration and the standard percussion and vibration treatment are presented in Figure 6. For mechanical vibration, the range was -.04 liters to +.24 liters from baseline with four
Figure 4. Calculation of Isovolume Flow Rates from the MEFV Curve — from Feldman (1976:42); used with written permission.
Figure 5. Absolute Range and Mean Differences from Baseline for FVC at 60 Minutes Post Mechanical Vibration and the Standard Percussion and Vibration Treatment.
Figure 6. Absolute Range and Mean Differences from Baseline for PEFR at 60 Minutes Post Mechanical Vibration and the Standard Percussion and Vibration Treatment.
subjects demonstrating an increase and five subjects a decrease. The mean difference was -0.08 liters from baseline.

For the standard percussion and vibration treatment, the range was -1.20 to +0.24 liters from baseline with two subjects demonstrating an increase, five a decrease and two remaining unchanged. The mean difference was -0.30 liters.

Figure 7 represents the absolute range and mean differences from baseline for $\dot{V}$ max 50 at 60 minutes post-mechanical vibration and the standard percussion and vibration treatment. For mechanical vibration, the range was -0.20 to +0.70 liters from baseline with seven subjects demonstrating an increase and two a decrease. The mean difference was +0.19 liters from baseline.

For the standard percussion and vibration treatment, the range was 0 to +0.40 liters from baseline. Eight subjects demonstrated an increase with one remaining unchanged. The mean difference was +0.16 liters from baseline.

Figure 8 represents the absolute range and mean differences from baseline for $\dot{V}$ max 25 at 60 minutes post-mechanical vibration and the standard percussion and vibration treatment. For mechanical vibration, the range was 0 to +0.90 liters from baseline with seven subjects demonstrating an increase and two remaining unchanged. The mean difference was +0.25 liters from baseline.
Figure 7. Absolute Range and Mean Differences from Baseline for $V_{\text{max}}$ 50 at 60 Minutes Post Mechanical Vibration and the Standard Percussion and Vibration Treatment.
Figure 8. Absolute Range and Mean Differences from Baseline for Vmax 25 at 60 Minutes Post Mechanical Vibration and the Standard Percussion and Vibration Treatment.
For the standard percussion and vibration treatment, the range was 0 to +.44 liters from baseline. Eight subjects demonstrated an increase and one remained unchanged. The mean difference was +.16 liters from baseline.

**Statistical Analysis**

All measurements obtained at 60 minutes posttreatment were subjected to statistical analysis. Because the number of subjects in each subgroup was too small, the total combined group was used for analysis. For all measurements, to assure that baseline data on the two treatment days were similar, and to assure that posttreatment improvements in volume and flows were true changes, and not due to differences in baseline pretreatment measurements for each treatment regimen, the Wilcoxon matched pairs signed rank two tailed test was used (Hollander and Wolfe, 1973). Comparisons of pre-postural drainage with mechanical vibration FVC, PEFR, \( \dot{V} \) max 50 and \( \dot{V} \) max 25; and pre-postural drainage with manual percussion and vibration values for FVC, PEFR, \( \dot{V} \) max 50 and \( \dot{V} \) max 25 showed no significant difference in baseline measurements (p greater than .12).

**Forced Vital Capacity**

At 60 minutes after postural drainage with mechanical vibration, the FVC increased in all nine subjects. The mean difference was +.36 liters with a range of +.16 to
+.70 liters for the total combined group. The hypothesis that there would be a significant increase in FVC at 60 minutes posttreatment was tested using a Wilcoxon matched pairs signed rank one-tailed test (Hollander and Wolfe, 1973) to test for increases between pretreatment and posttreatment measurements. There was a significant increase at the .002 level. At 60 minutes following postural drainage, manual percussion and vibration, the FVC was shown to be increased in eight subjects and remained unchanged from baseline in the one other subject (see Table 2). The mean difference was +.154 liters with a range of -.08 to +.20 liters for the total combined group. As it was also hypothesized that there would be a significant increase in the FVC at 60 minutes following the treatment, the Wilcoxon matched pairs signed rank one-tailed test (Hollander and Wolfe, 1973) was used to test for increases between pretreatment and posttreatment measurements. A significant increase was demonstrated at the .004 level. Therefore, the hypothesis that there would be a significant increase in FVC following either treatment at 60 minutes was accepted. To test for significant difference between the two forms of therapy, a two-tailed student T test was used to analyze the findings. It was found that for FVC there was a significant difference between treatment with mechanical vibration, resulting in a larger degree of improvement (p less than .005).
Table 2. Total Volume of Sputum Raised During Each Treatment Regimen for Subjects at 60 Minutes Post-treatment

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Vibrator (cc's)</th>
<th>Manual (cc's)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>M</td>
<td>CF</td>
<td>20</td>
<td>8</td>
</tr>
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<td>2</td>
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<td>F</td>
<td>CF</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>F</td>
<td>CF</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>F</td>
<td>CF</td>
<td>5</td>
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<td>5</td>
<td>26</td>
<td>F</td>
<td>CF</td>
<td>5</td>
<td>5</td>
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<tr>
<td>6</td>
<td>22</td>
<td>M</td>
<td>CF</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>F</td>
<td>B</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>41</td>
<td>F</td>
<td>B</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>71</td>
<td>F</td>
<td>B</td>
<td>45</td>
<td>25</td>
</tr>
</tbody>
</table>
Peak Expiratory Flow Rate

At 60 minutes after postural drainage and mechanical vibration, the PEFR was increased in four subjects and decreased in five. The mean difference was -.08 liters with a range of -.04 to +.24 liters for the total combined group. Following the postural drainage, manual percussion, and vibration treatment, two subjects increased their PEFR, five decreased it and two remained unchanged when compared to pretreatment baseline parameters. The mean difference for the total group was -.30 liters with a range of -1.20 to +.24 liters. It was originally hypothesized that there would be a significant increase in PEFR at 60 minutes following either treatment regimen. However, as the data demonstrated, many subjects decreased their peak flows and the hypothesis was rejected. An aposteriori hypothesis that pretreatment peak flows would equal posttreatment peak flows was substituted, therefore, and the data were subjected to analysis using the Wilcoxon matched pairs signed rank two-tailed test (Hollander and Wolfe, 1973). No significant change in peak flow rates with either treatment regimen was demonstrated when compared with pretreatment parameters. The significance level was greater than 0.05 for the total combined group. There was no significant difference for PEFR between the two therapies.
Isovolume Flow Near 50 Per Cent FVC

At 60 minutes following postural drainage and mechanical vibration, the isovolume flow near 50 per cent of FVC was increased in seven subjects and decreased in the remaining two subjects. The mean difference was +.19 liters with a range of -.20 to +.70 liters. The Wilcoxon matched pairs signed rank one-tailed test (Hollander and Wolfe, 1973) was used to test for an increase between pretreatment $V_{max50}$ and posttreatment $V_{max50}$ measurements. Results demonstrated a significant increase at the .049 level. Therefore, the hypothesis that there would be a significant increase in $V_{max50}$ at 60 minutes posttreatment with postural drainage and mechanical vibration was accepted.

At 60 minutes following postural drainage, manual percussion and vibration, the isovolume flow at near 50 per cent FVC was increased in eight subjects and remained unchanged from baseline measurements in the remaining subject. The mean difference was +.16 liters with a range of 0 to -.40 liters. The Wilcoxon matched pairs signed rank one-tailed test (Hollander and Wolfe, 1973) was then used to test for an increase between pretreatment $V_{max50}$ and posttreatment $V_{max50}$ measurements. A significant increase was found at a level of .004. The hypothesis that there would be a significant increase in $V_{max50}$ at 60 minutes following postural drainage, manual percussion and vibration was therefore
accepted. There was no significant difference in the degree of change for $\dot{V}_{\text{max} 50}$ between the two treatment forms.

**Isovolume Flow Near 25 Per Cent FVC**

The isovolume flow near 25 per cent of FVC was increased in eight subjects and remained unchanged from baseline measurements in the remaining one subject 60 minutes following postural drainage and mechanical vibration. The mean difference was +.25 liters with a range of 0 to +.90 liters. To test for increases between the pretreatment $\dot{V}_{\text{max} 25}$ and the posttreatment $\dot{V}_{\text{max} 25}$ measurements, a Wilcoxon matched pairs signed rank one-tailed test (Hollander and Wolfe, 1973) was used. Results demonstrated a significant increase at the .008 level. The hypothesis, therefore, that there would be a significant increase in $\dot{V}_{\text{max} 25}$ following postural drainage and mechanical vibration was accepted.

For the postural drainage, manual percussion and vibration treatment regimen, at 60 minutes posttreatment, the isovolume flow near 25 per cent of FVC was increased in eight subjects and remained unchanged from baseline measurements in the remaining subject. The mean difference was +.16 liters with a range of 0 to +.44 liters for the total combined group. The Wilcoxon matched pairs signed rank one-tailed test was done to test for increases between pretreatment and posttreatment flow measurements near 25 per cent FVC (Hollander and Wolfe, 1973). Results
documented a significant increase at the .004 level of significance. The hypothesis that there would be a significant increase in \( \dot{V} \) max 25 at 60 minutes following postural drainage, manual percussion and vibration was therefore accepted.

There was no significant difference in the degree of changes for \( \dot{V} \) max:25 between the two treatment forms.

**Sputum Production**

The sputum raised during both treatment regimens was collected, along with the sputum produced during the 60 minutes following the completion of both treatments. Sputum volumes were then measured, using a 10 cubic centimeter (cc) syringe. In all subjects, the volume of sputum raised during the postural drainage with mechanical vibration treatment was either equal to, or slightly greater than, that raised during postural drainage and manual percussion and vibration (see Table 2). However, there was no correlation between the volume of sputum raised and changes in FVC, PEFR, \( \dot{V} \) max 50 or \( \dot{V} \) max 25.

The total mean sputum volume for the combined group mean for the vibrator treatment was 14.4 cc's and 8.3 cc's for the manual percussion and vibration treatment. A Wilcoxon matched pairs two-tailed T test was done to test for true differences in sputum between the
two therapies. A significant difference was found at the .05 level for mechanical vibration.

Other Variables

Of the nine subjects in the study, six preferred the postural drainage with manual percussion and vibration treatment, and three preferred the mechanical vibrator with postural drainage. Two of the subjects with cystic fibrosis, ages seven and 26 years, preferred the mechanical vibrator. Only one subject with bronchiectasis, age 71 years, preferred the mechanical vibrator. All were female.

The subjective reasons given for preference of the mechanical vibrator, however, by the subjects ranged from "it seems to take less time," which was given by the seven year old child with a particular dislike for her percussion and drainage therapy, to "increased independence" and "increased sputum raised without increased effort."

The side effects caused by the mechanical vibrator may have also influenced a subject's preference. The main complaints with the mechanical vibrator were "jumping eyes" and "itching and redness of the skin," even though the vibrator was used over one layer of clothing.

Summary

In summary, the following significant changes were demonstrated in posttreatment flow volume measurements.
1. At 60 minutes following postural drainage and mechanical vibration there was a significant increase in FVC (p less than 0.01).

2. At 60 minutes following postural drainage with manual percussion and vibration there was a significant increase in FVC (p less than 0.01).

3. At 60 minutes following postural drainage and mechanical vibration there was a significant increase in \( \dot{V} \) max 50 (p less than 0.05).

4. At 60 minutes following postural drainage with manual percussion and vibration there was a significant increase in \( \dot{V} \) max 50 (p less than 0.01).

5. At 60 minutes following postural drainage and mechanical vibration there was a significant increase in \( \dot{V} \) max 25 (p less than 0.01).

6. At 60 minutes following postural drainage with manual percussion and vibration there was a significant increase in \( \dot{V} \) max 25 (p less than 0.01).

7. At 60 minutes following either treatment regimen, there was no significant increase in PEFR (p greater than 0.50). Peak expiratory flow rate remained unchanged.

8. At 60 minutes, there was no significant difference in flows between the two treatment regimens (all F values greater than .748 for any lung function
test), although FVC had a significantly greater increase with mechanical vibration.

9. At 60 minutes, there was a significantly greater amount of sputum raised with the mechanical vibrator treatment (p at the .05 level).
CHAPTER 5

DISCUSSION AND CONCLUSIONS

The following chapter compares and contrasts the findings of this study with those of other investigators. The results are interpreted in terms of physiological mechanisms, as well as drawing clinical implications from the data. Further study recommendations are also included.

**Forced Vital Capacity**

In the present study, FVC demonstrated a statistically significant increase (p value less than 0.01) from baseline measurements at 60 minutes post-drainage for both treatment regimens. A mean change of +.15 liters for manual percussion and vibration with postural drainage, and a +.36 liters mean change with postural drainage with mechanical vibration were observed. Also, a greater degree of improvement in FVC was noted with mechanical vibration when compared to postural drainage, percussion, and vibration.

These findings were in contrast to the study done by March (1971), where no significant change in FVC was reported at 30 minutes post-postural drainage in 20 subjects with chronic obstructive pulmonary disease. The study, however, did not include percussion and vibration.
with the postural drainage treatment. In Feldman's (1976) study, with a mixed sample of 19 subjects with cystic fibrosis or chronic bronchiectasis, there was no significant increase in FVC at five and 15 minutes post-postural drainage with manual percussion and vibration. However, at 45 minutes post-drainage, Feldman did report a trend toward an increase in FVC. The Motoyama (1973) study, with a sample of 10 cystic fibrosis subjects, on the other hand, also reported a significant increase in FVC at 45 minutes, although no significance level was given. The data at 60 minutes in the present study would tend, therefore, to support the conclusion that FVC increases following postural drainage with either treatment regimen.

**Peak Expiratory Flow Rates**

The peak expiratory flow rate (PEFR) at 45 minutes in the present study decreased for all subjects following both treatment protocols. At 60 minutes, the data for PEFR were subjected to statistical analysis, with a mean change from baseline of -.30 for manual percussion, vibration and postural drainage, and -.08 for postural drainage with mechanical vibration. However, further statistical analysis, using an aposteriori hypothesis, demonstrated PEFR to be unchanged from baseline measurements. This finding was in contrast to those of some other investigators. In the Feldman (1976:63) study at 45 minutes post-drainage, a
significant increase in PEFR was observed in the cystic fibrosis subgroup. Tecklin and Holsclaw (1975) also reported a statistically significant increase (p less than 0.0005) in PEFR with a mean change of +6 per cent at five minutes post-drainage in 26 subjects with cystic fibrosis. In the Motoyama (1973) study, a significant increase, with a mean change of +10 percent, was reported for PEFR at 45 minutes in 10 cystic fibrosis subjects.

Isovolume Flows

The present study also demonstrated a statistically significant increase in isovolume flows at near 50 per cent (V max 50) and 25 per cent (V max 25) FVC at 60 minutes posttreatments with all p values less than 0.05. Calculations of V max 50 and V max 25 at these isovolume points showed a mean change for both treatments of +.16 (p values of less than 0.01) when postural drainage, manual percussion and vibration were utilized. Mean changes for postural drainage with mechanical vibration at V max 50 and V max 25 were +.19 (p value less than .05) and +.25 (p value less than .01), respectively.

These findings are consistent with those of Feldman (1976), who found that there was a significant increase (p less than 0.05) in isovolume flows near 25 per cent and 50 per cent FVC at 45 minutes post-postural drainage. The findings of this study also are consistent with those of
Motoyama (1973), who demonstrated a statistically significant increase in $\dot{V}$ max 25 and $\dot{V}$ max 50 at 45 minutes post-postural drainage. The sample consisted of 10 subjects with cystic fibrosis. He reported a mean change in $\dot{V}$ max 50 of approximately +30 per cent and a mean change in $\dot{V}$ max 25 of about +58 per cent. Thus, the present study would support the conclusions of Motoyama and Feldman. These data support the theory that postural drainage with manual percussion and vibration clears secretions from peripheral airways (Motoyama, 1973:336). Although the magnitude of improvement in isovolume flows tended to be greater with postural drainage and mechanical vibration, no statistically significant difference for flow rates was found between the two treatment protocols of the present study. The same theory conclusions, therefore, may be drawn for the mechanical vibrator.

**Physiological Interpretations**

In an attempt to explain why flow rates significantly improved at low lung volumes, while little change was demonstrated at higher lung volumes, several theories are possible. As was previously stated in the study, the treatment of postural drainage with manual percussion and vibration is, in itself, an energy-consuming procedure. Patients often complain of fatigue following the treatment. Thus, since flow rates at high lung volume (PEFR) are
effort-dependent, they can be diminished if a subject is experiencing post-drainage fatigue. Also, if a subject is experiencing any shortness of breath or wheezing, both possible treatment side effects, the resulting increase in the work of breathing can further tire the subject and decrease flow rates at large lung volumes.

Another possible explanation of why PEFR may be decreased post-drainage is that secretions have been mobilized from peripheral airways into the larger central airways. Since PEFR is a function of high lung volume, the resulting increase in airway resistance from secretions within the larger airways would decrease flows. Changes in flow would be small but consistent.

As the sputum was mobilized into the larger airways, resistance to flow decreased in the smaller airways, thereby resulting in an increase in flow rates at low lung volumes. Low lung volume flows are also effort independent, unlike flows at high lung volume. Thus, as TLC was assumed to be constant throughout the study, increases in flow rates at low lung volume (V max 50 and V max 25) are functions of decreased airway resistance in small peripheral airways.

Another interpretation of flows at low lung volumes has been proposed by Mead (1978). He states that the shape of the MEFV curve in the non-homogenous (diseased) lung may result from differences and rate of emptying. Less obstructed areas empty first and at a faster rate, while
more obstructed areas empty slower and last. Thus, a
decrease in the number of obstructed or slow-phase areas
in the lung would be reflected in improved flows at low
lung volumes. Therefore, changes in airway resistance and
flow rates at low lung volume in small airways are more
sensitive indicators of improved lung function than those
at higher lung volume.

Sputum Production

Of the nine subjects in the study, eight produced
sputum during both treatments. Three of the eight demon­
strated no difference between the amount of sputum
expectorated during either treatment. The remaining five
subjects demonstrated a mean increase of +51 per cent with
postural drainage and mechanical vibration. In previous
studies done by Anthonisen et al. (1964), March (1971),
and Feldman (1976), no significant correlation could be
shown between the volume of sputum raised and changes in
flows posttreatment. The present study also supported
previous studies, as above, in the conclusion that the
volume of sputum raised during the treatments does not
reflect the efficacy of these treatments on the overall lung
function. The present study also supported Pavia et al.
(1976) in the fact that mechanical vibration raised more
sputum than postural drainage.
Contrary to previous reports of wheezing during the postural drainage procedure (Tecklin and Holsclaw, 1975; and Feldman, 1976), this investigator observed only mild wheezing in two subjects. Both had a diagnosis of bronchiectasis. A 60-year-old female experienced wheezing during the postural drainage and mechanical vibrator treatment in which no sputum was expectorated. The other subject, a 71-year-old female, experienced wheezing during the postural drainage, manual percussion and vibration treatment in which 25 cc's of sputum were expectorated. A possible explanation of why the other investigators observed wheezing with postural drainage can be found in the fact that they included more subjects with chronic obstructive pulmonary disease in their studies. As these subjects are more likely to have reversible bronchospastic components to their disease process, wheezing would be a more common finding. As demonstrated in the study done by Gorringe (1977:57), some subjects with chronic bronchitis have an underlying reversible bronchospastic component to their disease, and as a result, these subjects experienced an increase in airway obstruction rather than an increase in flows during postural drainage.

Other Variables

The subjective questionnaire given to subjects following participation in both treatment regimens provided
the investigator with information on the perceived benefits and side effects of each treatment. The data demonstrated no correlation between the subjects' perceived effect and that of actual objective measurements. Often the subject would state that breathing was no easier, although isovolume flow rates were better. The only side effect in which all subjects were in agreement was that of itching skin following the mechanical vibrator treatment. Whether the itching phenomena could be eliminated by removing that one layer of clothing, and whether that might make the mechanical vibrator more attractive as a treatment alternative to the other subjects, remains to be explored.

Clinical Implications

The purpose of this study was to evaluate two treatment modalities used in the treatment of patients with pulmonary disease characterized by excessive mucus production. Postural drainage, with manual percussion and vibration, is often a treatment prescribed for these patients. However, postural drainage, manual percussion, and vibration is a time-consuming, as well as energy-consuming procedure; requires a trained individual to administer; and can restrict the subject's lifestyle to one of dependency on others. As pulmonary patients become older, particularly those with cystic fibrosis, the ability to administer prescribed treatments themselves can lead to
greater independence and control over their lives. The use of a small hand-held vibrator, which has been adapted for self-use, can give that individual who desires it a sense of independence.

Through the use of MEFV curves, statistically significant evidence was obtained that demonstrated postural drainage with manual percussion and vibration, as well as postural drainage with mechanical vibration, increased FVC and isovolume flow rates near 50 and 25 per cent of FVC when compared to baseline data. It also was demonstrated that the mechanical vibration modality was as effective in improving lung function and in mobilizing sputum as was the usual manual postural drainage and percussion.

Peak expiratory flows remained the same for both treatment regimens; and although there were only two subjects who experienced audible wheezing, a possible explanation for the failure of peak flows to increase may be the presence of sputum in the central airways following the treatments. Bronchospasm or the mobilization of sputum toward the central airways would increase resistance to air flow and, thereby, decrease peak flows. As the subjects were kept quiet and allowed to rest following each treatment, the beneficial effects of ambulation on helping to expectorate sputum may have been denied the subjects. As one subject said, "When I get moving, after my treatments at home, it [sputum] really starts to come up."
Although the subjects in the present study did not experience a great deal of wheezing, shortness of breath or fatigue during the treatments, they are nonetheless side effects of the treatments. Fatigue and shortness of breath probably occur as a result of the energy expended in positioning and coughing during the treatment. Wheezing also can increase the amount of energy expended on the work of breathing. Therefore, it is important for health care professionals to be aware of these side effects, to inform the patient of their possible occurrence, and to provide adequate rest periods following such treatments.

Health professionals should continue to include postural drainage with manual percussion and vibration in the therapy prescription of patients with excessive mucus production. As improvements in isovolume flows near 50 and 25 per cent FVC have clearly demonstrated, postural drainage with percussion and vibration is an effective therapy in the mobilization of sputum away from peripheral airways. The same would hold true for postural drainage and mechanical vibration. However, it is important for those working with patients and the above treatments to keep in mind that the beneficial effects of the treatments may be difficult to evaluate in the clinical situation. Also, it is important to understand that the sputum volume produced and the subject's subjective impressions about the benefits of
Treatment regimens cannot always be positively correlated with the degree of improvement in air flow.

**Recommendations for Further Study**

The mobilization of sputum from small airways is an important goal in the treatment of patients with excessive mucus production. Therefore, the following research recommendations are suggested.

Because the available and consenting sample was so limited in this study, the study should be repeated with a larger sample size. The study also should be repeated on subjects during an acute exacerbation of their disease process, or on other hospitalized pulmonary patients. The study should also be repeated using air-helium MEFV curves to determine more specifically the treatment's effect on small airways.

While the present study and that of Feldman's (1976) did show and increased incidence of improved lung function at 45 and 60 minutes posttreatment, a study should be designed to examine the more long-range effects or benefits of these treatments. How long the benefits last, or what magnitude they increase or decrease after 60 minutes posttreatment is still not known. Measurements taken at 60, 120, and 180 minutes might prove very illuminating.

During the present study and others, the necessity of having to do three forced vital capacity (FVC) maneuvers
often stimulated coughing and sputum expectoration in the subjects. Whether this maneuver alone would be an effective treatment alternative should also be explored.

Lastly, the procedure of just deep breathing and coughing should be evaluated in patients with pulmonary disease. One study subject, who normally practiced yoga breathing, as well as doing postural drainage, percussion, and vibration, felt that the breathing exercises were often more beneficial than the drainage treatments. The breathing exercises also should be evaluated on post-surgery patients who are not chronically ill with pulmonary disease.
CHAPTER 6

SUMMARY

Cystic fibrosis and bronchiectasis, unrelated to cystic fibrosis, are diseases which are characterized by excessive mucus production, an impaired mucociliary transport system and obstructive lung disease. Postural drainage with manual persuasion and vibration is an important component in the treatment regimen of these patients. However, it is a time-consuming, as well as energy-consuming, treatment. It is also a treatment regimen that requires the assistance of another trained individual.

Since this is a society that cherishes independence, both of state and spirit, the purpose of this study was to examine the efficacy of an alternative treatment modality. A small hand-held mechanical vibrator, adapted with a long strap which allowed the subject to administer his or her own postural drainage treatment, was examined. The efficacy of this modification was compared to the more standard manual percussion and vibration treatment.

The use of the MEFV curve is a relatively new technique which looks at flows at both high and low lung volume. Previous studies have either demonstrated no
change, or were unable to evaluate the efficacy of treatment regimens by the more conventional research methods. The only exceptions are the studies done by Feldman (1976) and Motoyama (1973) which used the MEFV curve. These studies did show an increased FVC and improved isovolume flow rates.

In the present investigation, a total of nine subjects were studied. Six had a diagnosis of cystic fibrosis, and three a diagnosis of bronchiectasis unrelated to cystic fibrosis. All subjects experienced both treatment modalities. The treatment order was randomly assigned and was given three to five days apart.

Maximum expiratory flow volume curves (MEFV) were obtained prior to each treatment, as well as at 60 minutes after each treatment. Calculations of FVC and PEFR were obtained, as well as $V_{\text{max}}$ 50 and $V_{\text{max}}$ 25 at 50 per cent and 25 per cent of FVC on the pre-drainage curve. Isovolume points near 50 per cent and near 25 per cent of FVC were calculated on the posttreatment curves and were used to determine changes between pre- and posttreatment curves.

Results of the study showed that there was a significant increase (all p values less than 0.05) in FVC, $V_{\text{max}}$ 50 and $V_{\text{max}}$ 25 for both treatment regimens. The PEFR did not change, however, with either treatment form. Sputum production was slightly greater with postural drainage and mechanical vibration in five of the nine
subjects. Three produced the same amount of sputum with either treatment, and one produced no sputum with either treatment. Statistical analysis of the treatment regimens demonstrated a significant difference in treatment efficacy between the two treatment protocols.

The results of this study indicate, therefore, that postural drainage with manual percussion and vibration, as well as postural drainage with mechanical vibration, are effective treatments in improving lung function; and that, the use of a mechanical vibrator can provide effective lung hygiene, as well as give pulmonary patients a measure of independence in their own care.
APPENDIX A

SUBJECT'S CONSENT


I, Marilyn Hartsell, am conducting a study evaluating changes in breathing tests following treatment with postural drainage, percussion and vibration; and following treatment with postural drainage and mechanical vibration. I plan to record the changes in your breathing test measurements, should you agree to participate, after each of these treatments.

Benefits of the study will include demonstrating a way of evaluating effects of different treatments on breathing, and providing physicians and nurses with information about effects of each treatment on breathing tests of patients with chronic excessive mucus production. The information will be used when prescribing therapy.

Your participation in this study will require a total of four hours of your time. There is no additional cost to you for your participation. Participation will involve two, two-hour periods three to five days apart. One of these periods will consist of a 30 minute session of postural drainage during which time you will be asked to assume six different positions, each for five minutes. I will be performing percussion and vibration on your chest in each position. You will be asked to cough after each position and you will be allowed to rest for short intervals as needed. Immediately before and at 45 and 60 minutes after the treatment, I shall ask you to perform a simple breathing test. Each test involves performing three forceful and complete expirations into a recording device.

The second two-hour period will consist of a 30 minute session of postural drainage, during which time
you will be asked to assume the same six positions as described in treatment 1. During this session, however, you will be asked to self-administer vibration to your chest for two minutes in each position. An Oster handheld vibrator, which has been adapted with an additional strap for self control, will be used. You will be asked to cough after each position and you will be allowed to rest for short intervals, as needed. Immediately before and at 60 minutes after the treatment, I will ask you to perform a simple breathing test. Each test involves performing three forceful and complete expirations into a recording device.

Since you have participated in postural drainage, deep breathing and coughing, as well as participated in breathing tests before, you are aware of the temporary physical discomforts that can occur. They include a feeling of fullness in the head; increased difficulty in breathing; and tiredness. Temporary difficulty in breathing may result from positioning and/or the movement of secretions in the airways. It can be relieved by coughing up sputum and resting. A possible side effect with the use of the hand vibrator may be a slight headache.

On the days of the treatment sessions, I will ask you to abstain from the use of aerosol or positive pressure breathing treatments for at least four hours prior to each treatment and to abstain from postural drainage for at least six hours prior to treatment. For your own comfort, it is also requested that you abstain from a heavy meal before the treatment sessions. Your participation also includes permitting the investigator to record pertinent information from your chart. On the day of the study, I will ask you to answer a few questions about your feelings regarding your treatment sessions.

You can be assured of the confidential handling of the information obtained in this study. Your name will not be used. The information recorded will be coded and analyzed by computer.

If you decide not to participate in the study, it will not change your relationship with any doctor or nurse, or affect the quality of your treatment or care. I will answer any questions you may have about the study, at any time. You may withdraw from the study at any time.

If you understand what is involved and you consent to participate in this study, please sign your name below.
The nature, demands, risks, and benefits of the project have been explained to me and I understand what my (or my child's) participation involves. Furthermore, I understand that I am free to ask questions and withdraw from the study at any time without affecting any medical care, relationship with any institution or person.

Subject's signature: ___________________________ Date: ________

Parent's signature: ___________________________ Date: ________

I have carefully explained to the subject and parent the nature of the above project. I certify that to the best of my knowledge, the subject signing this consent form understands clearly the nature, demands, risks, and benefits involved in his participation in this study. A medical problem or language or educational barrier has not precluded a clear understanding of his/her involvement in this project.

Investigator's Signature: ______________________ Date: ________
LETTER GRANTING APPROVAL FOR RESEARCH

Ms. Marilyn B. Hartsell, R.N., B.S.
College of Nursing
Arizona Health Sciences Center

Dear Ms. Hartsell:

I have reviewed your proposal entitled, "The Effects of Postural Drainage with Manual Percussion and Vibration versus Postural Drainage with Mechanical Vibration on Maximal Expiratory Flows," which was submitted to the Human Subjects Committee and concur in the opinion of the College Review Committee that this is a minimal risk project. Therefore, administrative approval is granted effective October 10, 1977, with the understanding that no changes in either the procedures followed or the consent form used (copies of which we have on file) will be made without the knowledge and approval of the Human Subjects Committee and the College Review Committee. Any physical or psychological harm to any subject must also be reported to each committee.

A university-wide policy requires that all signed consent forms be kept in a permanent file in the College Office to assure their accessibility in the event that university officials need the information and the principal investigator is no longer on the staff or unavailable for some other reason. One exception is for those cases in which the subject is hospitalized or an out-patient. In such cases the consent form may be filed with the patient's chart.

Sincerely yours,

Milan Novak, M.D., Ph.D.
Chairman
Human Subjects Committee

xc: Ada Sue Hinshaw, Ph.D.
Departmental Review Committee
MEMORANDUM

TO: Marilyn Hartsell
FROM: Lynn M. Taussig, M.D.
RE: Masters Thesis Protocol

You have my permission to approach the cystic fibrosis patients for participation in your postural drainage study. However, I would like to clear the names with you with respect to those you wish to approach. I think I can be of help to you in indicating which ones would be more willing to participate.

/ral
APPENDIX D

PHYSICIAN'S CONSENT, USE OF CLINIC FACILITIES

THE UNIVERSITY OF ARIZONA
HEALTH SCIENCES CENTER
TUCCSON, ARIZONA 85724

COLLEGE OF MEDICINE
DIVISION OF RESPIRATORY SCIENCES

MEMORANDUM

TO WHOM IT MAY CONCERN

FROM: Robert A. Barbee, Director
St. Luke's Chest Clinic

DATE: October 24, 1977

Re: Use of Clinic Facilities by Marilyn B. Hartsell, R.N.

The above-mentioned student has my permission to utilize the facilities of St. Luke's Chest Clinic for the collection of data for her graduate school thesis.

RAB/mh
APPENDIX E

HISTORY SHEET

Name: ___________________ Date: ________________

I.D.# ___________________ Time: ________________

Age: ___________________ Diagnosis: C. F. _____

Bronchiectasis______

Height_____ Weight_____ Sex_____ Temp._____

Physical Finding

Chest X-ray date: ______ Findings:

Blood Gases: ph____ PaO2_______ PCO2_______

02 Sat._______ HCO3_______

Medications Taken:

Cystic Fibrosis Score______________

Frequency of Postural Drainage at home__________

Duration of Postural Drainage at home__________

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APPENDIX F

DATA COLLECTION SHEET

ID#_______

MEFV SAMPLES

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<thead>
<tr>
<th>Treatment 1</th>
<th>FVC</th>
<th>PEFR</th>
<th>( \hat{V} \text{ max } 50 )</th>
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<td></td>
</tr>
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<td>60&quot; post-treatment</td>
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Sputum Volume_______
" Color________
" Consistency_______

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<th>Treatment 2</th>
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<th>( \hat{V} \text{ max } 50 )</th>
<th>( \hat{V} \text{ max } 25 )</th>
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Sputum Volume_______
" Color________
" Consistency_______

77
APPENDIX G

QUESTIONNAIRE

Subject Code # ____________

1. Following my treatment with postural drainage with manual percussion and vibration, I experienced:
   - wheezing
   - headache
   - coughing
   - increased sputum
   - easier breathing
   - nothing at all

2. Following my treatment with postural drainage with mechanical vibration, I experienced:
   - wheezing
   - headache
   - coughing
   - increased sputum
   - easier breathing
   - nothing at all

3. I preferred the treatment with:
   - postural drainage with manual percussion and vibration
   - postural drainage with mechanical vibration

Additional comments:
APPENDIX H

INDIVIDUAL FLOW AND VOLUME CALCULATIONS,MECHANICAL VIBRATION
Table H.1. Individual Flows and Volumes Generated by Subjects During Postural Drainage and Mechanical Vibration

<table>
<thead>
<tr>
<th>Subject</th>
<th>Baseline FVC</th>
<th>Posttreatment FVC at 60 min</th>
<th>Baseline PEFR</th>
<th>Posttreatment PEFR at 60 min</th>
<th>50% Baseline FVC (%)</th>
<th>Baseline Flow at 60 min</th>
<th>Isovolume Flow at 60 min 50% Baseline Flow</th>
<th>Isovolume Flow at 60 min 25% Baseline Flow</th>
<th>Isovolume Flow at 60 min Baseline Flow</th>
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<tbody>
<tr>
<td>1</td>
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</table>
APPENDIX I

INDIVIDUAL FLOW AND VOLUME CALCULATIONS, MANUAL VIBRATION
<table>
<thead>
<tr>
<th>Subject</th>
<th>Baseline FVC</th>
<th>Posttreatment FVC at 60 min</th>
<th>Baseline PEFR</th>
<th>Posttreatment PEFR at 60 min</th>
<th>50% Baseline FVC (l)</th>
<th>Baseline V max 50</th>
<th>Isovolume Flow at 25% Baseline FVC</th>
<th>Baseline V max 25</th>
<th>Isovolume Flow at 60 min</th>
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Table I.1. Individual Flows and Volumes Generated by Subjects During Postural Drainage and Manual Vibration
REFERENCES


Traver, Gayle. "Approaches to Airway Care or Sputum is Beautiful," unpublished paper from the Division of Respiratory Diseases, University of Arizona, 1977.


