FACTORS CONTRIBUTING TO BREATHLESSNESS

By

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FACTORS CONTRIBUTING TO BREATHLESSNESS

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ABSTRACT

Breathlessness may be defined as the conscious awareness of respiratory muscle effort. As with any skeletal muscle it is to be expected that the sense of effort increases as the pressure generated by this muscle increases as well as the velocity and extent of shortening. The purpose of this study was; 1. to quantify the intensity of breathlessness during exercise and respiratory loading; 2. to isolate the contributions of inspiratory muscle pressure to breathlessness; 3. to see if extent of shortening, velocity of shortening, frequency (fb), and duty cycle (Ti/Ttot) contribute to the intensity of breathlessness independently. The intensity of inspiratory muscle pressure was quantified by measurement of mouth pressure (Pm) as well as the estimated esophageal pressure (Pes), the extent of shortening by tidal volume (Vt), and the velocity of shortening by inspiratory flow (Vi). Six normal subjects underwent eight incremental (100 kpm/min/min) exercise tests on a cycle ergometer to maximum capacity. The first and last test were unloaded and the intervening tests were performed with external added resistances and elastances presented in random order. The resistances and elastances were selected to provide a wide range inspiratory pressures, tidal volumes, and flows. The inspiratory resistive loads (33, 57, 73 cm H2O/l/s) were used mainly to vary the flow (functional velocity of shortening of inspiratory muscles). The inspiratory elastic loads (21, 41, 52 cm H2O/l) were used mainly to vary the tidal volume (functional extent of shortening). At rest and at the end of each min during exercise the subjects estimated the intensity of breathlessness (Y) by selecting a number ranging from 0–10 (Borg psychophysical scale), 0 indicating no appreciable breathlessness and 10 the maximum tolerable sensation.

When the velocity was altered (resistive loading study) breathlessness was significantly related to inspiratory pressure ($p<0.0001$), peak inspiratory flow ($p<0.0001$), frequency of breathing ($p<0.01$) and duty cycle ($p<0.01$). When the extent of shortening was altered (elastic loading study) breathlessness was significantly related to inspiratory pressure ($p<0.001$), tidal volume ($p<0.001$), and frequency of breathing ($p<0.001$).

The results indicated that the perceived magnitude of breathlessness is closely related to the pressure generated by the inspiratory muscles and the shortening pattern of these muscles as reflected in Vt, Vi, Fb, and Ti/Ttot. The results also indicated that the contribution of these factors to the intensity of breathlessness differs quantitatively between loaded and unloaded breathing. Thus, in normal unloaded breathing the velocity and degree of shortening are important factors contributing to breathlessness during exercise; with resistive loading the inspiratory pressure, the velocity, and the duty cycle are important; with elastic loading the inspiratory pressure, the extent of shortening, and the frequency are important.

The major contributions of these studies were in quantifying the intensity of breathlessness, and defining both the factors contributing to breathlessness and the relative importance of each.

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E	Elastance (cmH20/L)
fb	Frequency of breathing (Br/min)
FEV1	Forced expiratory volume measured over one sec (l)
FRC	Functional residual capacity of the lung (l)
HR	Heart rate (Beat/min)
KPM	Kilopound meter/min
MIP	Maximum Inspiratory pressure generated against occlusion at FRC (cmH20)
P-mouth	The pressure measured at the mouth (cmH20)
Pint	The integrated pressure at the mouth (cmH20.sec/min)
PEtCO2	End-tidal CO2 (mmHg)
PECO2	Mixed expired CO2 (mmHg)
PaCO2	Arterial CO2 (mmHg)
R	Resistance (cmH20/l/sec)
SaO2%	Arterial oxygen saturation (%)
TE	Expiratory Time (sec)
Ti	Inspiratory time (sec)
Ti/Ttot	Duty cycle
TTOT	Total time of respiratory cycle (sec)
$\dot{V}$A	Alveolar ventilation (l/min)
VC	Vital capacity (l)
$\dot{V}$CO2	Carbon dioxide output (l/min)
Vd	Dead space volume (l)
$\dot{V}$E	Minute ventilation (l/min)

LIST OF ABBREVIATIONS (continued)

$\dot{V}i$	Inspiratory flow rate (l/s)
$\dot{V}O2$	Oxygen uptake (l/min)
Vt	Tidal volume (l)
$\dot{W}$	Work rate (Kpm/min)
$\dot{W}resp$	Work rate of inspiratory muscles (kpm/min)
*	Sign of multiplication
±	Standard error

CHAPTER 1: BREATHLESSNESS

1.1 INTRODUCTION

Man experiences a variety of respiratory sensations under normal and pathological conditions, particularly when the act of breathing is mechanically hindered, either from internal or external factors, or whenever the breathing volume is increased. The terms "Dyspnea", "Shortness of breath", or "Breathlessness", are variously used by clinicians and physiologists; some use the terms interchangeably, but others consider that they describe sensations that differ in quality or quantity. In this thesis the use of the terms is governed by the following premises - that dyspnea or breathlessness is a sensation, so that the general principles of the sensory neurophysiology apply; that the sensations are most commonly associated with increased activity or weakness of the respiratory muscles; and that the sensation may vary in intensity and quality, but the intensity of breathlessness or dyspnea is independent of the quality and dependent only on the intensity of respiratory effort.

1.1.1 Dyspnea and Breathlessness

The sense of respiratory distress is often divided into two terms "dyspnea" and "breathlessness". This division ascribes to "dyspnea" the awareness of difficulty in breathing such as occurs with asthma, or when the breathing is mechanically hindered; and to "breathlessness" the awareness that breathing is increased, as in heavy exercise. However, in both conditions it is the respiratory muscles which carry the burden of breathing. Thus during exercise, when the metabolic demands increase, the respiratory muscles have to contract harder and faster to increase ventilation to supply the body gas exchange demands, while in patients with increased impedance of the respiratory system the respiratory muscles have to generate more force to maintain the required ventilation. For this reason, in this thesis dyspnea or breathlessness are used synonymously to describe the subjective sensation of the effort exerted by the respiratory muscles.

1.1.2 Quality vs Quantity

Is the sensation perceived during the mechanical hindrance of breathing different in quality from that perceived at the limit of exercise or it is a matter of quantity ? Breathlessness felt at the limit of exercise is different from the laboured, difficult, and uncomfortable sensation of hindered breathing in the quality of the sensation. However, the magnitude of respiratory muscle effort and the intensity of breathlessness or dyspnea is comparable. Furthermore, hyperpnea, the awareness of increased ventilation, when it is not accompanied by distress is often unaccompanied by significant respiratory effort. This does not imply that there are not other sensations which may be associated with the sense of distress, such as the sense of tightness in the neck or chest, or air hunger. In this thesis breathlessness is dealt with as any other sensory modality, in which the sensation is a continuum with a threshold and sensory magnitude.

1.1.3 Breathlessness and Subjective Sensory Physiology

For any sensory modality the linkages between the physical stimulus and the perception consist of the following elements (Fig 1.1)- the receptor which is activated by the stimulus; the sensory nerves which transmit the stimuli to the central nervous system where they are processed and become a sensory impression or sensation. As a rule, the sensation is accompanied by an interpretation with reference to what has been experienced and learned, to result in a perception. The relation between the intensity of the stimulus and the perception may be measured using psychophysical techniques.

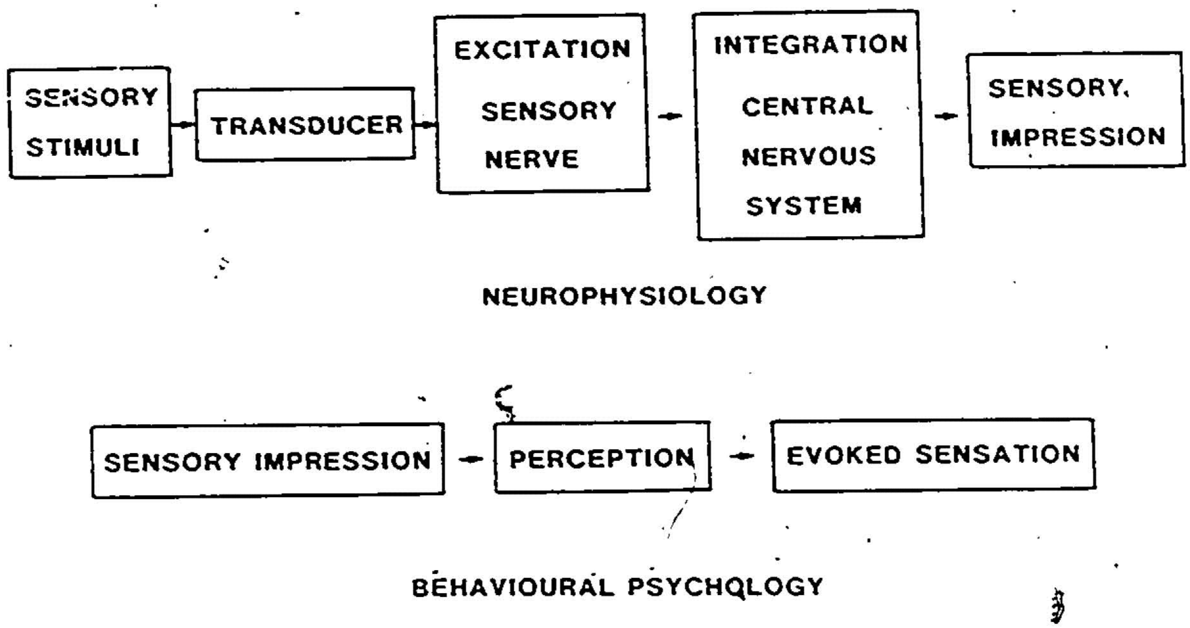

Fig 1.1 Schematic diagram of the series of sequential processes followed in the generation of conscious sensation.

The relationship between the factors contributing to breathlessness can be quantified using the psychophysical techniques. This thesis will define quantitatively the factors contributing to the perceived sensation of breathlessness resulting from exercise and loaded breathing. This information may be used to isolate specific receptors and nervous pathways utilised in the generation of breathlessness.

1.2 The Development of the Concept of Breathlessness

The understanding of breathlessness has reflected increasing understanding of respiratory and neural physiology. As each new advance has become accepted, physiologists and clinians have examined it to see what new light may be shed on breathlessness. In the last century, the understanding of breathlessness began from the interpretion of clinical observations and evolved through studies of the chemical, the reflex, the mechanical, and the psychophysical factors that may contribute to the sensation.

1.2.1 Clinical Observation Period

During the early part of the last century dyspnea was considered as a symptom. Its causes were interpreted by the observations made by the physicians mainly in pulmonary and cardiac diseases. As an example William (1840) described dyspnea as the following :" Dyspnea, difficult or disordered breathing, is the most important general symptom of disease of the chest, in as much as it implies more or less interruption to the due performance of some part of the great function of the chest respiration. Dyspnea may be caused by circumstances affecting any one or more of the several elements concerned in the function of respiration : viz the blood in the lungs, the air, the machinery of respiration by which these are brought together, and the nervous system through which the impression which prompts the respiratory act is conveyed from the lung to the medulla, and thence to the muscles which move the machinery". Thus even at that time it was recognised that many components might contribute to the symptom, including the respiratory muscles.

1.2.2 The Chemical Theory

With advances in research on the control of breathing the chemical theory regarding the mechanism of dyspnea was developed. Pfluger (1868) working on dogs found in one series of animals breathing nitrogen that arterial oxygen content fell from a control value of 14 to 18 volumes per cent to 1 or 2, with marked dyspnea resulting. In another series, breathing 30% CO2 and 70% O2 made CO2 content of arterial blood increased from 25-28 to 50-60%, with moderate dyspnea occuring. Pfluger concluded that both CO2 excess and O2 lack stimulate breathing. But he considered oxygen lack by far the stronger and quicker stimulus. He also concluded that the cause of dyspnea must be ascribed to the lack of free oxygen in the tissues of the body and particularly in the medulla oblongata. Miescher-Rusch (1885) examined the effect of breathing different mixtures of CO2 on human subjects. He stated that " a rather gross dyspneic acceleration of breathing becomes apparent when the CO2 content of air in the lungs is increased considerably less than 1 percent" and concluded that its concentration probably normally changes less than 0.1 % as a result of such process as nourishments and metabolism. Haldane and Smith (1893) showed in experiments carried out on subjects inside a closed chamber that dyspnea appeared when inspired CO2 had risen to only 3% whereas when the CO2 was absorbed by soda lime, no effect was observed until O2 fell to 14%. Winterstein (1910) introduced his theory that the arterial concentration of hydrogen ions was the common stimulus of respiratory activity. Haldane and Smith (1935), Winterstein (1921) and many other authors, found that the activity of the respiratory centre is dependent almost entirely on the hydrogen ion concentration of the arterial blood. This was followed by the studies of Gesell (1923) and Gesell and Hertzman (1926) which demonstrated the importance of the blood flow through the respiratory centre in the regulation of the breathing. This led to the general recognition of the fact that increased acidity per se or increased CO2 tension of either the arterial or the venous blood may be responsible for greater ventilation.

In the first quarter of this century, because of the results of these studies, the mechanism of dyspnea was related to the chemical factors that control breathing. Meakins (1923) stated that dyspnea is produced by two causes: (1) want of oxygen ; (2) carbon dioxide retention, absolute or relative. In his monograph on the subject Means (1924) stated that acidosis is a direct producer of hyperpnea and that hyperpnea will give rise to dyspnea to a varying degree depending in part upon its intensity and in part upon those factors which determine the available supply of pulmonary ventilation. Most of the causes of dyspnea in different diseases were interpreted according to this theory.

Although chemical factors (CO2,O2,H^+ ion) in the blood are important sources of the respiratory drive, they are not in themselves responsible for the sensation of breathlessness. This point was most elegantly established by simple experiment of Fowler. He showed that the discomfort of breath holding can be relieved by breathing gas mixtures which result in even further deterioration in blood gases (Fowler,1954). Patients with chronic airway obstruction varied greatly in their breathlessness inspite of similar levels of blood gases (Burns and Howell, 1969). Polio-encephalitis involving the medulla exhibited a progressive failure of automatic respiration and subsequently an inability to initiate the respiratory act (Plum, 1970). Abnormal chemical drives to breathe in blood must surely have been present, yet breathlessness is absent.

1.2.3 The Neural Theory

Cullen, Harrison, Calhoun, Wilkins, and Tims (1931) reported that neither during exercise nor after exercise were there significant alterations observed in hydrogen ion concentration, carbon dioxide content, carbon dioxide pressure or oxygen content of either arterial or venous blood in patients with heart diseases. They suggested that there are some mechanisms other than the chemical changes of the blood to produce dyspnea in such patients. Harrison, Harrison, Cahoun, and Marsh (1932) were amoung the first investigators to introduce the reflex theory of dyspnea. Working on normal individuals, cardiac patients and animals he and his colleagues were able to demonstrate that breathing could be stimulated by muscular movements of the hand when the circulation was cut off by means of inflatable cuffs. Also, in anesthetized dogs with intact sciatic nerves, breathing was stimulated when one leg was moved passively. When the sciatic nerve was cut, movement had no effect on respiration, and this was true whether the blood vessels were open or not. They demonstrated also that a reduction in vital capacity increased the resting ventilation through vagal reflexes from the lung. They showed the increases in pressure in the right side of the heart and the central great veins also produce reflex increases in ventilation. Harrison (1935), and Gesell and Moyer (1935) suggested that the afferent impulses from the thoracic cage and from other parts of the body can be factors in the production of dyspnea in cardiac and pulmonary diseases. Christie (1938) summarised the concept of dyspnea of this period as follows : "Though the conditions under which dyspnea occurs are various and manifold, giving rise to an impression of complexity, the fundamental causes are few and relatively simple. They consist of chemical and reflex disturbances. Chemical dyspnea would seem, however to be of minor importance. Dyspnea is usually reflex in origin".

There is no doubt that the above two factors, the humoral and the reflex, are important in driving the breathing and therefore they may induce breathlessness indirectly. This fact was confirmed by the curarization studies carried out by Campbell, Clark, Freedman, Norman and Robson (1967) and Campbell, Clark, Freedman, Godfrey, and Norman (1969) in which breath-holding carbon dioxide response curves were constructed from experiments in which rebreathing and breath-holding alternated so that exact control of PCO2 and lung volume was obtained. They found that total paralysis by curare not only grossly prolonged the breath-holding time (that is, the duration that the observers were prepared to allow the subject to remain apnoeic) but totally abolished any sensation whatever in the subjects, even though they were fully conscious. This was true at such grossly elevated CO2 pressures that the subject would have been totally unable to hold his breath under control conditions (Campbell et al., 1969). These experiments indicated that both chemical and non-chemical afferent stimuli only indirectly induce the sense of breathlessness by increasing the output to respiratory muscles: breathlessness required the development of tension by the muscles.

1.2.4 The Importance of Mechanical Factors

With the development of mechanical studies of the respiratory system, it became possible to measure all the forces and impedances involved in the act of breathing. These included the measurement of the compliance of the lung and chest wall, airway resistance, pulmonary nonelastic tissue resistance and the total work of breathing. Thus in the late thirties and forties, the attention was directed towards the respiratory muscles and their role in the genesis of breathlessness. Theories of increased work of breathing and increased oxygen cost of breathing provided the most attractive explanations of breathlessness during the third quarter of this century.

1.2.4.1 The Theory of Increased Work of Breathing

Theoretical estimation of the mechanical work of breathing was first introduced by Otis, Rahn, and Fenn (1950) based partly on theoretical and partly on experimental findings. They derived the following equation for predicting the mechanical work of breathing at low and moderate ventilation in which expiration is accomplished passively.

$$W = a\,\dot{V}^2/f + b\,\dot{V}^2 + c\,\dot{V}^3$$

where W is the work rate or power requirement, a is the elastance of the chest and lung, b and c are the constants representing nonelastic resistance involved in moving gas and displacing tissues, f is the frequency of breathing and $\dot{V}$ is the ventilation. The first term of the equation represents elastic work done in inspiration and recovered in expiration. The second and third terms represent nonelastic work. At higher ventilations where expiration involves active participation of expiratory muscles, the equation was modified to the following:

$$W = 2\,(b\,\dot{V}^2 + c\,\dot{V}^3)$$

The direct measurement of the work of breathing became possible after the introduction of intra-esophageal- pressure measurements. Marshall, McIlroy, and Christie (1954) using this technique found that mechanical work of breathing of patients in heart failure was about twice as much at rest and four or five times as much during exercise as that of normal subjects. They calculated the work of breathing in those patients by integrating the changes in besophageal pressure and tidal volume. They suggested that the sensation of dyspnea in such cases may be related to increased work of breathing. Cherniack and Snidal (1956), also using the esophageal pressure method, found the mechanical work of breathing usually to be greater than normal in patients with emphysema.

There is no doubt that conditions of increased work of breathing are associated with breathlessnesss. However, work in the strict sense (force x distance or pressure x volume) cannot be the basis of sensation because the most extreme dyspnea is caused by respiratory obstruction in which the change in volume is zero (McGregor and Blacklake, 1961). When there is absolute obstruction and the sensation is maximum, there is very little movement or displacement and therefore little work. Also there are some clinical conditions associated with respiratory muscle weakness and respiratory muscle paralysis, in which the work is not increased but patients are still suffering from severe breathlessness. Furthermore, Marshall, Stone, and Christie (1954) and Nisell (1960) found in other studies that the increase in transpulmonary pressure and not the work of breathing was more closely related to dyspnea. Finally, even if there is a general correlation between dyspnea and the increased work of breathing the translation of work into sensation must be very complex.

1.2.4.2 Oxygen Cost Theory

This theory was based on two main observations made in studies of the oxygen cost of breathing. First, the curvilinear increase in the oxygen uptake by the respiratory muscles when ventilation is increased (Campbell, Westlake, and Cherniack, 1957; Cournand, Richards, Bader, Bader, and Fishman 1954; Bartlett, Burbach, and Specht 1958) Second, the oxygen uptake of the respiratory muscles is higher for a given ventilation in patients with pulmonary and cardiac diseases than in normal subjects (Cournand et al., 1954). McIlroy (1958) concluded that when either the ventilation is increased, as during exercise, or the work of breathing increased, as when the lung and chest are mechanically abnormal, dyspnea occurs as a result of an increased oxygen cost of breathing. He suggested that dyspnea occurs when the respiratory muscles incur an oxygen debt. Inadequate supply of oxygenated blood to the respiratory muscles resulting in fatigue would be a popular present day extension of this hypothesis.

Oxygen uptake of the respiratory muscles increases with force generation. However, measured oxygen consumption by the respiratory muscles varies widely from study to study. A recent study from our own laboratory indicated that the oxygen uptake of the respiratory muscles may have been over estimated in many of some studies (Jones, Killian, Summers, and Jones, 1983, 1985); in addition, the relation between the oxygen uptake of the respiratory muscles and their force generation was found to be a linear function. Therefore with an inadequate supply of oxygenated blood to the respiratory muscles, their capacity to generate force will be reduced. Finally, this theory does not explain how dyspnea is felt or by what nervous pathways it is mediated.

1.3 The Psychophysics of Breathlessness

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science". (Lord Kelvin, 1891).

Psychophysics examines the quantitative relationship between the input parameters (i.e. the parameters of stimulus) and the output parameters (i.e. the evoked sensory response). This science has been confined to well defined domains, each of which asks specific questions about the psychophysical relationship: Is there *anything* there (detection)? Is this *different* from that (discrimination)?, *What* is it (recognition)? How *big* is it (scaling)?. Although all the domains are related, each question addresses a different aspect of the psychophysical relationship.

Psychophysical studies have been used to examine different sensory modalities. To quantify the relationship between the intensity of the stimulus and the perceived sensory magnitude open magnitude scaling is the most valid but not always the most useful technique (Stevens, 1957). The sensory magnitude is related to the physical magnitude by a power function, such that

$$W = K\,O^{n}$$

where W is the sensory magnitude, O is the physical magnitude, and n is the power function. This simple relationship is not only intuitively appealing, but neural impulse frequency also increases as a power function of the physical magnitude of stimulation for many of the primary senses (Stevens, 1970), lending further experimental support relating the sensory neural mechanism subserving the sensation .

Psychophysical studies regarding the respiratory sensation have taken two forms, detection / discrimination studies and scaling studies.

1.3.1 Detection Studies

Campbell, Freedman, Smith, and Taylor (1961) introduced the detection method to breathing and defined the threshold of detection of elastic loads in normal subjects. This method allowed for the presentation of a range of stimuli, small added elastic loads. The subject signaled detection or absence of a detectable stimulus, and the threshold was defined as the stimulus magnitude at which the subject detected the stimulus with 50% probability (Campbell et al., 1961). Later, they used the same method to define the threshold detection for resistive loads (Bennett, Jayson, Rubenstein, and Campbell, 1962).

As a result of these studies, Campbell and his collegues concluded that the mechanism of detection of such loads is most simply and generally explained by the detection of a disturbance in the appropriateness between the length and tension information generated proprioceptively in the act of breathing. They, and later Campbell and Howell (1963), suggested that in normal breathing there is an appropriate relationship between the force or tension developed by the respiratory muscles and the volume or flow that results. The presence of a mechanical hindrance to breathing disturbs this relationship and makes it inappropriate. Campbell subsequently modified this theory as follows: " The displacement (volume, flow) achieved is less than the displacement expected " and this was called "mechanical inappropriateness". Campbell suggested that breathlessness in different diseases might be due to the perception of this inappropriateness.

Accordingly, Campbell (1966) suggested the following neural mechanism for breathlessness. The respiratory stimuli integrated in the medulla with information about the mechanical state of the lungs are transformed into rhythmic nervous activity. This activity, which represents the demand for a given ventilation, is then transmitted to two control systems. Each system consists of a neural center and nerve fibers through which impulses are transmitted to the respiratory muscles. The executive system relays impulses to the regular or extrafusal muscle fibers by means of alpha-motor fibers. The supervisory system relays impulses to the intrafusal muscle spindle by means of gamma motor fibers. The spindle is parallel with the extrafusal muscle fibers. Its motor units are in series with a sensory component, the annulospiral endings, whose discharge is increased by stretch. The arrangement of the muscle fibers is such that the flow of afferent impulses from the spindles is increased by the contraction of the intrafusal muscle fibers and decreased with the contraction of extrafusal muscle fibers. Thus, variations in the rate of contraction of intra- and extrafusal muscles will be reflected in changes in the sensory output from the spindles. Additional information for the proprioceptive control of breathing may be relayed from joint receptors in the chest wall, volume receptors in the lungs and the centers controlling alpha- and gamma motor systems. There are several mechanisms by which information about length and tension may reach consciousness: (1) The afferent impulses from the peripheral receptors may be relayed directly to cortical areas subserving conscious awarness. (2) The activity of the respiratory center (demand for alveolar ventilation) and the activity related to executive and supervisory systems may have access to consciousness. (3) The proprioceptive reflex may operate via the respiratory center and change its activity, this activity then being relayed to consciousness.

The concept of "mechanical inappropriateness" initiated and stimulated the modern period of research into breathlessness and respiratory sensation in general. Thus psychophysical studies on the perception of tidal volume, inspiratory airflow, and pressure generated by the respiratory muscles have indicated that each of these variables can be perceived independently (Bakers and Tenney, 1970; Stubbing, Killian, and Campbell, 1981). The pressure generated by respiratory muscles and the effort required to generate this pressure, have been shown to be different and mediated by different mechanisms (Killian, Gandevia, Summers, and Campbell, 1984). Furthermore, the perceived effort is found to be more closely related to breathlessness than the changes in pressure (Killian et al., 1984).

1.3.2 Scaling Studies

Scalng studies are concerned with the measurement of the perceived magnitude of a stimulus with preset rules (Stevens, 1959). Two types of scaling methods have been used for the estimation of respiratory sensations, magnitude estimation and category scaling.

The magnitude estimation method, is a type of ratio scaling, in which the subjects assign a number that seems to them most appropriate to represent the magnitude of the stimulus. This method requires the subjects to maintain proportionality throughout. Sometimes a reference number is assigned to a reference stimulus so that the subjects have a reference modulus. However the use of open magnitude scaling is limited because it makes the direct comparison of sensory estimation impossible across individual subjects.

The category scaling method is a kind of interval scaling, in which a limited range of numbers are anchored to simple verbal expressions. In this method the subjects estimate the magnitude of the stimulus according to these numbers and verbal expressions. Although in certain aspects this scale is inferior to open magnitude estimation, it is useful as it allows comparison across the individual subjects and it is easy to use.

Baker and Tenney (1970) were the first to apply direct scaling to the problem of respiratory sensation. Using open magnitude estimation, they showed that the perceived magnitude of volume and pressure positively accelerated with increasing magnitude of the stimulus. The perception of volume and pressure grew as a power function of the stimulus. They showed that these findings were consistent in that the subjects reproduced volume and pressure responses to arbitrary numbers in the same numerical relationship. Their findings indicated that subjects can independently perceive tidal volume, flow, pressure, and ventilation.

Gottfried, Altose, Kelson, Fogarty, and Cherniack (1978) were the first to apply direct scaling to externally added loads. In a study on perceived magnitude of added resistive loads, they found that a group of both normal subjects and patients with airflow obstruction perceived the resistance on a ratio basis i.e. $w = K R^n$. Where K is a constant, R is the resistance , and n is a power function.

In a series of studies Killian, Mahutte, and Campbell (1981) used open magnitude scaling to examine the quantitative relationship between the sensation elicited by externally added loads to breathing and the magnitude of these loads. They found that the perceived magnitude of externally added loads follows a predictable relationship in which the psychological magnitude (w) grows as a power function (n) of the added loads. In these studies targeting either increased flow with added resistive loads or increased tidal volume with added elastic loads increased the exponent of the added loads.

In another study, they (Killian, Bucens, and Campbell, 1982) examined the nature of load sensation by examining the effects of flow rate, tidal volume, peak inspiratory pressure, and inspiratory duration on the perceived magnitude of a range of added resistive and elastic loads to breathing. They showed that the perceived magnitude of externally added loads to breathing was directly dependent on the inspiratory muscle force developed and its duration, and indirectly on the added load. This relationship was again emphasized in a later study (Stubbing, Ramsdal, Killian, and Campbell, 1983).

They examined also, the effect of increased ventilatory drive using hypercapnia, hypoxia and exercise on the perceived magnitude of externally added loads to breathing (Burdon, Killian, and Campbell, 1982). They found that the perceived magnitude of added loads increased with increasing ventilatory drive in such a manner that the increase in sensory magnitude is proportional to the increase in inspiratory muscle force developed and suggested that something dependent on this force mediates sensation. Altose et al. (Altose, Dimarco, and Strohl, 1981) reached a similar conclusion in another study using the integrated diaphragmatic electromyogram as an index of ventilatory drive. In this study Altose et al. examined the effect of drive on respiratory sensation by matching static inspiratory forces generated against an occluded airway above and below functional residual capacity. Their results led them to conclude that respiratory sensation depended primarily on muscle tension.

The relation between the perceived magnitude of added loads and the strength of inspiratory muscles was examined by Campbell et al. (Campbell, Gandevia, Killian, Mahutte, and Rigg, 1980). They showed that the perceived magnitude of an added resistive load increased after weakening of the inspiratory muscle with a partial neuromuscular blockade. In a later study Gandevia et al. (Gandevia, Killian, and Campbell, 1981) demonstrated that the perceived effort associated with maintainance of a maximal inspiratory pressure increased with the onset of fatigue whereas the perceived tension declined with the development of fatigue, accurately reflecting pressure.

Furthermore, Killian et al. (1984) examined the relation between breathlessness, effort, and tension. They added inspiratory elastic loads at both functional residual capacity and increased lung volumes in normal subjects. They asked the subjects to rate the perceived magnitude of respiratory effort, tension, and breathlessness at different lung volumes and elastic loads using Borg scale. The reproducibilty of the results was examined by open magnitude scaling and sensory matching. They found that the perceived magnitude of respiratory effort and breathlessness increased significantly as the inspiratory pressure and lung volume increased and both were highly correlated to each other as shown in figure 1.2. However, the perceived tension increased only as the inspiratory tension increased and not as lung volume increased. These results suggested that the sensation of breathlessness and effort are psychophysically the same and served by the same mechanism whereas tension is perceived by a different mechanism.

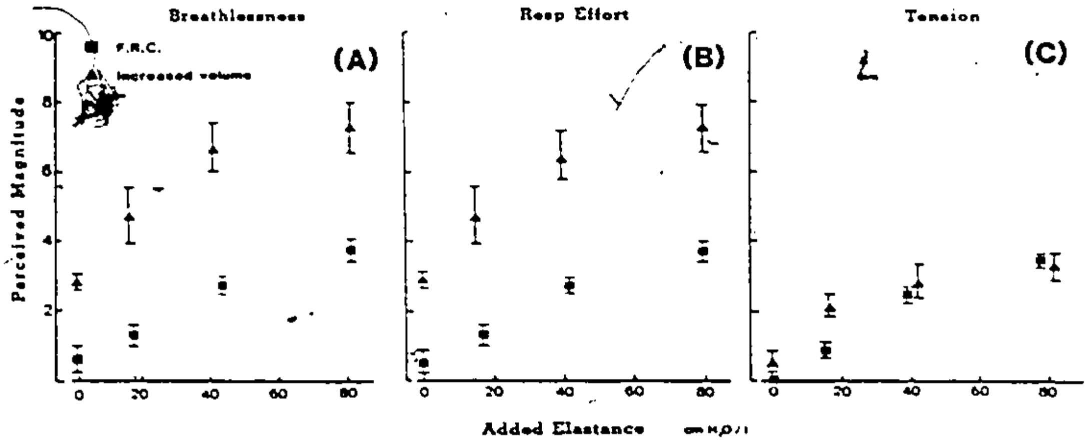

Fig 1.2 The perceived magnitude of breathlessness (A), perceived effort (B), and perceived tension (C) at functional residual capacity (FRC) and at increased lung volume with added elastic loads (group means ± SE) (Killian et al. (1984)).

In a recent studies Jones et al.(1983, 1985) used a progressive loading technique to fatigue to examine the endurance of the inspiratory muscles. Subjects were allowed to freely adopt their breathing pattern in one experiment and targeted a fixed inspiratory duration in another experiment. They found that the sense of respiratory effort was related to the peak mouth pressure and to the static strength of the inspiratory muscles. Thus for a given peak mouth pressure, the subjects with weak inspiratory muscles had a higher sense of effort than subjects with strong inspiratory muscles. They also found that the sense of effort increased with the prolongation of the pressure generated by the inspiratory muscles.

1.4 Summary

"Many physiologists and clinician have written articles entitled 'Dyspnea' which were in fact articles on the regulation of respiration, the causes of hyperpnea, or the causes of hyperventilation - which in fact, had nothing to do with the sensation of dyspnea". This remark was made by the late Julius Comroe in the opening statement of an international symposium on the topic of breathlessness in 1965 (Comroe, 1966). This remark was a reflection on the extent of the efforts made to explain breathlessness using chemical or neural theories of breathing control instead of explaining the symptom on the basis of the factors contributing to the sensation.

Common theories have involved increases in the mechanical work and oxygen cost of breathing. Although the mechanical work of breathing increases with increases in ventilation it neither explains all the circumstances of breathlessness nor does it have any neurophysiologic basis. The same arguments applies to the oxygen cost of breathing theory.

These early workers studied factors which increased breathing: although the sense of dyspnea increased with increased ventilation, it was ventilation and not dyspnea was being measured.

A great step towards the understanding of the sensation of breathlessness was made by applying psychophysical techniques to define the factors contributing to breathlessness. Most of the work done so far examined these factors at rest and in isometric conditions. The conclusions drawn from these studies were that breathlessness represents the sense of respiratory effort and is related to the force generated by the inspiratory muscles, the duration and frequency of force generated by these muscles and to their static strength. This concept echoed the definition of breathlessness given by Jonathan Meakins 60 years ago -" Dyspnea is the consciousness of the necessity for increased respiratory effort" (Meakins, 1923).

Although this concept offers a unitary explanation of breathlessness experienced when the impedance to breathing increases and when the inspiratory muscles are weak, without expansion it does not explain the occurrence of breathlessness during exercise. During exercise the force generated by the inspiratory muscles is very low compared to that generated during impeded breathing but the intensity of breathlessness is comparable.

1.5 OBJECTIVE OF THE PRESENT STUDIES

The present studies were undertaken to expand the findings of the psychophysical studies on breathlessness at rest to the exercise condition. Thus main objectives of the present studies were; 1. to quantify the intensity of breathlessness associated with exercise and respiratory loading; 2.to isolate the contribution of inspiratory pressure to breathlessness; 3. to see if tidal volume (Vt) (functional extent of shortening), inspiratory flow (Vi) (functional velocity of shortening), frequency of breathing (fb) and duty cycle (Ti/Ttot) contribute to breathlessness independent of their effect on the increasing pressure.

A secondary obective was to review the previous postulations that the frequency response is determined by the criteria of minimum work rate or minimum peak force.

1.5.1 The Hypothesis

Recent psychophysical studies with added inspiratory loads (Killian et al., 1981,1982, 1983, 1984, Jones et al., 1983, 1985) indicated that both the capacity of the inspiratory muscles to generate force (the static strength of the inspiratory muscles), the pressure generated by these muscles, frequency of breathing, and the duty cycle are important contributors to the sensations of perceived load magnitude, inspiratory muscle effort and breathlessness.

During increased ventilation, as in muscular exercise, the inspiratory muscles have to increase the tidal volume (reflecting the functional extent of shortening), the inspiratory flow (reflecting the functional velocity of shortening), the frequency of breathing, and the duty cycle, to maintain the ventilatory demands of the exercising muscles. In doing so the capacity of the inspiratory muscles to generate force (pressure) should decrease. Thus we hypothesize that the magnitude of breathlessness should increase not only as pressure increases but in addition as tidal volume and inspiratory flow rate increase because of the associated reduction in capacity. The perceived breathlessness should also be greater at any given pressure as the extent and velocity of shortening increase.

1.5.2 Design of the Study

In the present work we wished to quantify the contributions to the sensation of respiratory muscle effort in a way that may be considered comparable to a study of skelatal muscle effort. Thus we wished to study a wide range of forces, velocities of contraction, extent of contraction, frequency and duration of contraction: The analogous variables are pressure generated (force), inspiratory flow (velocity), tidal volume (extent), and frequency of breathing, and duty cycle. We used exercise and externally added loads to inspiration to increase the ventilatory forces, to provide a wide range of tidal volumes and inspiratory flows, and to have a continuum of the sensation of breathlessness.

The externally added resistive loads to inspiration were used to alter the inspiratory flow (functional velocity of the inspiratory muscles). Similarly, the externally added elastic loads to inspiration were used to alter the tidal volume (functional length of the inspiratory muscles).

Although inspiration is carried out mainly by the diaphragm, the role of the intercostal, accessory, and abdominal muscles cannot be ignored especially with either impeded or increased breathing. All these muscles are different in their anatomy and geometry, which complicates the measurement of tension, extent and velocity of shortening of each individual muscle. To overcome this problem some approximations have been made; the pressure measured (mouth or esophageal) represents the total tension of the inspiratory muscles; the tidal volume represents the total extent of shortening of these muscles; and the inspiratory flow represents the total velocity of shortening of these muscles.

The use of mouth pressure as an index of the total pressure generated by the inspiratory muscles in present studies may be criticised, as pressure measured at mouth does not include the pressure required to overcome the impedance of the lung and the chest wall. We opted to use an estimate of the esophageal pressure, assuming normal pulmonary dynamic compliance and resistance for simplicity, in that it reflects the pressure required to overcome the external resistance and impedance of the lung. The dynamic elastance and resistance of the lung would not be expected to change significantly over the study period. Thus the additional pressure required to overcome the impedance of the lung can be calculated using normal values for the dynamic elastance and resistance, and the tidal volume and flow rates. We validated estimates of peak esophageal pressure in two of the subjects by simultaneous measurement of esophageal pressure and estimated esophageal pressure under similar operating conditions. We did not attempt to measure or add the pressure generated by the chest wall for the following reasons; it is very difficult to measure; we believe that its value is very small, and if measured it will add to the pressure measured under unloaded or loaded condition i.e. it will not change our results. As we were not attempting to precisely define the effects of tension, velocity, extent of shortening, frequency, and duty cycle but to show their relative contribution to breathlessness, we feel this approach was reasonable. Finally, both the esophageal pressure and mouth pressure are only approximate measures of the true inspiratory muscle tension.

CHAPTER 2: METHODS USED TO STUDY BREATHLESSNESS IN EXERCISE

The objective of the work was to quantify various contributions to the perception of breathlessness in exercise by imposing inspiratory loads to breathing in healthy subjects. Six normal subjects exercised on a cycle ergometer with and without the addition of a series of external resistive or elastic loads to inspiration; the work loads were increased progressively to their maximum capacity. Using a psychophysical technique the magnitude of perceived breathlessness was measured. The factors contributing to breathlessness were quantified by using the intensity of breathlessness as the dependent variable, selecting independent variables based on logical inference, and taking their importance by statistical regression analysis. In this analysis the independent variables were introduced in the order of their importance, each considered as contributing to breathlessness if it significantly reduced the residual variability. The variables were selected on the basis of circumstantial and previous experimental evidence as to their contribution to breathlessness. By varying the magnitude of the added elastic, resistive loads and the intensity of exercise, ventilation, inspiratory pressure, tidal volume, flow rate and duty cycle varied widely as did the intensity of breathlessness (Fig 2.1). Thus the contribution of each of these factors to breathlessness could be ascertained.

2.1 General Procedure

Each subject performed 8 progressive incremental exercise tests in 8 different sessions to their maximum exercise capacity on 8 separate days. Exercise was performed on a calibrated electrically braked cycle ergometer. The first and the eighth exercise tests were control tests in which no external inspiratory loads were added. Three external elastic loads (21, 41, 52 cmH20/l) and three external resistive loads (33, 57, 73 cmH20/l/sec) were added to the inspiratory line in the remaining 6 exercise tests. In any of these loaded exercise tests, either an elastic or a resistive load was used on random basis as an inspiratory load. This inspiratory load was constant for any given exercise test. Subjects breathed through the respiratory circuit for 5 minutes at rest and exercise was begun at 100 kpm/min (16.3 w); the power was increased by 100 kpm/min at the end of each minute up to the capacity of the subjects (Jones and Campbell, 1982). Measurements of respiratory variables were recorded continuously. At the end of the resting period and subsequently at the end of each min during exercise the subjects were asked to estimate the magnitude of their breathlessness using the Borg scale. Having selected a number it was immediately recorded by the observer. The breathing pattern was freely adopted by subjects.

Before performing the first exercise test, each subject underwent the following baseline tests : 1) Forced expiratory spirometry (FEV1), and (VC). 2) Maximum static inspiratory mouth pressure (MIP) recorded at FRC.

During each exercise test the following variables were monitored minute by minute : 1) Perceived Breathlessness. 2) Mouth pressure (Pm) and integrated mouth pressure with time (InP). 3) Tidal volume (Vt), inspiratory flow (Vi), frequency of breathing (Fb), ventilation (VE), and respiratory timing, inspiratory time (Ti), expiratory time (Te), and total time (Ttot). 4) End tidal CO2 (PEtCO2), expired CO2 (PECO2) arterial oxygen saturation (SaO2%), oxygen consumption (VO2), and carbon dioxide output (VCO2). 5) Rib cage and abdominal displacement. 6) Heart rate.

2.2 Subjects

Six normal subjects were studied. The anthropometric and pulmonary function measurements are shown in table 2.1. Four of them had had previous experience with respiratory studies. Informed consent was obtained after a detailed description of the study.

2.3 Apparatus and Measurements

Subjects exercised on cycle ergometer (Quinton Instrumment B44). The initial power setting was 100 Kpm/min increasing by 100 Kpm/min at the end of each minute of the test. The pedalling frequency was maintained at 60 / min. The cycle ergometer was calibrated by torsion balance before the study for power output and pedalling frequency.

Subjects breathed through a low resistance high velocity Hans Rudolph valve which had a resistance of 3cmH20/1/s at a flow of 500 1/min. On the inspired side the valve was connected by a short wide bore plastic tube to a 3-way valve. This valve connected the inspiratory tube to room air or to the resistive or to elastance

Subject	1	2	3	4	5	6	Mean ± SD	units
Age	33	34	31	35	24	23	30 ± 5.2	yr
Weight	73	70	84	82.5	67.5	68.4	74.9 ± 7.30	kg
Height	180	170	175	186	180	168	176 ± 16.8	cm
VC	5.9	5	5.8	6.6	6	4.9	5.7 ± 0.90	l
FEV1	5.3	4.6	5.2	5.7	5	4.4	5 ± 0.30	l
MIPS	95	144	106	123	106	127	117 ± 17.8	cmH_2O

Tab 2.1 The anthropometric and pulmonary function measurements of the 6 subjects.

loading circuits. The expiratory side of the Hans Rudolph valve was connected to an automated exercise system (MMC Horizon system) to measure ventilation and other related variables. Mouth pressure, inspiratory flow, and end tidal PCO2 were measured at the mouth as described below.

The Elastance Circuit (Fig 2.2) was essentially similar to those described by Campbell et al. (1961). It consisted of a series of airtight rigid drums. Each drum was connected to the inspiratory side of the respiratory valve by a tube with a side opening to connect the drum to room air. The side opening was closed by the hand of the observer during inspiration and vented to the atmosphere following each inspiration to avoid variability in added elastic load. Three elastic loads were used; E1 = 21, E2 = 41, E3 = 52 cmH20/l. These elastic loads were estabished by a preliminary study before the experiments (Appendix 7.4).

The Resistive Circuit (Fig 2.2) consisted of a brass tube (7 cmID) from which segments of the wall were removed leaving longitudinal and circumferential ribs. The tube itself was covered with filter paper selected to provide the requisite resistances and secured at the ribs by clamps. Resistances were selected by moving a plunger with an airtight seal from rib to rib. This circuit allowed the resistances used to range from 10 to 400 cmH20/l/sec. Three resistances were used; R1 = 33, R2 = 57, R3 = 73 cmH20/l/sec. These resistances were also established by a preliminary study. These resistances were linear over the range of the inspiratory flows used in these studies (0.3 - 5 l/s) (Appendix 7.4).

The Borg Scale was used to estimate the perceived

BREATHLESSNESS	0	←	BORG SCALE	→	10
POWER OUTPUT	0	←	KPM/MIN	→	2000
MOUTH PRESSURE	0	←	CMH2O	→	80
INSPIRATORY FLOW	0.4	←	L/SEC	→	4.5
TIDAL VOLUME	0.5	←	L/BR	→	3.0
FREQUENCY	5	←	BR/MIN	→	45
DUTY CYCLE	0.2	←	TI/Ttot	→	0.8

Fig 2.1 Illustrates the ranges of the variables in the present study.

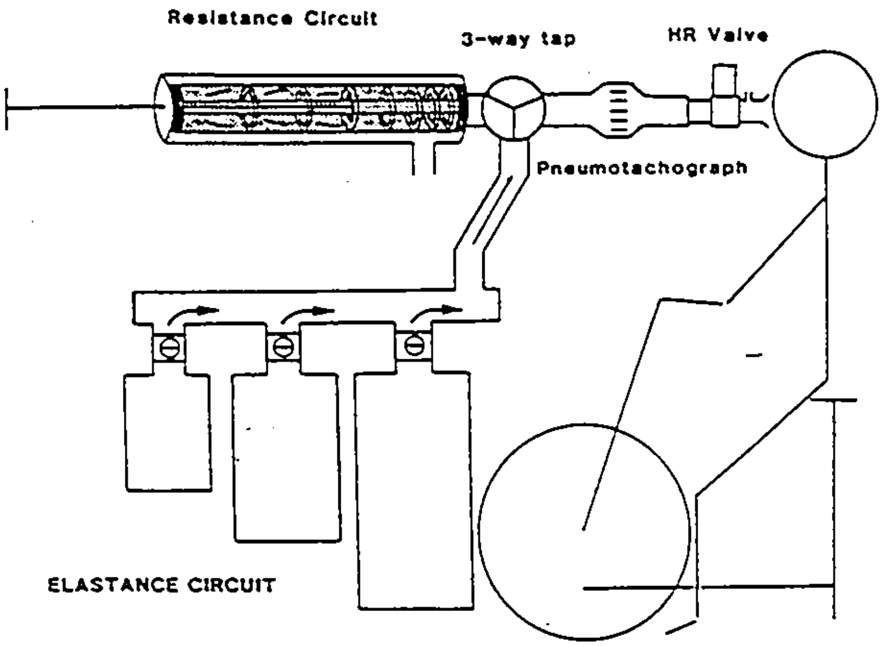

Fig 2.2 Resistive and elastic circuit.

intensity of breathlessness (Fig 2.3) (Borg, 1980). The scale consists of a range of numbers from 0-10 anchored to simple verbal expressions (categories); 0 denotes nothing at all and 10 denotes maximum. The intervening numbers are tagged to simple verbal expressions such as "very slight" to "very very severe". These expressions (categories) are arranged at points selected to preserve the ratio properties of the psychophysical relationship between the sensory magnitude and the stimulus (Appendix 7.1). When using the scale the subjects were permitted to use decimals or fractions between integers; if breathlessness increased beyond what they had previously rated 10, they were asked to select a number greater than 10.

10	MAXIMAL
9	Very, very severe (almost maximal
8	
7	Very severe
6	
5	Severe
4	Somewhat severe
3	Moderate
2	Slight
1	Very slight
0.5	Very, very slight (just noticeable)
0	Nothing at all

Fig 2.3 Borg scale.

<u>The Mouth Pressure</u> was measured using a differential pressure transducer (Hewlett-Packard 267). This transducer was calibrated by a water manometer and was accurate to 0.5 cmH2O. The response of the transducer was linear over the range of measurement.

Mouth pressure was integrated against time using Hewlett-Packard 8815A respiratory integrator. The integrated pressure signal was calibrated by adding a known pressure for a fixed period of time. As the integral of a wave form is the area under that wave form, we calculated the area under the added square wave and applied that measurement to the deflection of the integral signal.

Inspiratory Flow was measured using a Fleisch No. 3 pneumotachograph and a Hewlett-Packard 270 differential pressure transducer. Flow rates were calibrated using a variable flow source (a vacuum cleaner and a rotameter) (± 0.05 l/s). Inspiratory tidal volume was determined by integration using a Hewlett-Packard 8815A respiratory integrator. The integrated volume was calibrated with a reference syringe (± 100 ml). Respiratory times, Ti, Te, and Ttot were measured from tidal volume trace on the recording paper.

Abdominal and Rib cage Displacements were measured with a respiratory inductance plethysmograph (Respitrace) (Cohn, Watson, Weisshaut, Scott, and Sackner, 1978). Respitrace was standardised for the individual subjects using isovolume manouvers as described by Cohn et al. (1980). The respitrace data was used to give a qualitative contribution of the rib cage and abdomen to the tidal volume during the test.

End-tidal PCO2 was measured at the mouth using an infrared analyser (Godart 17070), calibrated with gases analysed by the Lloyd-Haldane apparatus and accurate to ± 2mm Hg. Arterial oxygen saturation was measured with an ear oximeter (Hewlett-Packard 47210A). The ear oximeter was standardised using an internal procedure designed by its manufacturer and was accurate to 1%

(Saunders, Powles and Rebuck, 1976).

Heart Rate A lead II electrocardiograph was used to measure heart rate and for monitoring purposes.

Recorder Mouth pressure, integrated mouth pressure, inspiratory flow, tidal volume, respiratory durations, rib cage and abdominal displacements, end-tidal PCO2, and heart rate were recorded throughout the tests on an eight - channel recorder (Hewlett-Packard 7758). The sensory magnitude of breathlessness and the reading of ear oximetry were recorded at the end of every minute throughout the test.

The Automated Metabolic Measurement System (MMC Horizon System) Ventilation, tidal volume, frequency of breathing, expired CO2, oxygen consumption, and carbon dioxide output were measured using MMC Horizon system. This is an integrated instrument operated by a microprocessor which employs floppy disks for program and data storage.

Expired gases passed through the expiratory tube to a mixing chamber inside MMC cabinet. The gases from several successive breaths over 15 sec were mixed in the 3 - liter mixing chamber to form an average concentration of mixed expired gases. These averages are sampled by analyzers in the sample path. Expired gas temperature and pressure are measured in the mixing chamber.

Oxygen is detected with a temperature controlled fast response, polarographic sensor, and carbon dioxide with a dual-beam infrared analyser. Expired volume is measured by a turbine volume transducer mounted on top of the mixing chamber. The turbine generates a train of pulses for each expired breath. The total number of pulses per breath is proportional to the volume of the breath. A breath switch is attached to the top of the turbine. Its function is to detect the start and the end of each expired breath. Temperature is measured with a Yellow springs 44008 transducer and pressure with a Honeywell 140PC transducer.

Calibration procedures are built in to the system. For the gas analyses, the processor samples a zero gas (100% N2) and a precision calibration gas (nominally 4% CO2 and 16% O2), sets the zero and gain of the O2 and CO2 channels and uses these factors for subsequent measurements. The process is automatic; the calibration sequence includes tests for noise, linearity and drift; warnings are printed when gain or zero are outside normal limits and an interpretation of the calibration is also given. Volume calibration is made by delivering fixed volumes at specific flow rates with a manually driven pump. This procedure is monitored by the microprocessor. Then the microprocessor linearizes the volume signal by selecting anchor points at each flow rate and writes a series of equations stored in the system calibration file. The pressure transducer is automatically calibrated during the gas calibration procedure by sampling gas at two pressures and deriving the slope and intercept relating the measured pressure to the actual pressure in the O2 and CO2 sensors. The pressure correlation makes the gas analyzers insensitive to pressure changes in the sample system.

A time alignment procedure is incorporated into the software to delay time periods and ventilation measurements and align them to the gas concentration measurements. This alignment corrects for both fixed time delays (gas flows through the sampling system) and those which depend on ventilation (transit time for expired air to reach the mixing chamber and the period of washing-in of the mixing chamber).

During the time of the studies this analysis system was extensively validated against reference analysis methods (calibrated syringes and Lloyd-Haldane analyses). These studies indicated that precision of measurements of ventilation and mixed expired gas concentrations was high (Jones, 1984). In steady-state exercise (n=100) VO2 was measured with a high percision (± SD) of 66ml/min (4.3%); there was a small systematic underestimation of VCO2, but precision was comparable with VO2, with ± SD being 67ml/min (4.55%) (r=0.993). Good agreement was obtained between measurements made in progressive incremental exercise in healthy subjects with correlation coefficients of o.997 for VE, o.995 for VO2, and 0.994 for VCO2. It also showed that rapid changes in these variables were followed accurately.

Calibrations was carried out before and after each test for all the instruments used.

2.4 Variables Estimated from the Data

Peak esophageal pressure, power output of the inspiratory muscles, and the predicted frequency of breathing were estimated from our measurement as described below.

2.4.1 Estimated Peak Esophageal Pressure

Peak esophageal pressure was estimated by adding the measured mouth pressure to the pressure needed to overcome the impedance of the lungs (resistance and elastance). The tarnspulmonary pressure represent the pressure generated by the inspiratory muscles to overcome the resistance and elastance of the lung and airways. The pressure needed to overcome the elastance equals $Vt * E$, where Vt is the tidal volume and E is the dynamic elastance of the lung. The pressure needed to overcome the resistance equals $\dot{V}i * R$, where $\dot{V}i$ is the peak flow and R is the resistance to airflow.

As illustrated in Fig 2.4 peak mouth pressure and peak esophageal pressure occurs at 80% of the tidal volume (line P). The sum of the peak mouth pressure and transpulmonary pressure at 80% of Vt equals approximately the peak esophageal pressure. The contribution of the resistance and elastance to the transpulmonary pressure can be calculated in the following way: the peak pressure ~~occurs at~~ 80% of the tidal volume (hence the pressure generated to overcome the dynamic elastance = $0.8 * Vt * E$). Because inspiratory flow rises quickly to a peak value, remains constant for most of the breath and declines rapidly, the pressure generated to overcome the resistance = $\dot{V}i * R$. Thus the Pes (peak) can be estimated :

$$Pes\ (peak) = Pm + (\dot{V}i * R + 0.8 * Vt * E)$$

This equation can be applied to both unloaded and resistive loading conditions.

During elastic loading peak Pes occurs at end tidal volume. Thus the resistive component does not contribute to the peak esophageal pressure. Pes (peak) can be estimated during elastic loading as follows:

$$Pes\ (peak) = Pm + (Vt * E)$$

To validate this approach we measured transpulmonary pressure using an esophageal balloon in 2 of our subjects. Dynamic elastance and resistance of the lung were measured using Mead and Whittenberger (1953) technique at different tidal volume and inspiratory flows with inspiratory resistive loads 33 & 53 cmH2O/l/s and elastic loads of 21 & 42 cmH2O/l. The estimated peak Pes was compared to the actual measured Pes (Fig 2.5). Extrapolating this result to our data we assumed normal resistance (3 cmH2O/l/s) and dynamic elastance (3 cmH2O/l if Vt < 2.0 L; 5.5 cmH2O/l if Vt > 2.0 L) for all our subjects in the estimation of peak esophageal pressures.

2.4.2 Estimation of the Power Output of the Inspiratory Muscles

The power output of the inspiratory muscles was calculated to evaluate the effect of increased inspiratory work rate on the measured $\dot{V}O2$. The total work rate equals the work done to overcome the internal impedance of the respiratory system plus the work done to overcome the external added impedance. The internal work was estimated using the equation derived by Otis et al (1950):

$$W\ (int) = [5000*fb*(Vt)^2 + 150*(\dot{V}E)^2 + 3*(\dot{V}E)^3]/100000\ \ kpm/min$$

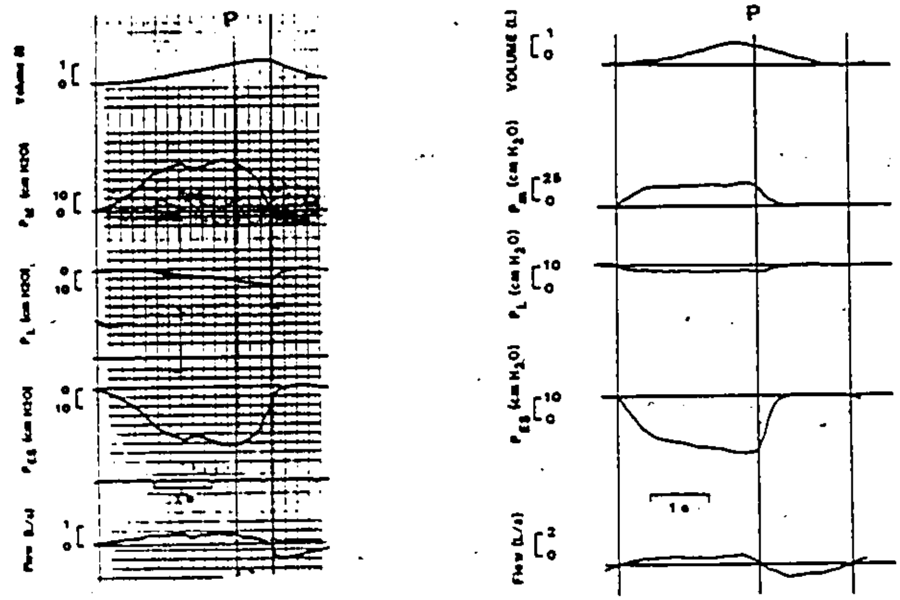

Fig 2.4 Recorder trace of tidal volume, mouth pressure, tranpulmonary pressure, esophageal pressure, and inspiratory flow for a single breath to illustrate the basis for the derived equation of estimated peak Pes with unloaded and resistive loads (2.4A), and with elastic loads (2.4B). Line P in both figures represents the point of peak pressure.

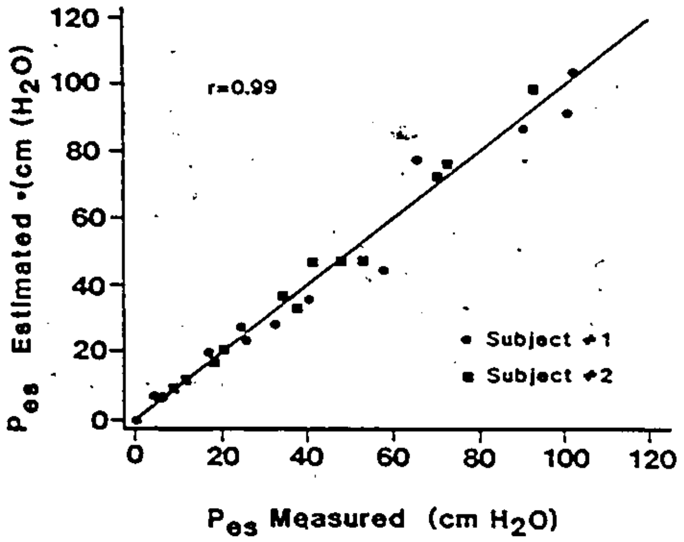

Fig 2.5 Estimated esophageal pressure against measured esophageal pressure at different lung volumes, flows, elastic and resistive loads in 2 subjects.

where W(int) is the work rate (kpm/min) of the inspiratory muscles to overcome the the internal impedance of the lungs. fb is the frerquency of breathing, Vt is the tidal volume, $\dot{V}E$ is the total ventilation. The external work was calculated by multiplication of the integrated pressure and their mean flow:

$$W\ (ext) = (\ Pdt * Vt/Ti)/100 \qquad \text{kpm/min}$$

where W(ext) is the work rate (kpm/min) to overcome the added external impedance. Pdt is the integrated mouth pressure (cmH20.sec/min) and Vt/Ti is the mean inspiratory flow (l/s). The total inspiratory work was the sum of both work done on the lung and the external resistance. The work done on the chest cage was ignored as its magnitude was small relative to the work done against the lung and external load.

2.4.3 Estimation of the Predicted Frequencies

The following equations were used to calculate the predicted frequency to minimize work (fw) and peak force (fp):

$$fw = (2n^2RC)^{-1}[\ (1+4n^2RC*\dot{V}A/Vd)^{1/2}-1] \quad \text{(Mead, 1960)}$$

$$fp = (\dot{V}A/Vd)^{1/3}(2nRC)^{-2/3} \quad \text{(Mead, 1960)}$$

where R is the total resistance of the respiratory system and C is the total compliance of the respiratory system.

To estimate the predicted frequency of breathing using the criterion of minimum work (fw) and minimum peak force (fp) the following variables have been calculated from our data; 1. arterial PCO2; 2. physiologic dead space (Vd); 3. alveolar ventilation ($\dot{V}A$) using the following equations:

$PaCO2 = 5.5 + 0.9\ PEtCO2 - 0.0021\ Vt$ (Jones et al., 1982)

$Vd = ((PaCO2)^{-1}(PaCO2-PECO2))*Vt$ - apparatus dead space (Jones et al., 1982)

$\dot{V}A = \dot{V}E - (Vd * fb)$

2.5 Analysis of the Results

The eight exercise tests performed by each subject were named according to whether or not there was an addition of external inspiratory load. The two control tests without adding external loads were called C1 for the first test and C2 for the last test. The three tests with added resistive loads were called R1 for the lower load, R2 for the medium load, and R3 for the biggest. The three tests with added elastic loads were called E1 for the lower load, E2 for the medium load, and E3 for the biggest load.

Values for peak inspiratory pressure (mouth and estimated esphageal), integrated mouth and estimated esophageal pressure, inspiratory flow, tidal volume, respiratory durations, frequency of breathing, oxygen consumption, carbon dioxide output, minute ventilation, end-tidal PCO2, expired PCO2, rib cage and abdominal displacement, and heart rate were averaged for the resting period and for each min during the progressive exercise tests. The rating of breathlessness and oxygen saturation at the end of each min were taken as the represehtive for each exercise work load during the test.

The means of all the variables were calculated at each work load during the control, each resistive load, and each elastic load tests at work loads completed by all subjects (n at any work load = 6). Because of the differences in exercise capacity of the subjects, the final points were calculated by averaging the maximum work load achieved by each subjects (n final = 6). The means of the measured variables at the mean maximum work loads of the control, resistive and elastic tests were averaged in the same way.

Two approaches, statistical and graphical, were used in analysing the results. The statistical method employed unequal two-way analysis of variance as well as multiple regression to assess the effect of exercise and loading. Multiple regression analysis was used on the individual data to examine the effect of the progressive increase of work loads and the effect of the progressive increase in inspiratory loads. An Apple computer; utilizing the Statpro data base and statistical package (Imhof and Hewett, 1983) was used to perform the calculation involved in the statistics. Unequal two-way analysis of variance using SPSS, statistical package for the social sciences (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975), and the HP/3000 computer) was also used to compare between the control and each of the resistive loading (R1, R2, and R3), and the elastic loading (E1,E2, and E3) tests. The comparison was also done between the resistive loading tests themselves and between the elastic loading tests themselves. The relationship between the measured $\dot{V}O2$ and the power output of both the leg and the inspiratory muscles were examined using multiple regression analysis. Paired T-test was used to compare the signficance between the observed and predicted frequency of breathing. The level of significance of any test was considered at $P<0.05$.

Using the estimate of breathlessness as the dependent variable multiple linear regression (Appendix 7.5) was used to assess the independent roles of Pm, $\dot{V}i$, Vt, fb, and Ti/Ttot in contributing to breathlessness under both unloaded and resistive loaded conditions and unloaded and elastic loaded conditions.

The graphical approach was also used to demonstrate the competition between the pressure required to increase Vt and $\dot{V}i$ and the reduction in pressure generating capacity that accompanies increases in Vt and $\dot{V}i$. It has been shown (Rahn, Otis, Chadwick, and Fenn, 1949, Ringqvist, 1966, Leblanc, Bowie, Summers, Jones, and Killian, 1984) that the maximum pressure that can be generated fell by 18% for each 10% increase of the tidal volume from FRC to TLC expressed as Vt/TLC%. The maximum pressure also fell by approximately 6% for each 1/s increase in inspiratory flow rate (Hyatt and Flath, 1966, Leblanc et al., 1984). This competition between the pressure required and the reduction in inspiratory muscle capacity is illustrated using the modified pressure-volume and pressure-flow curves developed by Campbell (1958) (Fig 2.7). In unloaded and resistive conditions peak pressure occured at 80% of tidal volume when flow is maximal. Thus the maximum predicted pressure that can be generated by the inspiratory muscles was calculated taking into account the effect of tidal volume and flow. In elastic loading the actual peak pressure occured at end inspiration when the inspiratory flow equals zero. Thus the maximum pressure that could be generated by the inspiratory muscles was calculated at the same point from rest to maximum exercise. Both the maximum pressure that can be generated and the actual pressure were plotted against the increased work load in unloaded and elastic loaded studies. In resistive loading studies a modified Campbell diagram was used to illustrate the effect of both tidal volume and inspiratory flow. Thus the values at mean maximum achieved work load were used.

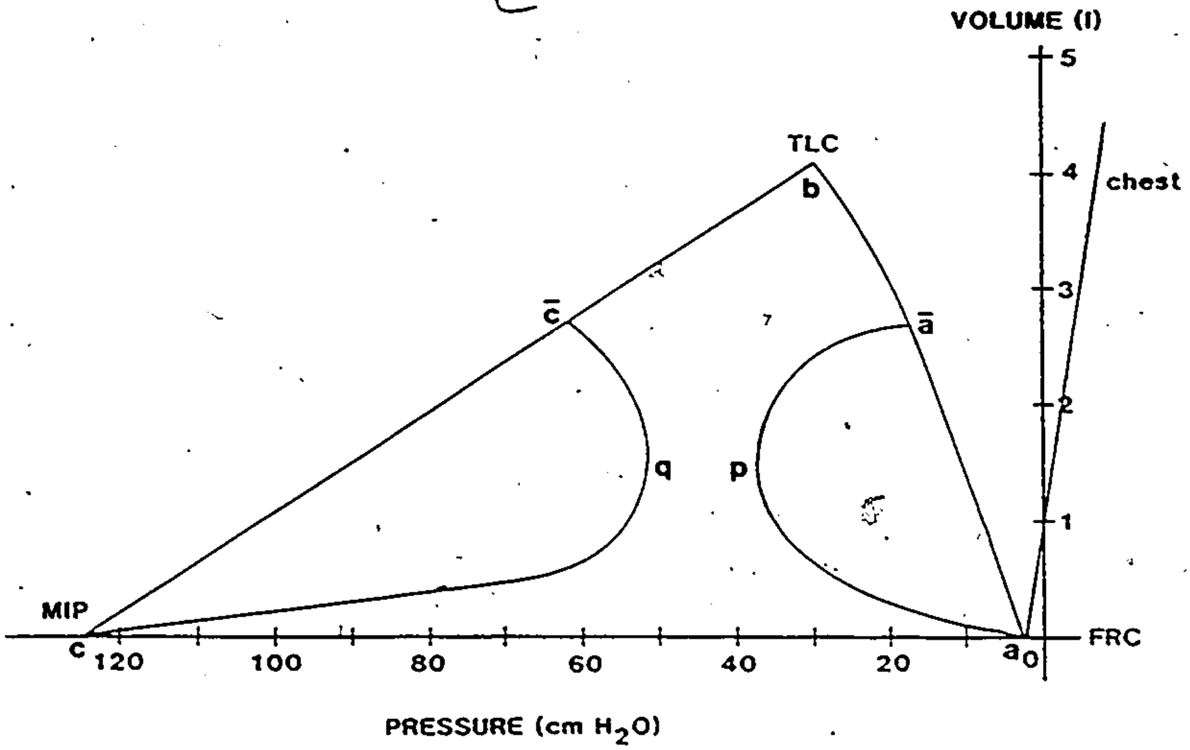

Fig 2.7 Illustrates the competition between the inspiratory pressure required to increase tidal volume and inspiratory flow and the reduction in pressure generating capacity. Thus the esophageal pressure required to generate tidal volume is represented by a-ā. The resistive forces within .a breath lead to the pressure curve represented by apā. Similarly, the capācity to generate maximum pressure does not follow the line c-c̄ but the curve c-q-c̄, due to the effect of increasing both the extent and velocity of inspiratory muscle shortening. Thus the proportion of the capacity that is employed to generate a breath is not given by ā/c̄ but by p/q. In this example this proportion instead of being 20/70 is much higher at 35/50.

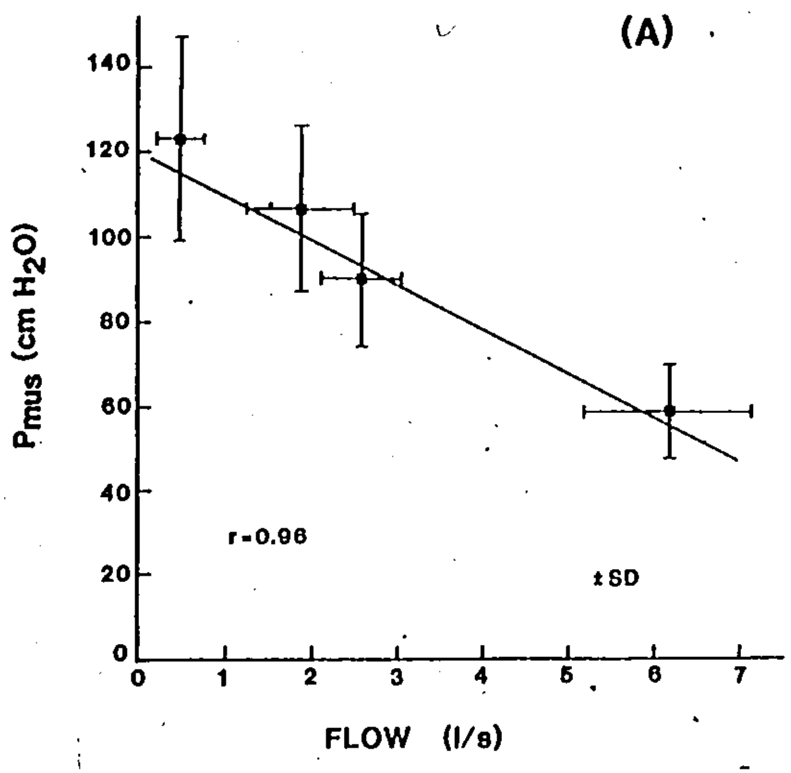

Fig 2.6A Illustrates the decline in maximum inspiratory pressure that can be generated with maximum effort at different inspiratory flow rate. The slope of the decline is approximately 6% / l/s at differen lung volume (Leblanc et al., 1984).

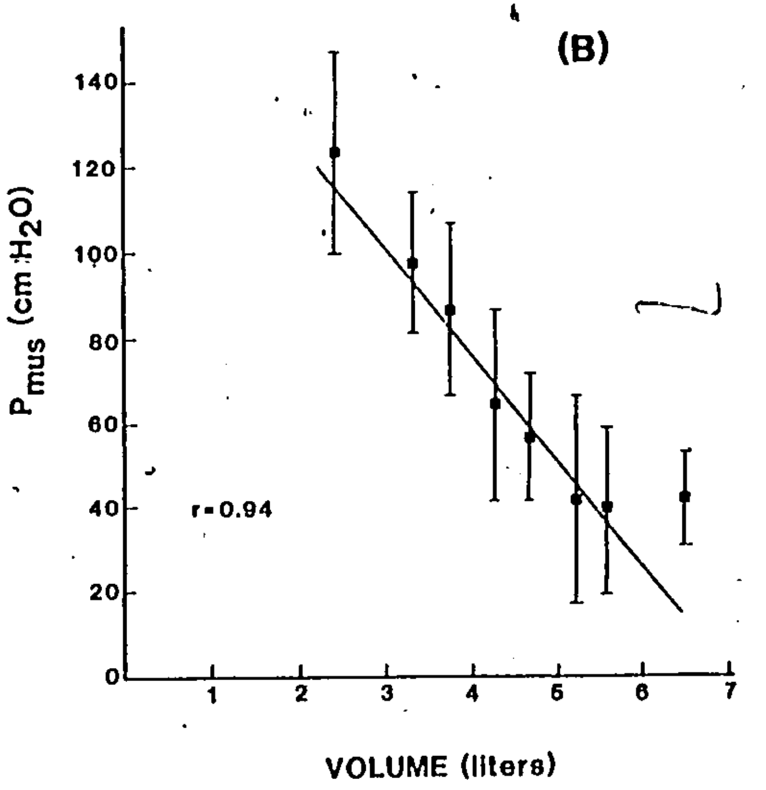

Fig 2.6B Illustrates the decline in maximum inspiratory that can be generated at different lung volume (FRC to TLC) against occlusion (zero flow) using maximum effort. The slope of the decline is approximately 18% for each 10% increase in lung volume from FRC to TLC (Leblanc et al., 1984).

CHAPTER 3 RESULTS

In this chapter the results of the thesis experiments will be described by examining the change in the perceived magnitude of breathlessness associated with increases in the intensity of exercise and the added resistive and elastic inspiratory loads. The metabolic cost of inspiratory muscle activity during exercise and loading will be addressed, and the concept of an optimum frequency of breathing that minimize the work of breathing and the peak force will be reexamined in light of the current results.

3.1 Exercise Capacity

The exercise capacity of the six subjects progressively decreased with increasing added elastic or resistive loads from 1733 ± 78.7 kpm/min (peak VO2 3.3 ± 0.23 l/min) in unloaded study to 1193 ± 114.5 kpm/min (peak VO2 2.1 ± 0.18 l/min) with the largest elastic load, and 733 ± 68.5 kpm/min (peak VO2 1.3 ± 0.08 l/min) with the largest resistive load (Table 3.1,3.2). The maximum ventilation achieved was 96 ± 10.23 l/min in control study, 76 ± 6.21, 55 ± 5.37 and 48 ± 5.50 l/min with E1, E2, and E3 respectively, and 49 ± 2.82, 33 ± 2.33, and 24 ± 1.74 l/min with R1, R2, and R3 respectively (Fig 3.1).

The subjective limiting factor in the control studies (C1 and C2) was leg fatigue. However, even in the control studies the mean intensity of breathlessness at maximum capacity was as high as 7.9 ± 1.9 ("very severe" to "very very severe"). During C2 there

Subject No.	1	2	3	4	5	6	Max kpm/min Mean ± SD	VO_2 l/min Mean ± SD
Control 1	1800	1800	1700	1800	1900	1400	1733 ± 176	3.3 ± 0.51
Resistance 1	1600	1300	1000	1200	1500	1000	1267 ± 250	2.5 ± 0.34
Resistance 2	1100	900	1000	900	1100	800	967 ± 121	1.8 ± 0.17
Resistance 3	900	500	700	900	800	600	733 ± 153	1.3 ± 0.08
Control 2	1700	1900	1700	1700	2000	1400	1733 ± 207	3.3 ± 0.40

Tab 3.1 Maximum kpm/min achieved by individual subjects with and without resistive loading.

Subject No.	1	2	3	4	5	6	Max kpm/min Mean ± SD	VO_2 l/min Mean ± SD
Control 1	1800	1800	1700	1800	1900	1400	1733 ± 176	3.3 ± 0.51
Elastance 1	1800	1700	1400	1700	1900	1400	1650 ± 207	3.0 ± 0.43
Elastance 2	1400	1200	1100	1500	1700	1000	1317 ± 264	2.7 ± 0.52
Elastance 3	1500	900	1000	1100	1500	1100	1193 ± 256	2.2 ± 0.31
Control 2	1700	1900	1700	1700	2000	1400	1733 ± 207	3.3 ± 0.40

Tab 3.2 Maximum kpm/min achieved by individual subjects with and without elastic loading.

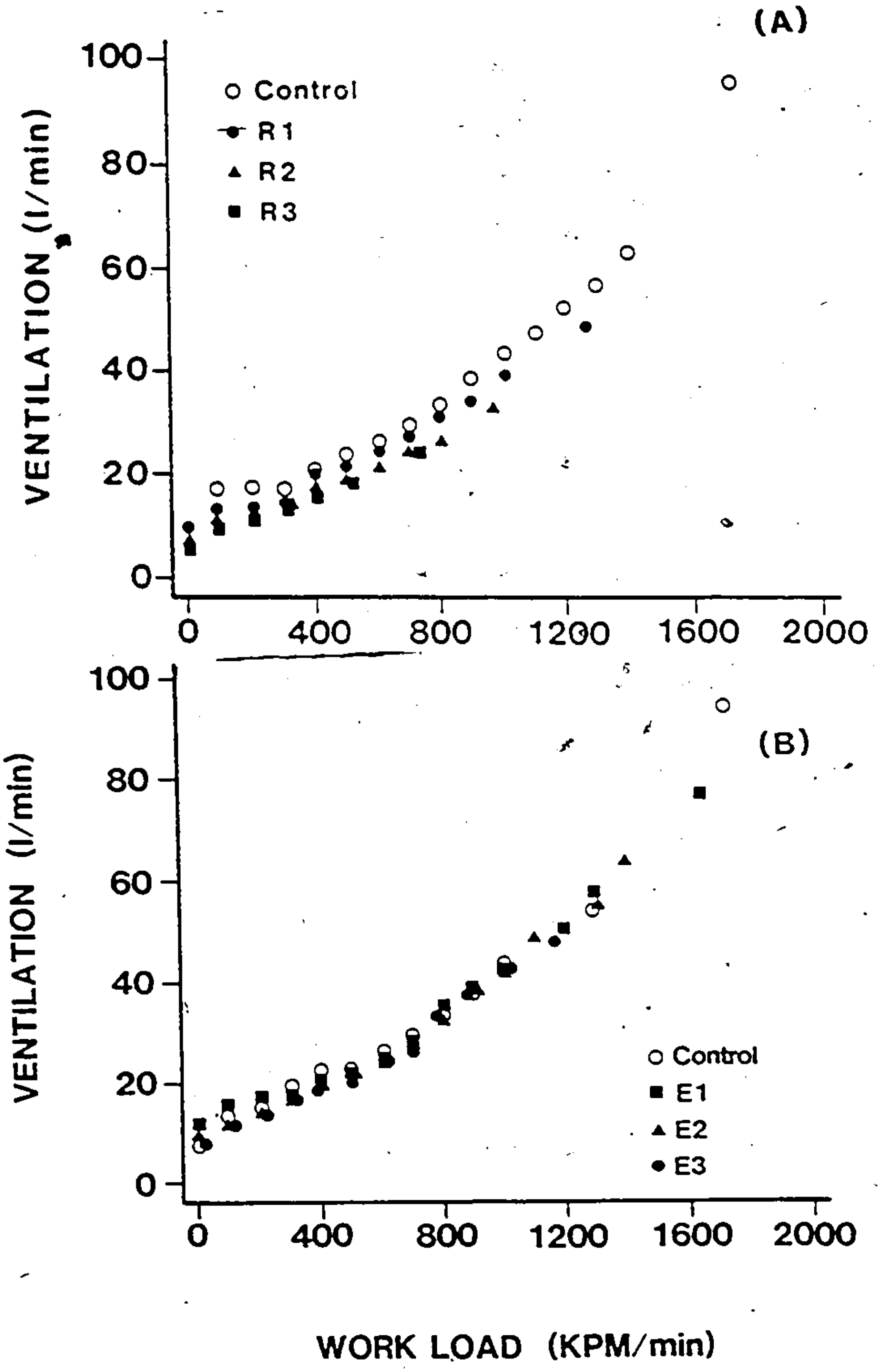

Fig 3.1 Ventilation plotted against increasing work loads, resistive loads (3.1A) and elastic loads (3.1B).

was a small but significant reduction in the estimated magnitude of breathlessness compared to that estimated in C1 at comparable workload ($P < 0.05$). However, at maximum workload there was no significant difference in rating between C1 and C2.

The main subjective limiting factor with added resistive or elastic loads was breathlessness. The mean intensity of breathlessness in resistive loaded exercise tests was 9.7 ± 0.33, 9.9 ± 0.0.9, 10 ± 0.0 in R1, R2, and R3 respectively (Fig 3.2A). During elastic loaded exercise tests the mean intensity of breathlessness was 8.6 ± 0.98, 10 ± 0.0, 10 ± 0.0 (very severe to "maximum" in E1, E2, and E3 respectively (Fig 3.2B). Thus at maximum exercise capacity in both loaded and unloaded tests the intensity of breathlessness was maximum (loaded) or close to maximum (unloaded).

3.2 Factors Contributing to Breathlessness

3.2.1 Quantification of Breathlessness

The perceived magnitude of breathlessness progressively increased with the progressive increases in workloads as well as with the increase in added inspiratory loads in all exercise tests ($P<0.001$).

$$Y = 0.005 * W + 0.08 R - 1.28 \quad (r=0.82)$$

$$Y = 0.005 * W + 0.08 E - 1.41 \quad (r=o.85)$$

where Y is the percieved magnitude of breathlessness and W is leg muscle power out put (kpm /min), R is the total resistance (cmH2O/l/s), and E is the total elastance (cmH2O/l).

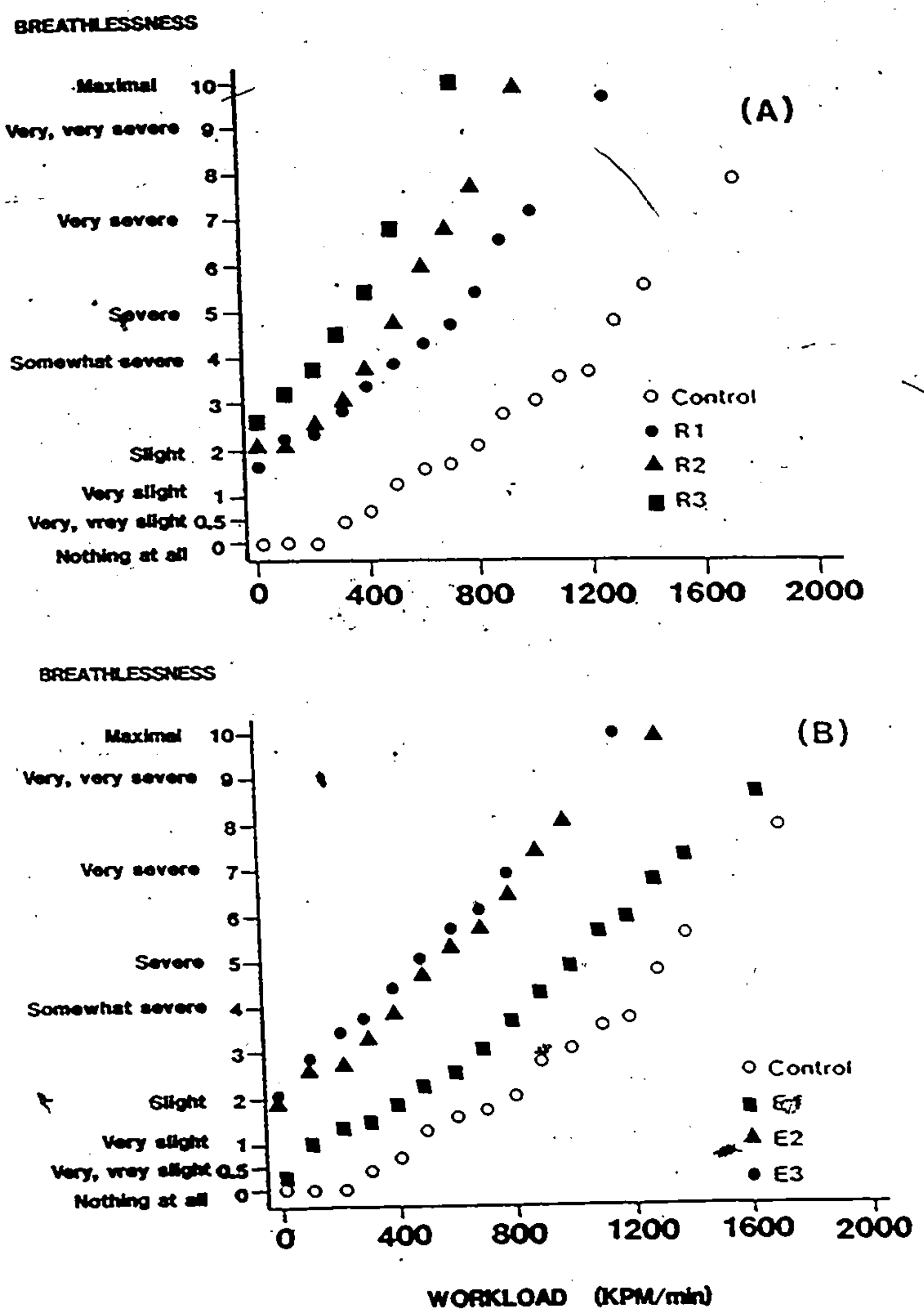

Fig 3.2 Rating of breathlessness plotted against increasing work loads, resistive loads (3.2A), elastic loads (3.2B).

The increase in the perceived magnitude of breathlessness showed a threshold and a slope. During the control study (no added load) no breathlessness was perceived until 230 ± 45 kpm/min, when breathlessness was first appreciated. Above this threshold the intensity of breathlessness increased progressively as exercise intensity increased with a slope of 0.4 (± 0.02) /100 kpm/min (Fig 3.3).

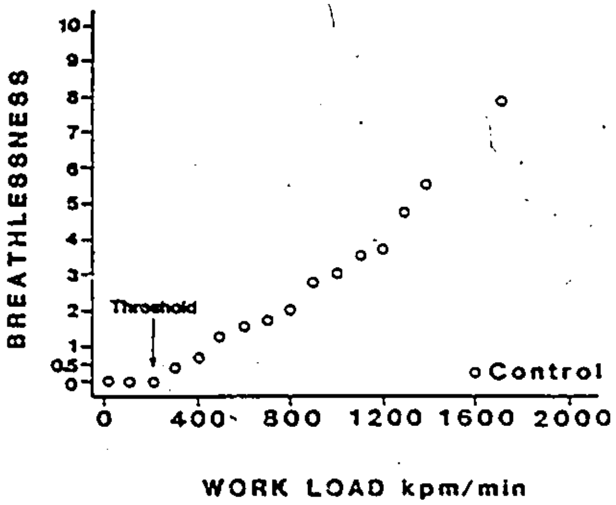

Fig 3.3 Rating of breathlessness plotted against work loads (control study) illustrating the threshold and the slope.

In contrast, with added elastic loads all subjects were symptomatic at rest, Borg score of 0.22 (± 0.31), 1.98 (± 0.30), and 2.01 (± 0.30) being obtained with E1, E2, and E3, respectively. The slope of the intensity of breathlessness increased to 0.48 (± 0.03), 0.56 (± 0.04), 0.60 (± 0.04) / 100 kpm/min with E1, E2 and E3 respectively. With added resistive loads the subjects also were all symptomatic at rest rating the intensity of breathlessness as 1.78 (± 0.48), 2.09 (± 0.35), and 2.52 (± 0.48) with R1, R2, and R3 respectively. The slope of the intensity of breathlessness increased to 0.45 (± 0.06), 0.82 (± 0.06), and 0.80 (± 0.01) / 100 kpm/min with R1, R2, and R3 respectively.

Breathlessness increased signifcantly ($p<0.001$) both as ventilation ($\dot{V}E$=1/min) increased and as the magnitude of the added load increased (Fig 3.4).

$Y = 0.11\ \dot{V}E + 0.08\ E - 1.94$ ($r=0.81$)

$Y = 0.10\ \dot{V}E + 0.08\ R - 1.45$ ($r=0.76$)

3.2.2 Breathlessness and Inspiratory Pressure during Exercise and Loading

In resistive loading the magnitude of breathlessness was also closely related to peak inspiratory pressure; esophageal or mouth (Fig 3.5).

$Y = 0.14 + 0.11\ Pes$ ($r=0.78$)

$Y = 1.54 + 0.09\ Pm$ ($r=0.72$)

In elastic loading the magnitude of breathlessness was closely related to peak inspiratory pressure; estimated esophageal or mouth (Fig 3.6).

$Y = 0.07 + 0.11\ Pes$ ($r=0.71$)

$Y = 1.65 + 0.09\ Pm$ ($r=0.61$)

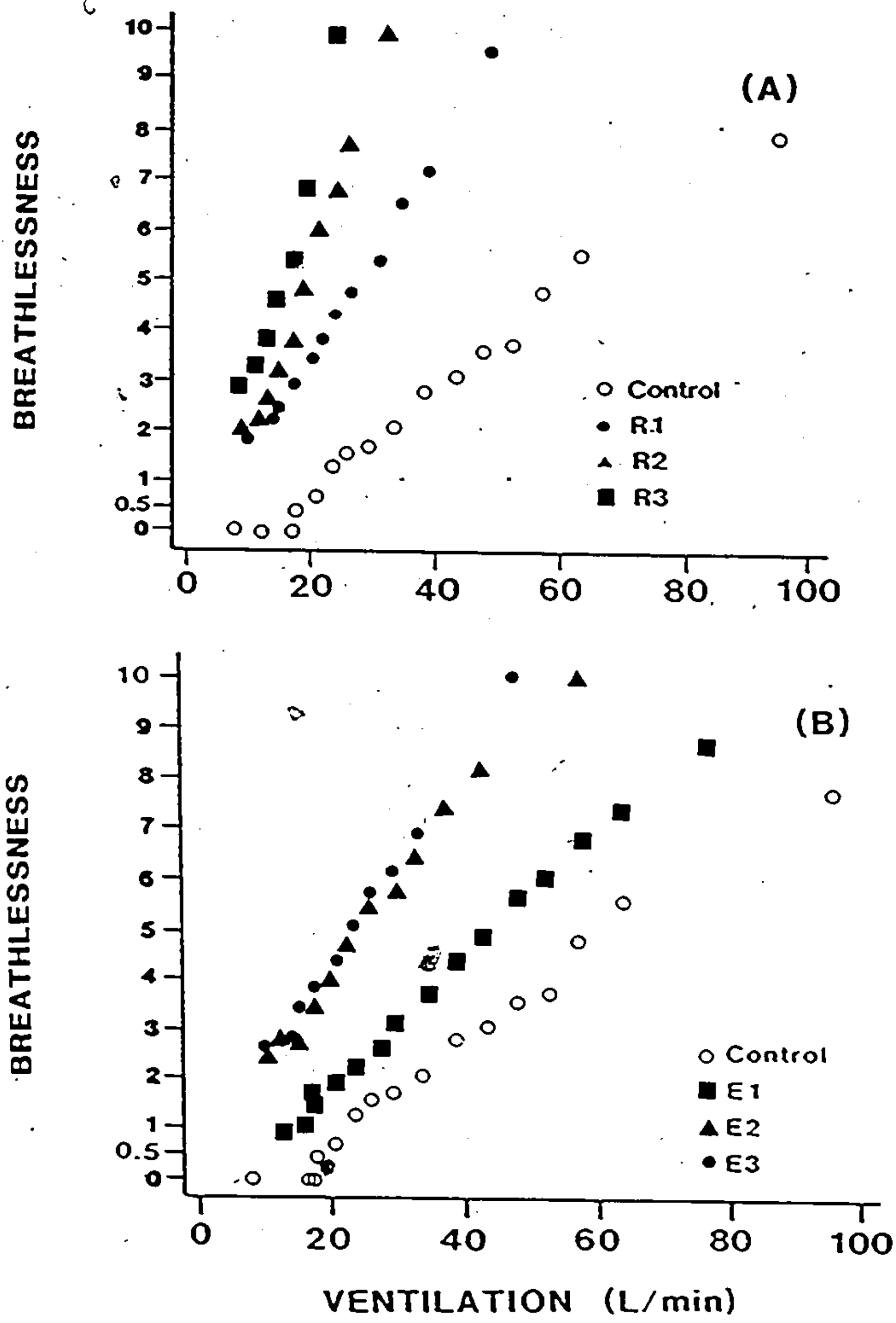

Fig 3.4 Rating of breathlessness plotted against Ventilation, resistive loads (3.3A), elastic loads (3.3B).

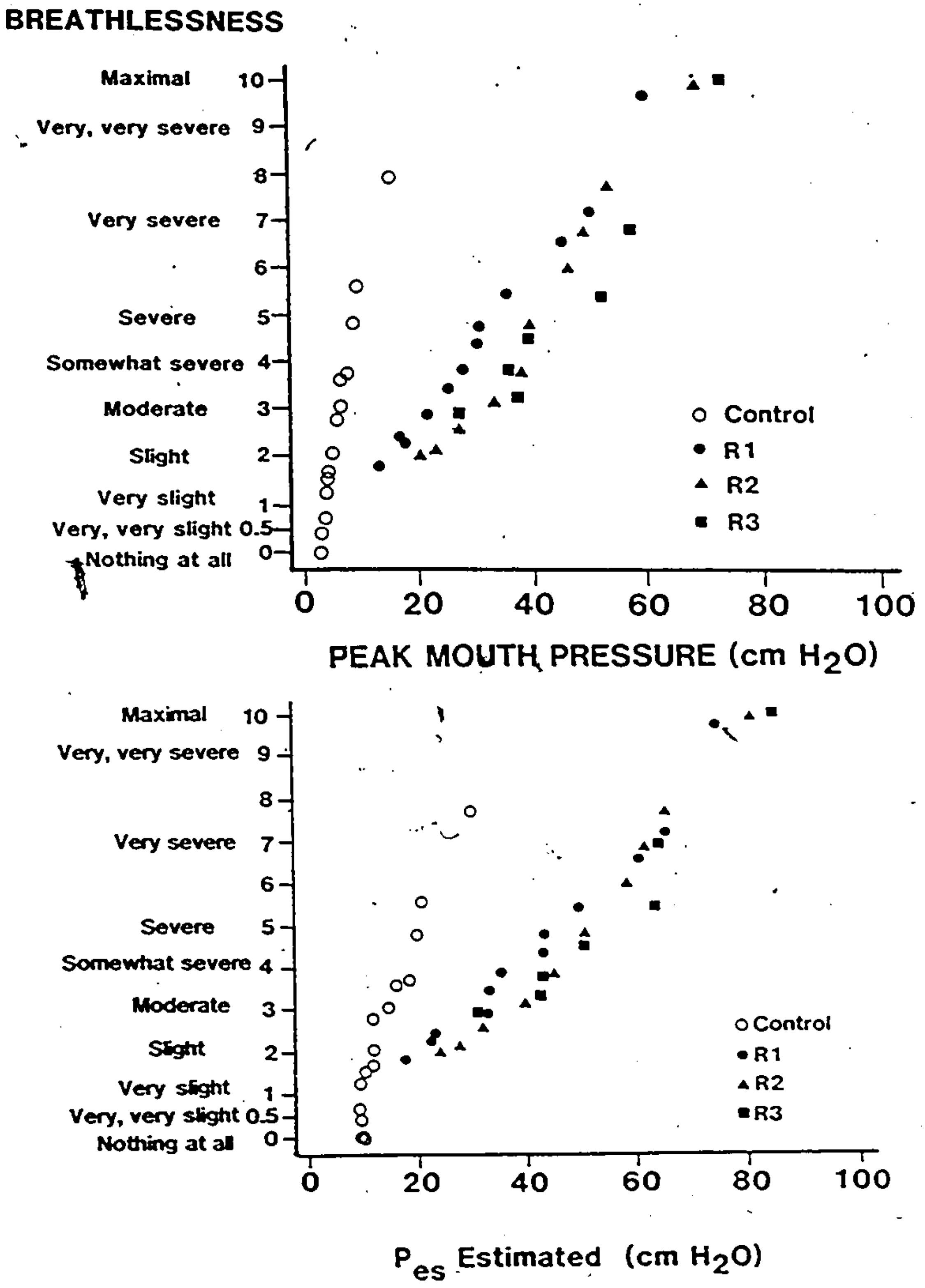

Fig 3.5 Rating of breathlessness plotted against peak inspiratory pressure (mouth and estimated esophageal)in unloaded and resistive loads.

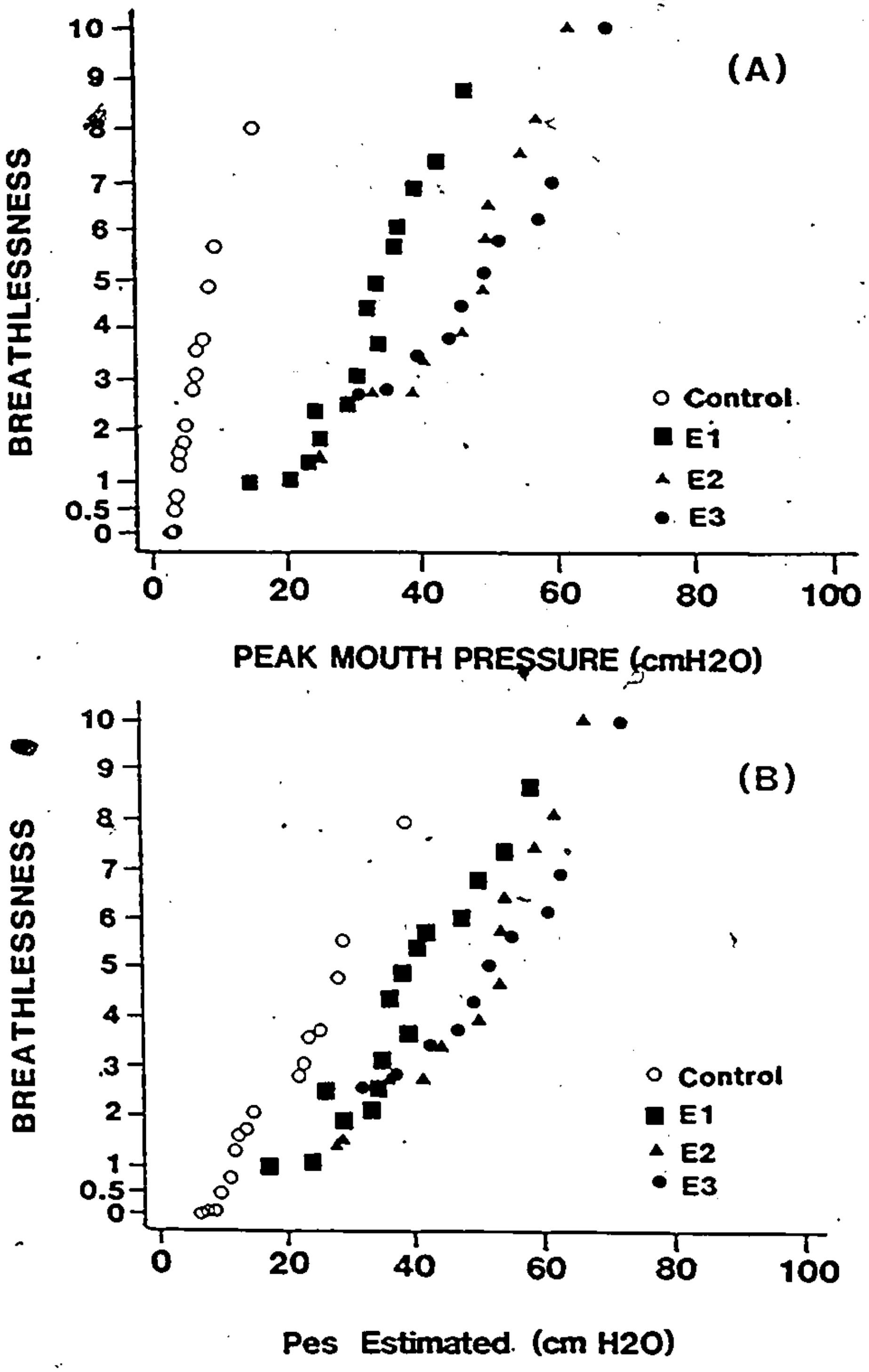

Fig 3-6 Rating, of breathlessness plotted against peak inspiratory pressure (mouth and estimated esophageal pressure) in unloaded and elastic loads.

3.2.3 Effect of Stressing Functional Force-Velocity Relationship (Resistive Loading)

Inspiratory resistive loads were used to reduce the inspiratory flow or functional velocity of shortening compared to unloaded condition. Although the perceived magnitude of breathlessness was closely related to peak inspiratory pressure, for any given magnitude of peak inspiratory pressure, the subjects were less breathless the greater the resistive load (C>R1>R2>R3) (Fig 3.5) i.e. the lower the inspiratory flow or the functional velocity of shortening. This effect may be expressed quantitaively by the following equations:

$$Y = 0.13 + 0.12\ \text{Pes} - 0.02\ R \qquad (r=0.80)$$

$$Y = 1.75 + 0.12\ \text{Pm} - 0.03\ R \qquad (r=0.74)$$

The effect of Vt (functional extent of shortening) and $\dot{V}i$ (functional velocity of shortening) on the capacity of the inspiratory muscles to generate maximum pressure was examined graphically (Fig 3.7) and their contribution to breathlessness was examined using multiple linear regression.

3.2.3.A The Graphical Analysis

The capacity of the inspiratory muscles to generate pressure decreased with the increase in flow and tidal volume (Fig 2.6). During exercise with unloaded control tests as well as resistive loaded tests the peak pressure generated occured at approximately 80% of the tidal volume where the flow reached its peak value (Fig

2.4). At these points during exercise the predicted maximum pressure that can be generated by the inspiratory muscles was calculated taking into account the effect of volume and flow. Using the modified Campbell diagram both the maximum and the actual generated estimated esophageal pressure at maximum level of exercise in unloaded and resistive loaded tests were plotted (Fig3.7 A, B, C, and D). At maximum level of exercise the drop in the predicted maximum pressure in unloaded tests was greater due to the larger increase in both Vt and $\dot{V}i$ (Fig 3.7A). In resistive loading studies the drop in the predicted maximum pressure was less, however, the actual pressure generated to overcome the the added resistive loads was much higher than unloaded tests (Fig 3.7B, C, and D).

3.2.3.B Statistical Analysis

3.2.3.B.1 Contribution of Tidal Volume and Inspiratory Flow

Using multiple linear regression and breathlessness as dependent variable and Pes, $\dot{V}i$ and Vt as independent variables, Pes and $\dot{V}i$ were significantly and independently related to the perceived magnitude of breathlessness (F = 501, 323). However, Vt was not significant (Partial F = 1.5).

3.2.3.B.2 Contribution of Frequency (fb) and Duty Cycle (Ti/Ttot)

Both frequency and duty cycle were significantly and independently related to the perceived magnitude of breathlessness (F = 227, 172).

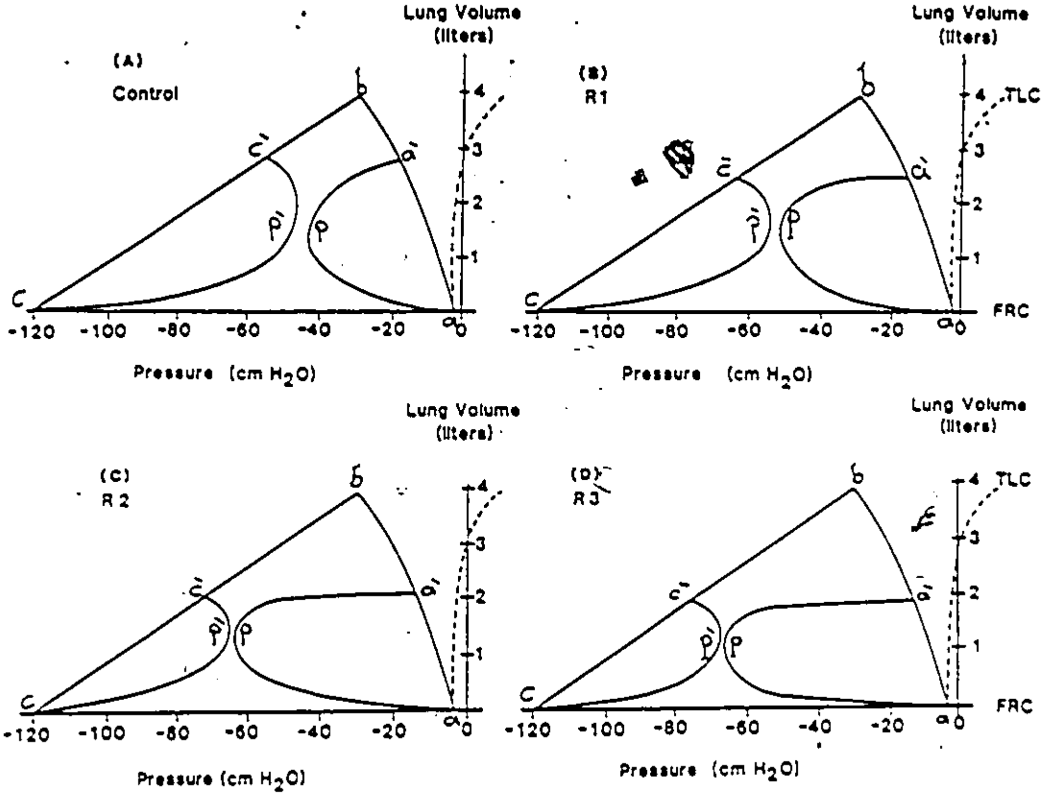

Fig 3.7 The Diagrams illustrate relationship of the mean static pressure-volume of the lung, line ab, and the mean maximum inspiratory esophageal pressure at different lung volumes from FRC to TLC, line cb. The diagrams illustrate, also, the increase in inspiratory pressure due to increased volume and flow at maximum exercise (loop $ap\bar{a}$). Also, the reduction in maximum inspiratory pressure at same tidal volume and inspiratory flow (loop $cp\bar{c}$) is illustrated in unloaded (3.7A), and resistive loaded (3.7B,C,D).

3.2.3.B.3 Contribution of Pes, Vi, Vt, Fb, and Ti/Ttot

The relationship between breathlessness (dependent variable) and Pm or Pes, $\dot{V}$i, Vt, Fb, and Ti/Ttot (independent variable) were examined using multiple regression analysis. Pm, $\dot{V}$i, and Ti/Ttot were found significantly related to rating of breathlessness independently and collectively (P <0.01). The equation describing this relationship was as follows :

$$Y = 0.11\,\mathrm{Pes} + 0.61\,\dot{V}i + 1.99\,\mathrm{Ti/Ttot} + 0.04\,\mathrm{fb} - 2.60 \quad (r=0.83)$$

$$Y = 0.10\,\mathrm{Pm} + 1.46\,\dot{V}i + 1.98\,\mathrm{Ti/Ttot} - 1.83 \quad (r=0.83)$$

where Y is the predicted perceived magnitude of breathlessness, Pes is the estimated peak esophageal pressure, Pm is the peak mouth pressure, Ti/Ttot is the duty cycle, $\dot{V}$i is the peak inspiratory flow, and fb is the frequency of breathing. Tidal volume did not contribute collectively to the perceived magnitude of breathlessness because the difference between unloaded and resistive conditions was small inspite of being significant.

3.2.4 Effect of Stressing Functional Length-Tension Relationship (Elastic Loading)

Inspiratory elastic loads were used to reduce the tidal volume or the functional extent of shortening (Vt) of the inspiratory muscles compared to the unloaded condition. Although the perceived magnitude of breathlessness was also closely related to peak inspiratory pressure, for any given magnitude of peak inspiratory pressure (mouth or esophageal) the subjects were less breathless the greater the elastic load (C>E1>E2>E3) (Fig 3.6) i.e. the lower the tidal volume and the extent of shortening. This effect may be expressed quantitatively in the following equations:

$$Y = 0.10 + 0.14\ Pes - 0.04\ E \qquad (r=0.76)$$

$$Y = 1.91 + 0.14\ Pm - 0.07\ E \qquad (r=0.66)$$

The contribution of the tidal volume, inspiratory flow, and inspiratory pressure were examined graphically and statistically. The contribution of the frequency of breathing and the duty cycle was examined statistically also.

3.2.4.A The Graphical Analysis

The effect of Vt and Vi on the maximum pressure generating capacity of the inspiratory muscles was examined graphically during elastic loading and unloaded exercise. The drop of the predicted maximum pressure generating capacity of the unloaded tests was calculated as described above. However, during elastic loading the peak pressure occured at end inspiration where the flow was 0. Thus, the predicted maximum pressure that can be generated by the inspiratory muscles was calculated at these points without taking into account the effect of flow or the resistive component. In Fig 3.8 (A,B,C,D) both the maximum pressure that can be generated by the inspiratory muscles at the points of peak pressure and the actual peak pressure were plotted against work load. In elastic loading exercise tests the drop due to increased Vt was not as much as

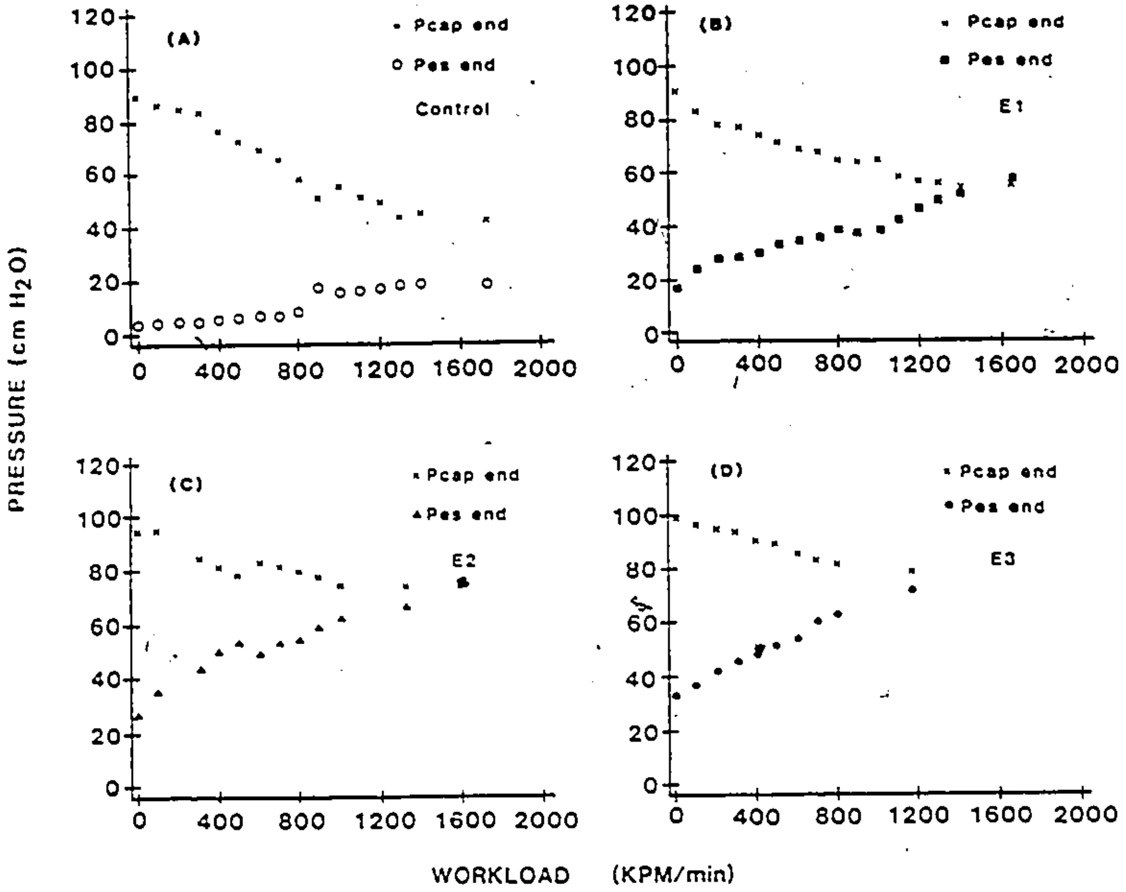

Fig 3.8 The estimated reduction in maximum esophageal pressure (Pcap) taking into account the effect of volume and flow in the unloaded condition (3.8A) and the effect of volume with the elastic loading (B,C,D) and the measured peak inspiratory pressure (Pes) generated during exercise plotted against work loads in unloaded (3.8A), and elastic loads (3.8B,C,D).

unloaded condition i.e. The capacity of the inspiratory muscles was reduced due to the increase in the actual pressure generated by these muscles to overcome the external added impedance (Fig 3.8 B,C,D). On the other hand in unloaded condition the capacity of the inspiratory muscles was reduced due to the increase in the extent and velocity of shortening (Fig 3.8 A).

3.2.4.B The Statistical Analysis

3.2.4.B.1 Contribution of Tidal Volume and Inspiratory Flow

The contribution of Pm, Vt, and $\dot{V}i$ to breathlessness was examined also using multiple regression analysis. The perceived magnitude of breathlessness increased significantly with Pes (partial F = 387) and with Vt (partial F = 229). Both were highly significant ($P<0.001$). $\dot{V}i$ or Vt/Ti did not significantly contribute to the perceived magnitude of breathlessness. Both inspiratory flow rate and mean inspiratory flow were similar at a given workload with and without elastic loading. Thus they did not significantly contribute collectively to breathlessness as expected from the graphical analysis (partial F=0.5).

3.2.4.B.2 Contribution of Frequency and Duty Cycle

Frequency of breathing (fb) was significantly and independently related to breathlessness (parial F = 280). However Ti/Ttot failed to contribute collectively to breathlessness (partial F=2.10) because the difference between the loaded and unloaded conditions, although significant, was small.

3.2.4.B.3 Contribution of Pes or Pm, $\dot{V}i$, Vt, fb, and Ti/Ttot

The relationship between these variables and the perceived magnitude of breathlessness was examined using multiple rgression analysis. Pes/Pm, Fb, and Vt were significantly related to the perceived magnitude of breathlessness individually and collectively:

$$Y = 0.07\ Pm + 1.7\ Vt + 0.16\ fb - 4.12 \qquad (r=0.84)$$

$$Y = o.08\ Pes + 1.14\ Vt + 0.16\ fb - 4.10 \qquad (r=0.84)$$

3.2.5 Loading and Volume Contribution of Rib Cage and Abdomen

During the control studies the relative contribution of RC and ABD displacement remained approximately similar from the beginning to maximum exercise (RC:ABD 2.33:1). The relative contribution of rib cage to the abdomen significantly decreased during exercise tests with added resistive loads (2.13:1, 1.78:1, 1.70:1) with R1, R2, and R3 respectively ($P<0.05$). During exercise with added elastic loads this ratio decreased significantly further to 1.63:1, 1.33:1, and 1.22:1 with E1, E2, and E3 respectively ($P<0.05$). The relative contribution of rib cage to abdomen was also significantly decreased during the second control exercise tests (1.20:1) ($P<0.05$). However, there was no paradox movement of rib cage and abdomen at any time of the test.

The relative movement of the RC and ABD was not significantly related to the perceived magnitude of breathlessness during loaded or unloaded conditions.

3.3 Ventilatory Control

3.3.1 Ventilatory Response to Loading

The mean ventilation achieved at the mean maximum workload in exercise tests without added inspiratory loads (C1,C2) was 96 ± 23 and 94 ± 23 l/min respectively. The ventilation was not significantly different in C2 test from C1 test. The mean maximum ventilation achieved in exercise tests with added resistive loads was 48 ± 6.3, 32 ± 5.2, and 24 ± 3.9 l/min in R1, R2, and R3 tests respectively (Fig 3.1A). The mean maximum ventilation achieved in exercise tests with added elastic loads was 76 ± 13.9, 55 ± 12, and 47 ± 12.3 l/min in E1, E2, and E3 tests respectively (Fig 3.1B). At a given workload the ventilation was reduced in exercise tests with added resistive and elastic loads. This reduction was small but significant ($P<0.05$).

$$\dot{V}E = 8.35 + 0.04\ W - 0.07\ E \qquad (r=0.94)$$

$$\dot{V}E = 8.48 + 0.04\ W - 0.10\ R \qquad (r=0.93)$$

where $\dot{V}E$ is total ventilation (l/min), W is leg power output (kpm/min), E is the total elastance (cmH2O/l), and R is the total resistance (cmH2O/l/s). This reduction is difficult to detect graphically with elastic loading.

3.3.2 Ventilatory Response to Metabolic Demands

$\dot{V}E$ was closely related to $\dot{V}CO_2$ in both control and loaded conditions (Fig 3.9). There was significant reduction of the slopes

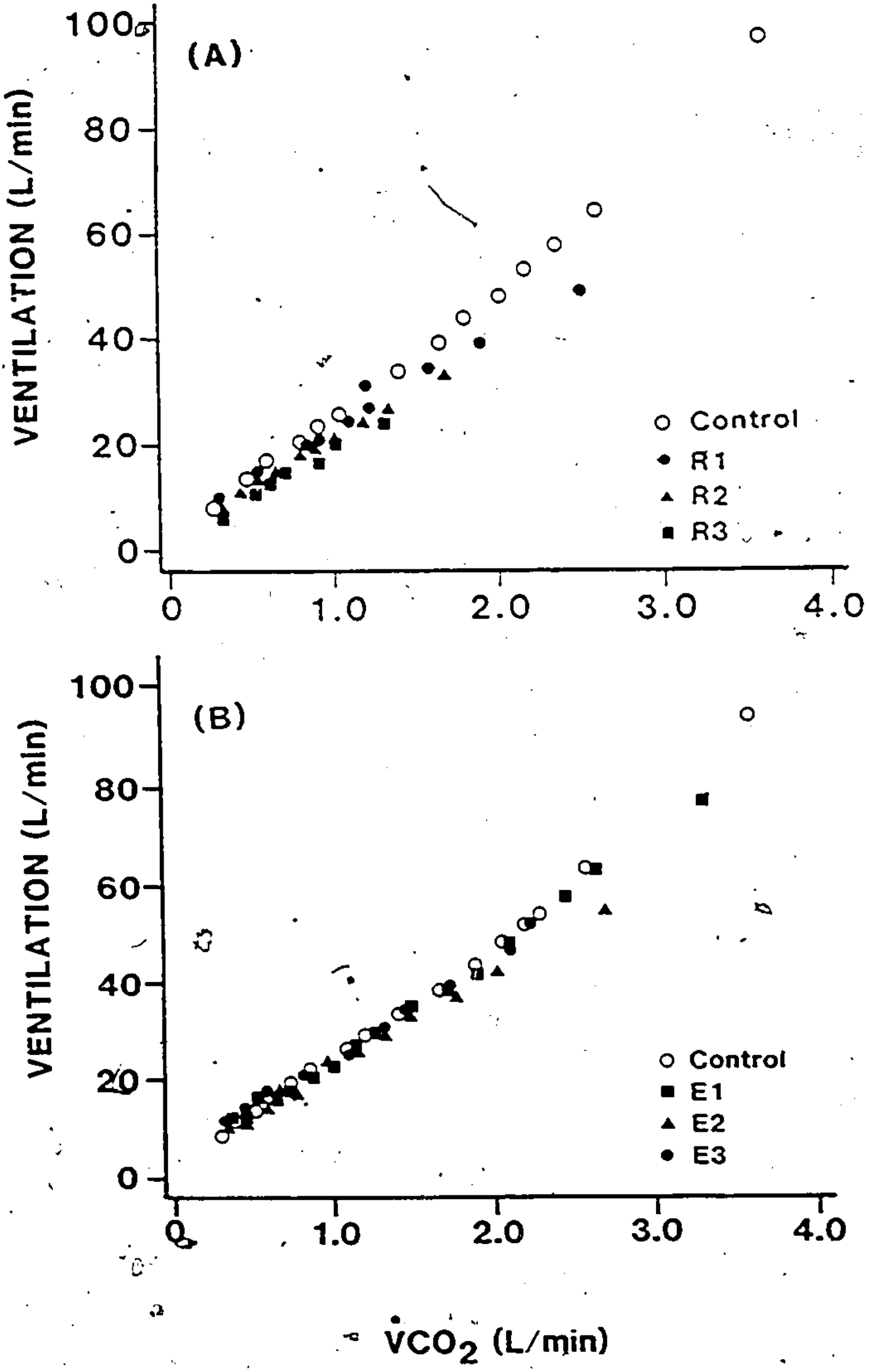

Fig 3.9 Ventilation plotted against CO2 output, resistive loads (3.9A), elastic loads (3.9B).

with R1 and R2 and significant increase with R3. The intercepts significantly decreased in resistive loading condition. During elastic loading there was no significant difference between loaded and unloaded conditions (Fig 3.9) (Table 3.3, 3.4).

In exercise tests with added resistance $\dot{V}CO2$ (ml/min) was slightly and insignificantly reduced (Fig 3.10);

$\dot{V}CO2 = 189 + 1.75\ W - 0.001\ R$ (r=0.98, partial F=1611, 2.90).

$\dot{V}O2$ (ml/min) showed a small but insignificant increases with added inspiratory loads (Fig 3.11);

$\dot{V}O2 = 398 + 1.60\ W + 0.0001\ R$ (r=0.99, partial F=2119, 0.5)

The measured VO2 was significantly related to the power ouput (kpm/min) of the exercising leg muscles ($p<0.0001$) and the power output of the inspiratory muscles (kpm/min) ($p<0.001$):

$\dot{V}O2$ (ml/min) $= 430 + 1.4\ W + 8.8\ Wresp$ (r=0.99)

where Wresp is the estimated power output of the inspiratory muscles (kpm/min).

In exercise tests with added elastic loads $\dot{V}CO2$ increased very slightly but insignificantly as the elastance increased (Fig 3.10);

$\dot{V}CO2 = 151 + 1.80\ W + 0.0003\ E$ (r=0.99, partial F= 11591, 0.43).

	Intercept ± SD	Slope ± SD	R^2 ± SD
Control 1	0.83 ± 1.97	24.44 ± 3.86	.99 ± .004
Resistance 1	4.35 ± 2.67	18.53 ± 2.82	.99 ± .009
Resistance 2	3.33 ± 1.86	17.82 ± 4.01	.98 ± 0.02
Resistance 3	2.78 ± 0.76	16.64 ± 2.49	.98 ± 0.02
Control 2	0.09 ± 2.62	24.60 ± 3.64	.96 ± 0.08

Tab 3.3 Ventilatory response as a function of VCO_2 in control and with resistive loading.

	Intercept ± SD	Slope ± SD	R^2 ± SD
Control 1	0.83 ± 1.97	24.44 ± 3.86	0.99 ± 0.004
Elastance 1	2.20 ± 1.93	22.5 ± 3.85	0.99 ± 0.60
Elastance 2	2.95 ± 2.66	19.6 ± 3.33	0.99 ± 0.36
Elastance 3	3.70 ± 1.93	20.0 ± 4.17	0.99 ± 1.67
Control 2	0.09 ± 2.62	24.60 ± 3.64	0.96 ± 0.08

Tab 3.4 Ventilatory response as a function of VCO_2 in control and with elastic loading.

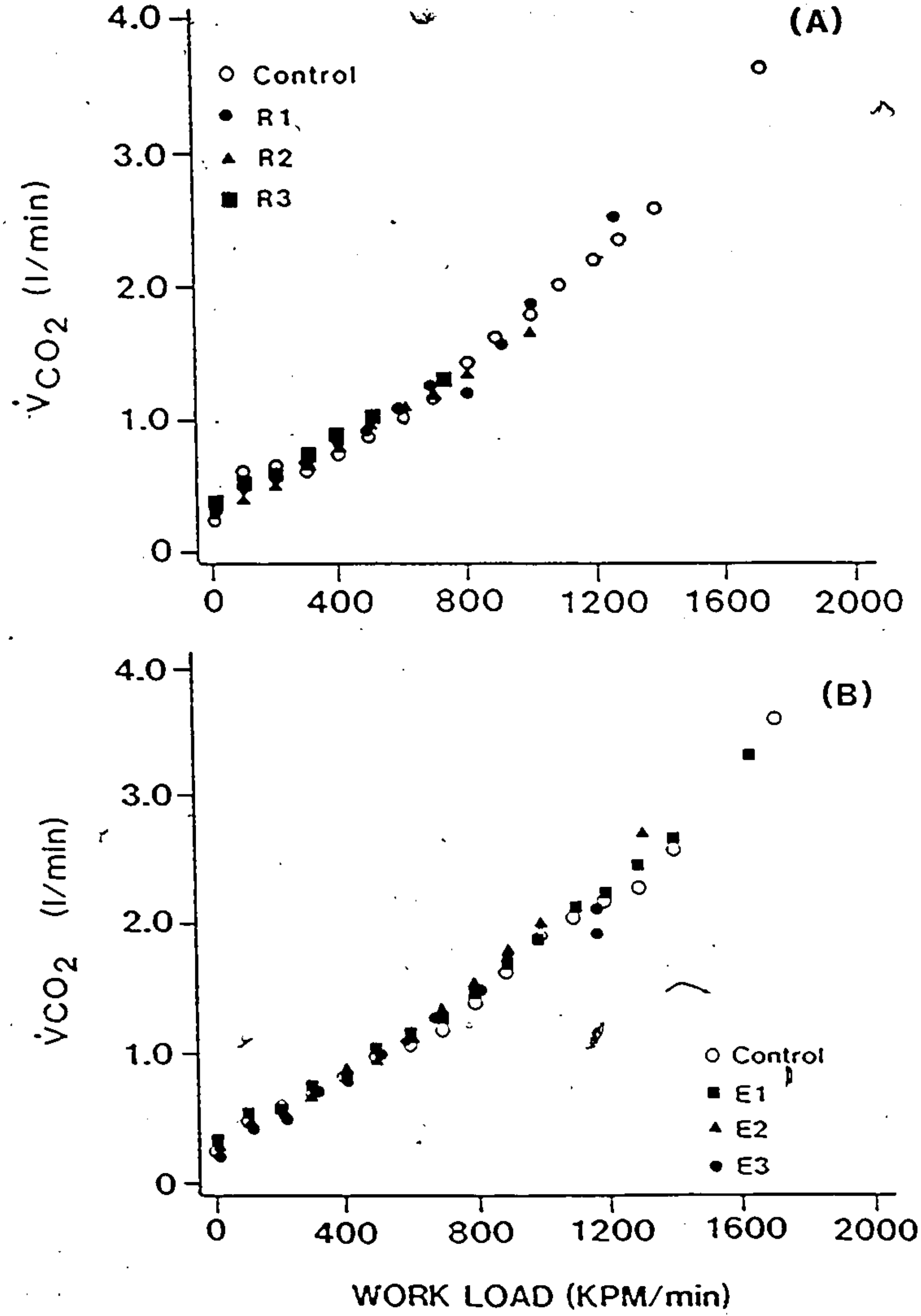

Fig 3-10 CO2 output plotted against work loads, resistive loads (3-10A), elastic loads (3.10B).

$\dot{V}O2$ increased slightly but significantly with the increase in added elastic loads ($P<0.05$) (Fig 3.11);

$$\dot{V}O2 = 379 + 1.60\ W + 0.8\ E \quad (r=0.99,\ \text{partial}\ F=17686,\ 7.55).$$

The measured $\dot{V}O2$ was significantly related to the power output of the exercising leg muscles ($p<0.001$) and the inspiratory muscles ($p<0.001$):

$$\dot{V}O2\ (\text{ml/min}) = 425 + 1.4\ W + 6.0\ W_{resp}\ (r=0.99)$$

3.3.3 Loading and Gas Exchange

PetCO2 increased significantly at same work load with added resistive and elastic loads indicating a reduction in alveolar ventilation ($P<0.05$). Thus at 500 kpm/min (the work load achieved by all subjects) PetCO2 increased from 41 mmHg in C1 to 44, 48, and 49 mmHg in R1, R2, and R3 respectively (Fig 3.12A). Similarly at 800 kpm/min (the work load achieved by all subjects in elastic loading studies) PetCO2 increased from 41 mmHg in C1 to 45, 46, and 48 mmHg in E1, E2, and E3 respectively (Fig 3.12B).

There was little or no decrease in SaO2 % with added resistive and elastic loads. Thus at 500 kpm/min SaO2 % was 96 % in C1 and 96, 95, and 95 % in R1, R2, and R3 respectively (Fig 3.13A). Similarly at 800 kpm/min, SaO2 % was 96 % in C1 and 95, 95, and 95 % in E1, E2, and E3 respectively (Fig 3.13B).

3.3.4 Loading and Ventilatory Pattern

The subjects varied widely in their ventilatory patterns in

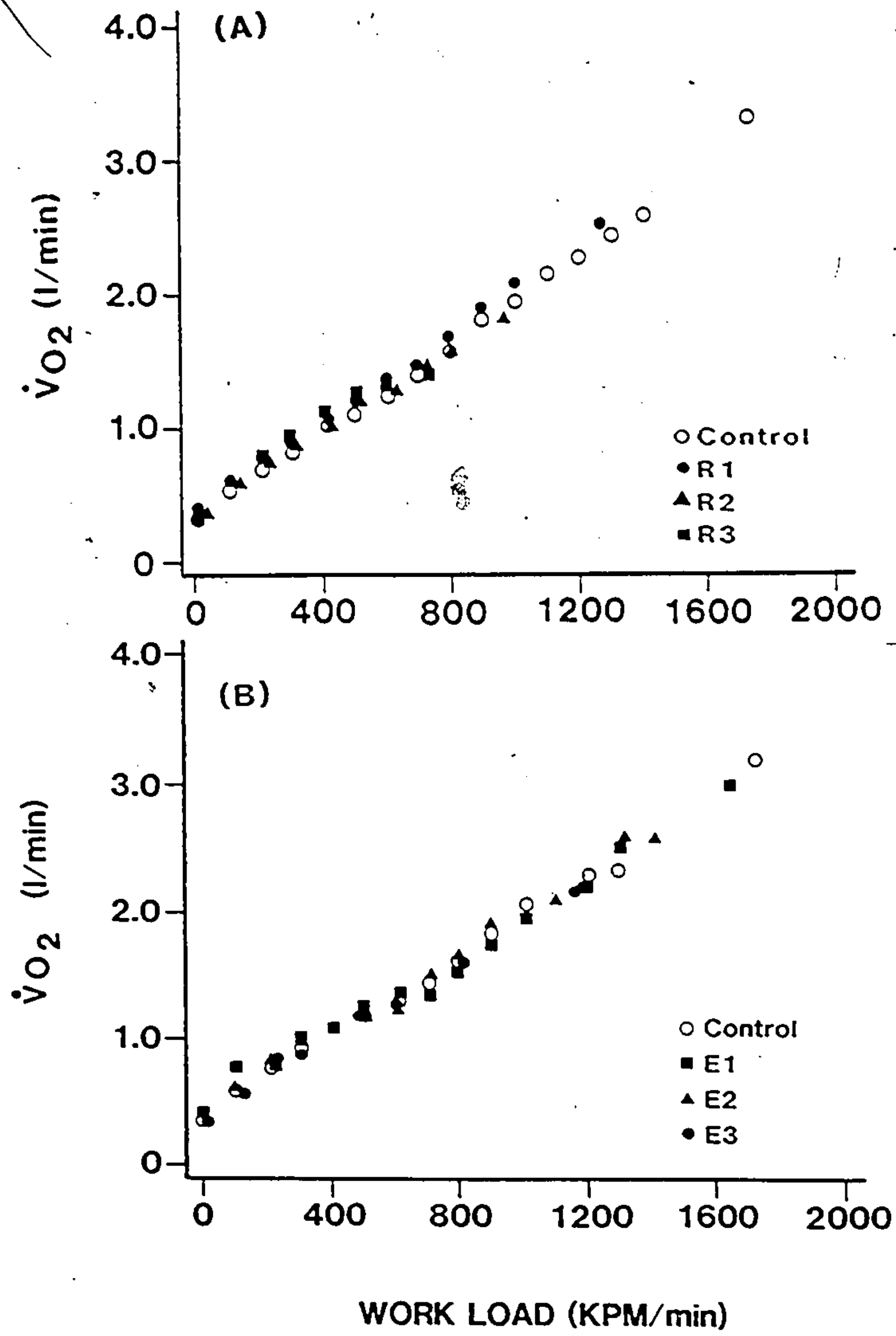

Fig 3.11 O2 uptake plotted against work loads, resistive loads (3.11A), elastic loads (3.11B).

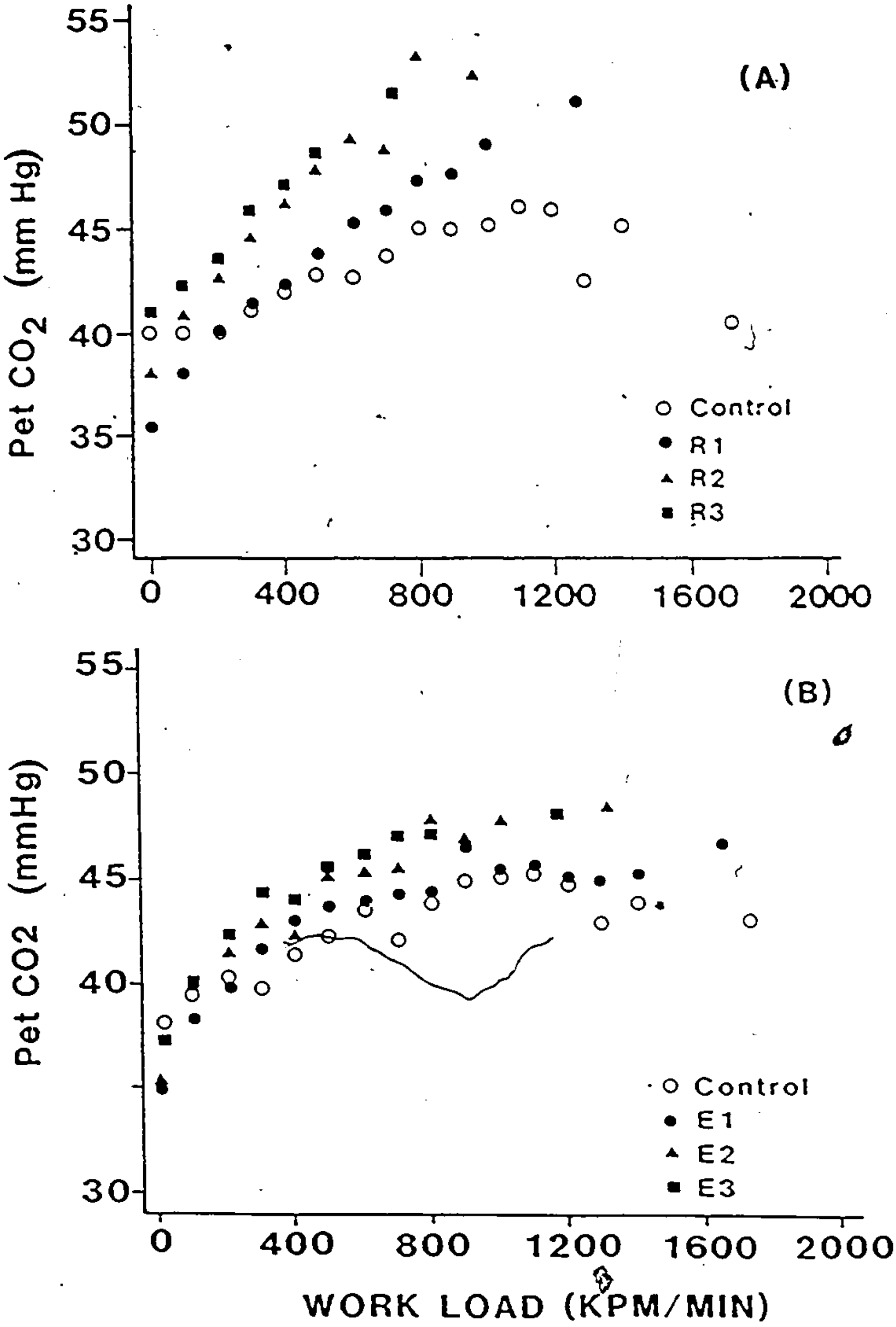

Fig 3.12 End-tidal CO2 plotted against work loads, resistive loads (3.12A), elastic loads (3.12B).

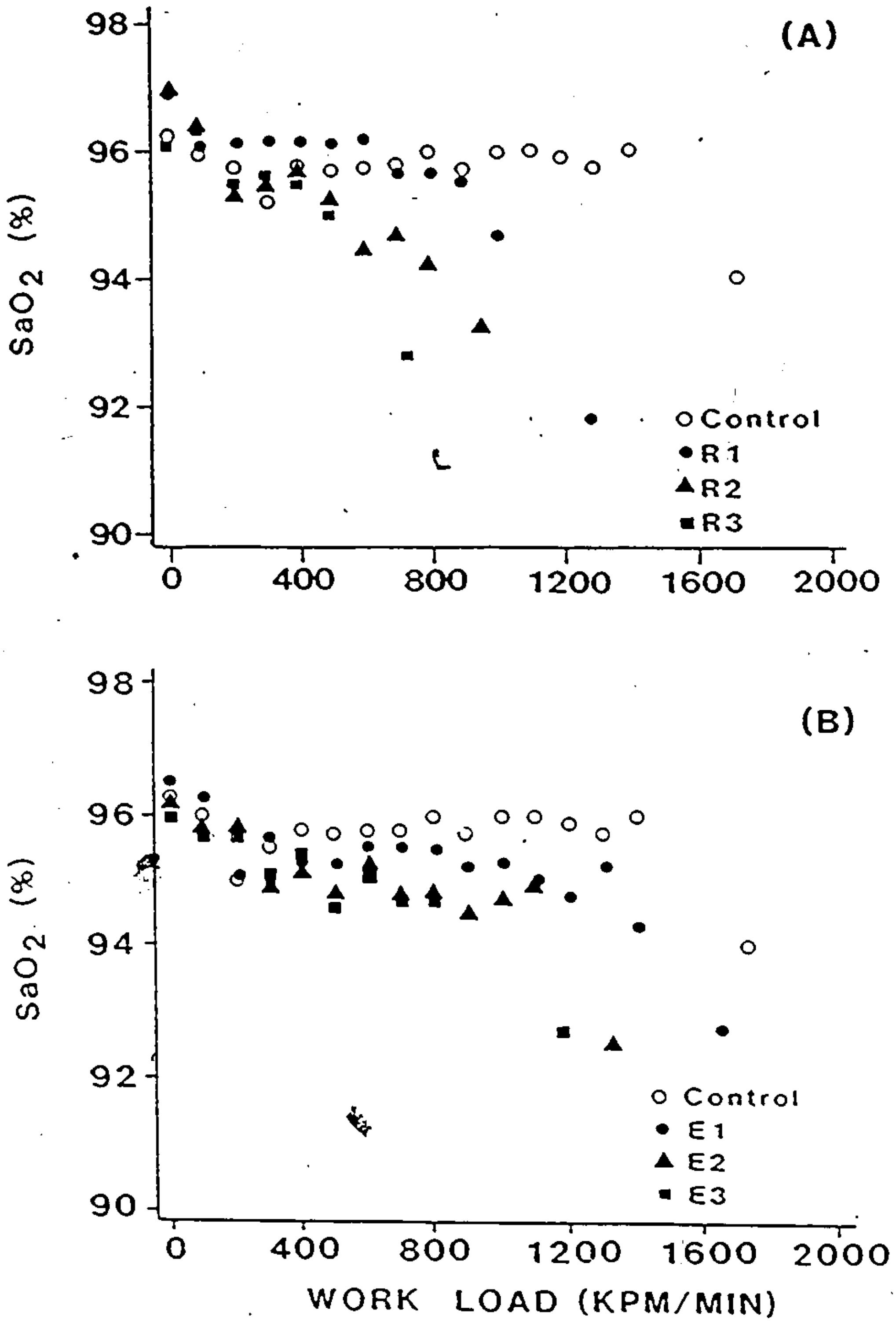

Fig 3.13 Arterial oxygen saturation plotted against work loads, resistive loads (3.13A), elastic loads (3.13B).

exercise tests without added inspiratory loads (appendix 7.3). The peak and mean inspiratory flow as well as the breathing frequency increased slightly but significantly at comparable workloads during the second control unloaded exercise tests (C2), whereas the inspiratory time (Ti) and the duty cycle were reduced slightly but significantly.

With resistive loading at the same work loads Ti, Ttot, Ti/Ttot, and Vt significantly increased as resistance increased ($P<0.05$) (Fig 3.14, 3.15). At 500 kpm/min, the workload achieved by all subjects during the three resistive loading conditions, the mean of Ti increased from 1.75 sec to 3.57, 4.66, and 5.89 sec in R1, R2, and R3 respectively. Similarly the mean of Ttot increased from 4.16 sec to 5.6, 6.6, and 6.9 sec in R1, R2, and R3 respectively. Vt increased also from 1.5 l in C1 to 1.97, 2.0, and 2.0 l in R1, R2, and R3 respectively at 500 kpm/min. $\dot{V}i$ and fb declined significantly as resistance increased ($P<0.05$) (Fig 3.16, 3.17). The mean of fb at 500 kpm/min decreased from 15.8 b/min in C1 to 11.5, 10.5, and 9 b/min in R1, R2, and R3 respectively. The mean of $\dot{V}i$ decreased from 1.5 l/sec in C1 to 1.09, 0.74, and 0.77 l/sec in R1, r2, and R3 respectively.

With elastic loading Ti, Ttot, Ti/Ttot, and Vt were significantly reduced at comparable workload as the added elastance increased ($P<0.05$) (Fig 3.14, 3.15). For example at 800 kpm/min, a workload achieved by all subjects during the three elastic loadings, Ti decreased from 1.69 sec in C1 to 1.13, o.94, and 0.85 sec with E1, E2, and E3 respectively. Similarly Ttot decreased from 3.5 sec in C1 to 2.84, 2.29, and 2.17 sec in E1, E2, and E3 respectively.

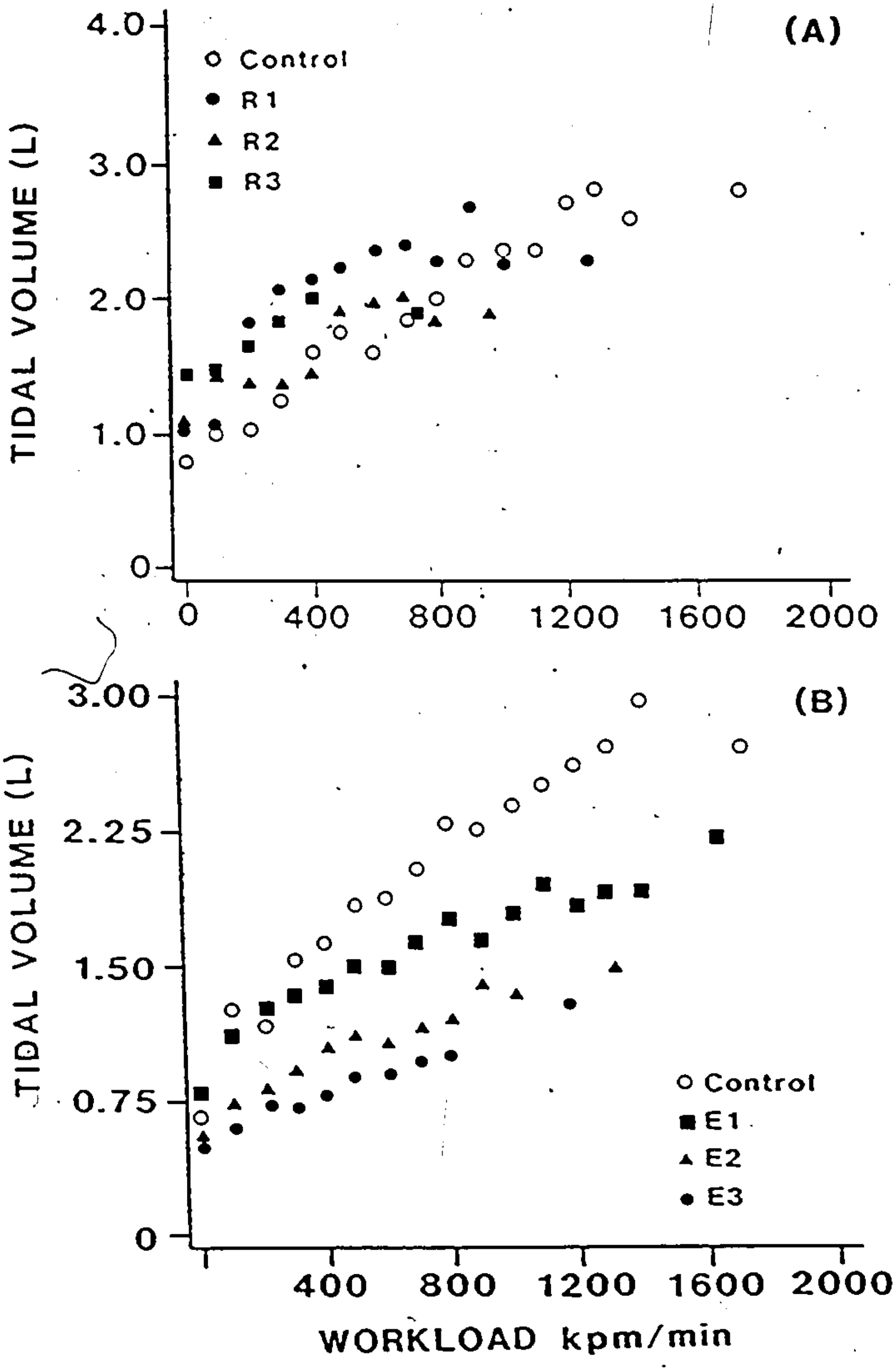

Fig 3.14 Tidal volume plotted against work loads, resistive loads (3.14A), elastic loads (3.14B).

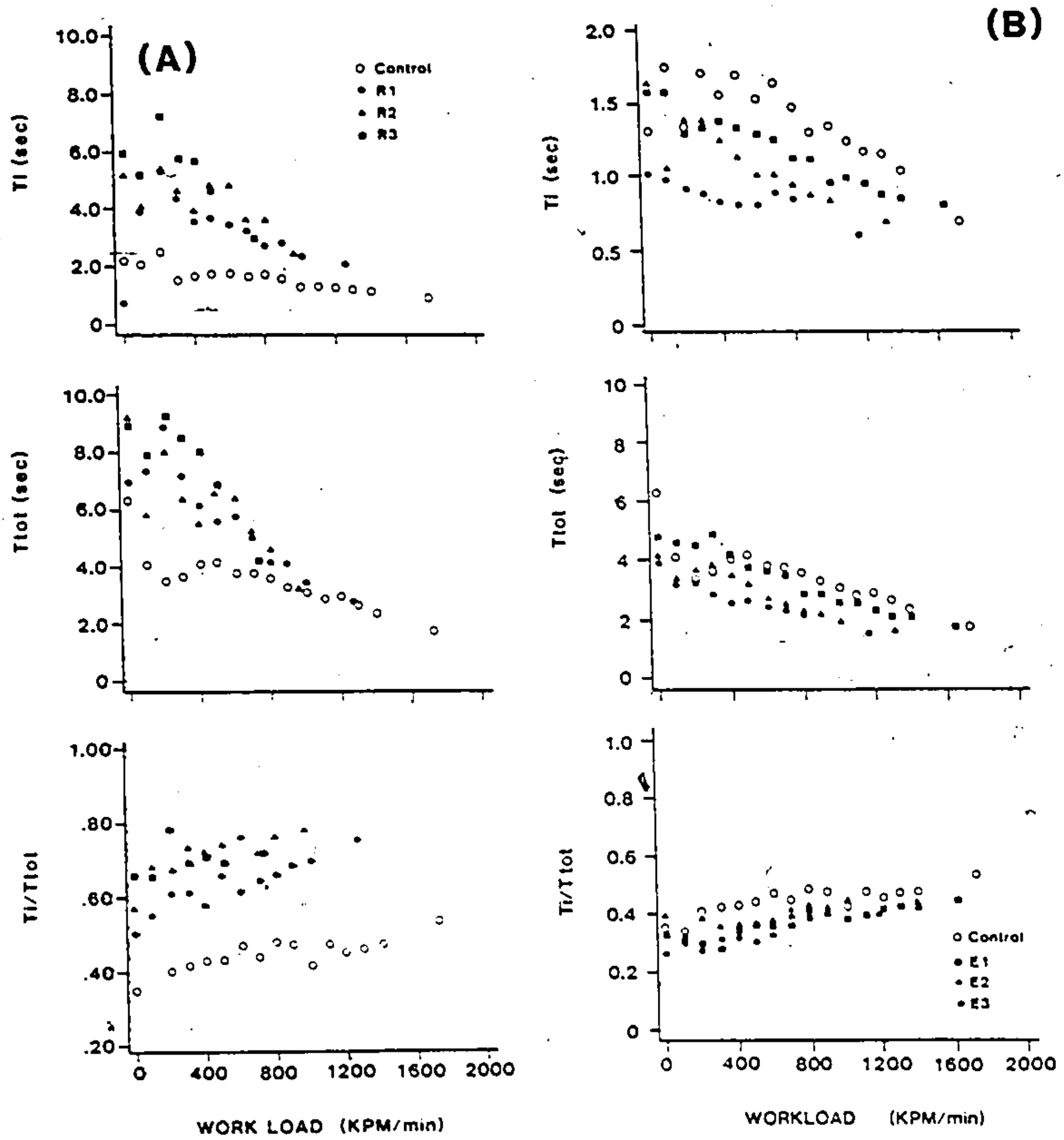

Fig 3.15 Inspiratory time (Ti), respiratory time duration (Ttot), duty cycle (Ti/Ttot) plotted against work loads, resistive (3.15A), elastic loads (3.15B).

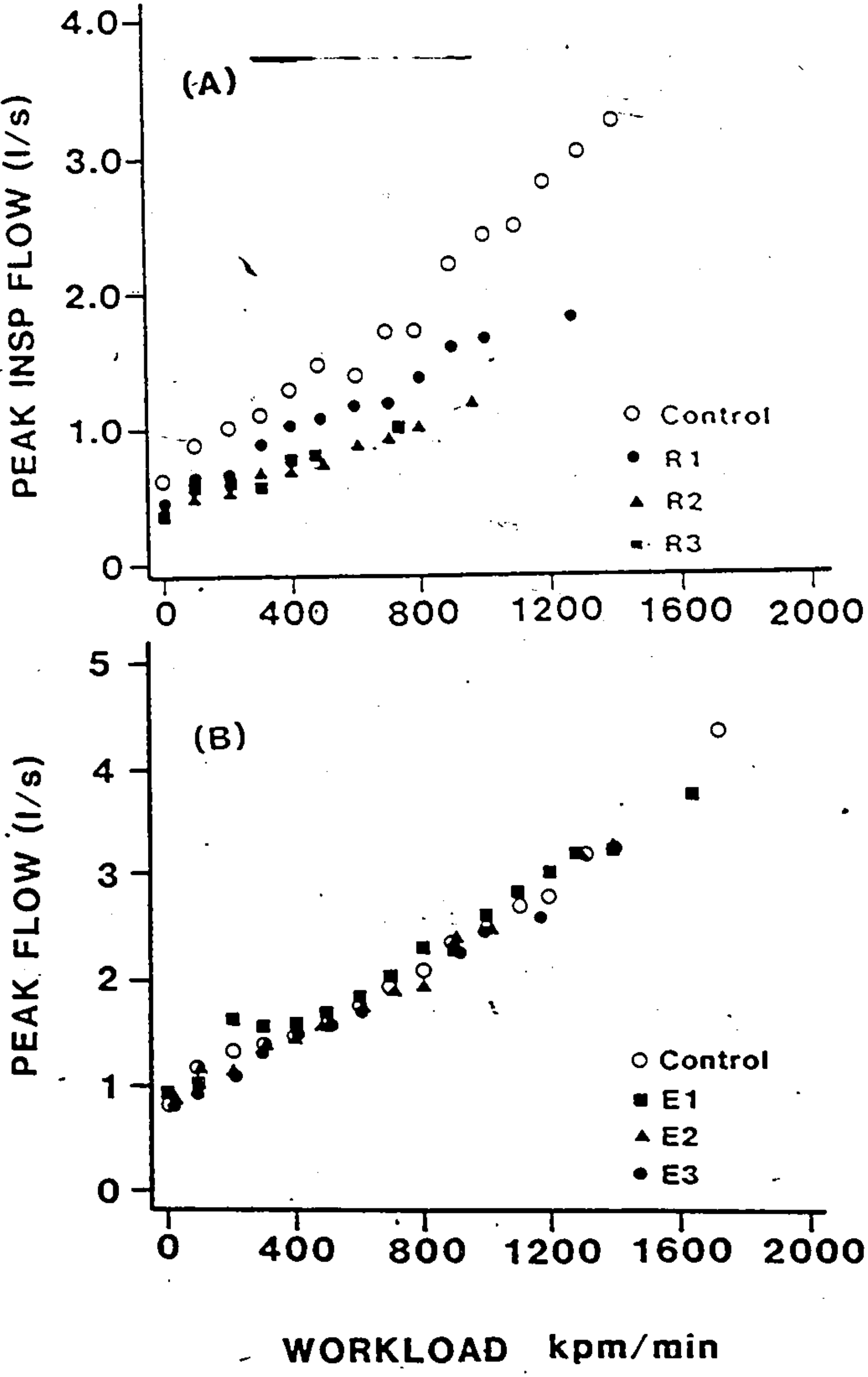

Fig 3.16 Inspiratory flow rate against work loads, resistive loads (3.16A), elastic loads (3.16B).

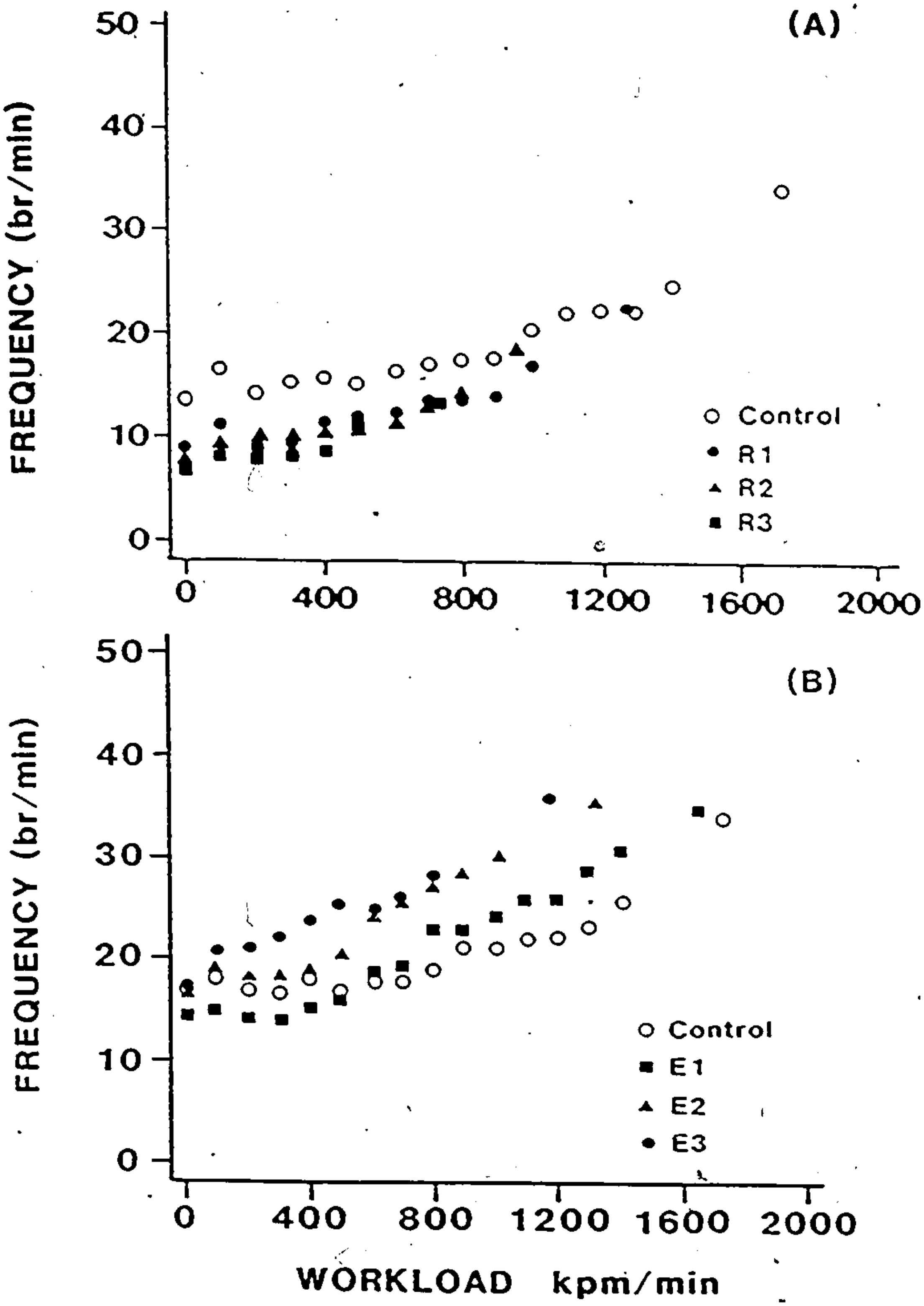

Fig 3.17 Frequency of breathing plotted against work loads. resistive loads (3.17A), elastic loads (3.17B).

Similarly Vt decreased from 2 l in Cl to 1.7, 1.2, and 1.0 l at same work load. The mean fb significantly increased in the exercise tests with added elastic loads ($P<0.05$) (Fig 3.17). At 800 kpm/min breathing frequency increased from 17 br/min in Cl to 23, 27, and 28 br/min in E1, E2, and E3 respectively. $\dot{V}i$ increased slightly only in exercise tests with added elastic loads E1 and E2, but this increase was significant ($P<0.05$) (Fig 3.16).

3.3.5 Observed vs Predicted Frequency of Breathing

The measured frequency was compared with the calculated values for predicted frequency to minimize work and predicted frequency to minimize peak force.

During unloaded exercise tests the observed frequency was consistent with the predicted frequency to minimize peak force (both were not significantly different). However, the observed frequency was significantly lower than the predicted frequency to minimize work ($p<0.05$) (Fig 3.18A).

During exercise tests with the lowest added resistance (R1) the observed frequency was consistant with the predicted frequency to minimize work. However, the observed frequency was significantly ($P<0.05$) higher than the predicted frequency to minimize peak force (Fig 3.18B). During exercise tests with added resistances R2 and R3 the observed frequency was significantly higher than both predicted frequencies ($P<0.05$) (Fig 3.18C).

During exercise tests with added elastic loads (E1,E2,E3) the observed frequency was significantly lower than the both predicted frequencies under all elastic conditions (Fig 3.18D,E)

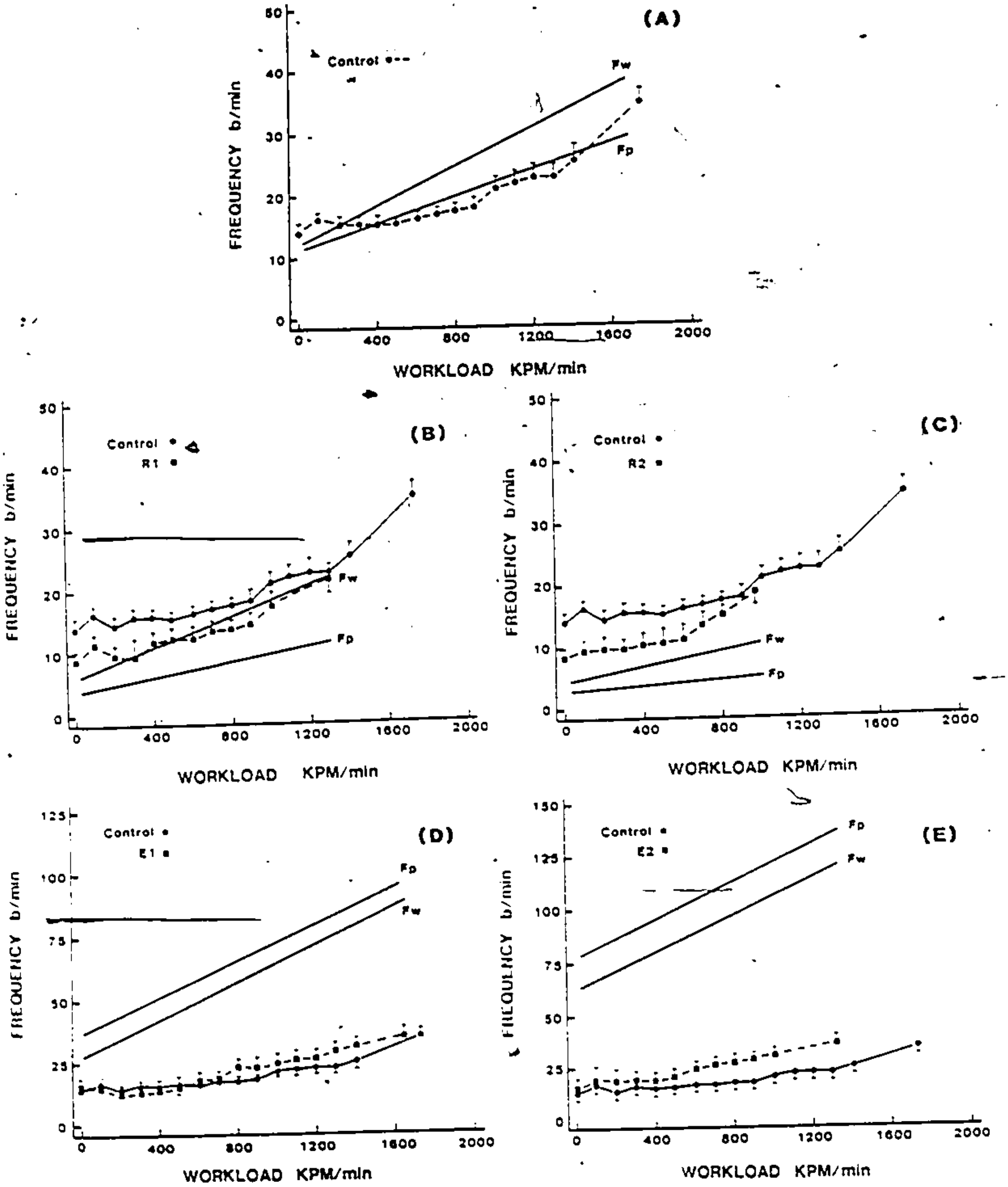

Fig 3.18 Frequency of breathing plotted against work loads. Closed circles are the mean observed frequency in unloaded tests (control studies), closed square are the mean observed frequency in loaded studies, the two solid lines are the regression lines for the predicted frequency to minimize work (Fw), and predicted frequency to minimize peak force (Fp). Unloaded control studies (18A), first resistive load (18B), second resistive load (18C), first elastic load (18D), second elastic load (18E).

(P<0.0001). Both predicted frequencies were in the unphysiologic range of response of the respiratory pattern.

The frequency of breathing was quantitatively related to the metabolic demands ($\dot{V}CO2$), the capacity of the inspiratory muscle to generate force (MIP), the elastance (E), and the resistance (R) of the respiratory system as shown in the following equation:

$$fb = 12.56 + 6.6\ \dot{V}CO2\ (l/min) + 0.18\ E - 0.06\ R - 0.04\ MIP \quad (r=0.85,\ p<0.01).$$

CHAPTER 4: DISCUSSION

Respiratory loading during rest and exercise has been used to examine the effect of loading on ventilation, ventilatory pattern, blood gases, and the work of breathing (Cerretelli, Sikand, and Farhi, 1969; Gee, Vassallo, and Gregg, 1968; Hanson, Tabakin, Levy, and Falsetti, 1965; Tabakin, and Hanson, 1960). The findings in the present study in general were similar to those of previous studies. However, in this thesis exercise and inspiratory loading were used to achieve different aims. First, to quantify the intensity of breathlessness associated with the increased respiratory forces. Second, to isolate the contribution of inspiratory pressure to the perceived magnitude of breathlessness. Third, to see if tidal volume (functional extent of respiratory muscle shortening), inspiratory flow rate (functional velocity of respiratory muscle shortening), duty cycle, and frequency of breathing contribute to the sensation of breathlessness independent of their effect in increasing respiratory pressures. Finally, to evaluate previous hypotheses that the frequency of breathing is selected to minimise peak inspiratory force or the work of breathing.

4.1 Summary of the Findings

During exercise with and without added inspiratory loads the intensity of breathlessness increased as the ventilation increased. However, at any level of exercise or ventilation, the intensity of breathlessness was greater as the added resistance or elastance increased. At maximum exercise in both loaded and unloaded exercise the intensity of breathlessness was close to maximal and approximately similar. Breathlessness was variably related to pressure even when corrected for the pressure required to overcome the impedance of the lung. For a given pressure the perceived magnitude of breathlessness was less with increasing added inspiratory load. This was true regardless of the nature of the added load (resistive or elastic). In resistive loading studies, the perceived magnitude of breathlessness was higher for a given pressure—the higher the inspiratory flow. Taking into account the factors we hypothesised would contribute to breathlessness in resistive loading - inspiratory pressure, inspiratory flow, frequency of beathing, and duty cycle - all significantly and independently contributed to the perceived magnitude of breathlessness. In elastic loading studies, the perceived magitude of breathlessness was higher for a given pressure as the tidal volume increased. Again the variables that we hypothesised would contribute to breathlessness in elastic loading - inspiratory pressure, tidal volume and frequency of breathing significantly and independently contributed to the perceived magnitude of breathlessness.

The major contributions of the study were in quantifying the intensity of breathlessness, and defining both the factors contributing to breathlessness and the relative importance of factors tending both to increase the forces and to reduce the capacity to generate force by the respiratory muscles.

4.2 Breathlessness and the Examined Hypothesis

The hypothesis examined in the present study defined the sensation of breathlessness as the subjective sensation of respiratory muscle effort. The hypothesis implies that under most of the circumstances in which sensation of breathlessness occurs there should be common factors contributing to its magnitude, and that the sensation of breathlessness is related to the motor function of the respiratory muscles. The factors contributing to breathlessness are recognized to be the strength of the inspiratory muscles, the pressure generated by these muscles (functional tension generated), the tidal volume (functional length of shortening), the inspiratory flow (functional velocity of shortening), the frequency of breathing and the duty cycle. The hypothesis suggested that the intensity of breathlessness increases with any of the following changes acting alone or in combination - decreased strength of the inspiratory muscle; increased pressure generated; increased tidal volume; increased inspiratory flow; increased frequency of breathing; increased duty cycle. The reasoning behind these factors will be discussed below.

Before interpreting the findings in the present study several points should be considered. First, with any voluntary muscle contraction a number of discrete sensations are generated. To initiate a motor act, graded effort is generated. Subjects can sense the magnitude of this effort but also, as the effort results in displacement and tension, the magnitude of tension or displacement may also be sensed. All depend on the impedance opposing the motor act. For example if unimpeded effort results in high velocity and extent of shortening but little tension; whereas if totally impeded effort results in tension with little displacement. Both tension and displacement (and its derivatives including the magnitude of impedance) can be sensed independent of effort. The magnitude of effort required to generate a given tension increases as the velocity of contraction increases, and as the length shortens (Elmanshawi, Summers, Campbell, Killian, 1986). Second, the maximum force that can be generated by a muscle decreases as its length decreases. However, the effort to generate the maximum force at different lengths remains the same (Cafarelli et al, 1979). The maximum force also decreases as the velocity of shortening increases. Third, the maximum tension that can be generated by a muscle approximately repesents the maximum motor output to this muscle (Gandevia et al., 1977, Cafarelli et al, 1979). Fourth, the effort perceived is proportional to the motor output to the muscle (McCloskey, Ebeling, and Goodwin, 1974, McCloskey, 1978).

4.2.1 Breathlessness and Respiratory Effort

As mentioned earlier in the introduction, the hypotheses that breathlessness is the perception of respiratory work, power, force, etc., failed to explain the different circumstances associated with the sensation of beathlessness. The perception of respiratory effort is suggested as an alternative explanation for all the circumstances associated with breathlessness. Increased impedance, weakness of respiratory muscles, or increased ventilation are the commonest circumstances in which breathlessness occurs. Respiratory effort increases under all these circumstances, and assuming that the sensation has a common mechanism, a neurophysiological process must be common to all these circumstances, as will be described latter in the discussion. The design of the present study allowed us to examine the factors contributing to the sensation of breathlessness with both the increased ventilation and the increased impedance.

Breathing is a motor act and in common with other motor acts, respiratory muscle action can be perceived. Thus the tension generated by these muscles, the displacement, the velocity, the impedance overcome by these muscles, and the effort required to produce tension and displacement all can be perceived independently. Using psychophysical techniques, Baker et al. (1970) showed that subjects can perceive tidal volume, pressure and ventilation independently. They found that the perceptual magnitude of volume or pressure or flow was related to the physical magnitude by a power function. Wolkove, Altose, Kelsen, Konapalli, and Cherniack (1981) found that tidal volumes can be matched with reference tidal volumes in a group of normal subjects. Stubbing et al., (1983) and Killian et al (1984) were able to illustrate the increase in the perceived magnitude of inspiratory muscle force with the increase in the pressure generated by these muscles in normal subjects. In the same studies Killian et al. (1984) measured the perceived magnitude of respiratory effort and breathlessness required for a given pressure generated by the inspiratory muscles at different lung volumes. They found that the perceived magnitude of effort increased as the pressure generated by respiratory muscle increased, but the perceived magnitude of respiratory effort and breathlessness were similar for a given pressure and increased as the volume increased. These studies indicated that sensations associated with the act of breathing can be perceived and quantified. Also, there was a high correlation between the perceived magnitude of respiratory effort and breathlessness suggesting that both have a similar mechanism (Killian et al., 1984). Thus in the present study, the perceived magnitude of breathlessness was defined as the subjective sensation of the perceived effort exerted by the respiratory muscles.

Two characteristics are common to most sensory modalities - quality and quantity (intensity). For example, the sensation perceived while a muscle is contracting isometrically is different in quality from that experienced during an isotonic contraction. However, the subjects can quantify the muscle effort for each task. Similarly the sensation during unloaded breathing is qualitatively different from that during loaded breathing, but the respiratory effort in both conditions can be quantified. In the present studies, at maximum exercise, with or without loading, the intensity of breathlessness was comparable. This observation suggests either that there are many sensations associated with the act of breathing that may be unpleasent and labeled as breathlessness, or that something is common to all conditions. We favour the latter explanation, as developed below.

4.2.2 Quantification of Breathlessness

The sensation of breathlessness, in common with other sensory modalities, lends itself to quantification by psychophysical scaling methods including ratio scales (open magnitude estimation) (Stevens,1958), category scaling (Borg scale) (Borg, 1980) and ordinal scales (Fletcher, 1952). The Borg scale used in this study is a category scale with ratio properties (Borg, 1980). This scale was used in preference to other scales for the following reasons. First, the scale is widely used to measure the sense of effort accompanying muscular exertion of many types (Borg, 1982). Second, in contrast to open magnitude scaling, it allows comparisons across individual subjects and within individual subjects when testing has taken place at different times. Third, it is simple to use in that the numbers are anchored to verbal expressions which are easily understood by most people. Finaly, it covers the whole sensory continuum for any given sensation (zero to maximum).

As most normal subjects and patients are limited during exercise by either breathlessness or leg fatigue, the quantification of breathlessness is useful in the interpretation of limiting factors to exercise. It may usefully complement ~~the~~ conventional physiolgical measurements of ventilation, heart rate, etc. The results of the present work show that the sensation of breathlessness is a continuum increasing in intensity with exercise, as expressed by a threshold and a slope. The threshold is lowered and the slope is increased as the impedance of the respiratory system increases (Fig 3.2). The rating of breathlessness at maximum exercise was maximum (loaded tests) or close to maximum (unloaded tests) (Fig 3.3). Yet the pressure generated under the two conditions was quite different (Fig 3.5, 3.6). During unloaded exercise the peak pressure was approximately 40 cmH20, whereas during loaded execise the peak pressure was approximately 80 cmH20. These results suggest that there are other factors in addition to the pressure generated by the inspiratory muscles that contribute to breathlessness.

4.3 Factors Contributing to Breathlessness

The contribution of the pressure generated by the inspiratory muscles, the static strength of these muscles, the frequency of breathing and the duty cycle were investigated by Jones et al. (1983, 1985). All were found to contribute independently to breathlessness with inspiratory loading (Jones et al., 1983, 1985). In the present study, the contribution of these variables to breathlessness were examined at wider range of extent and velocity of shortening of inspiratory muscles using incremental exercise and inspiratory loading. Thus contribution of the tidal volume (functional length of shortening) and the inspiratory flow (functional velocity of shortening) to breathlessness has been emphasised. The role of these two variables as well as the other variables will be explained in the following sections taking into account the above mentioned points.

4.3.1 Contribution of Pressure, Tidal volume, and Inspiratory Flow

In skeletal muscles effort is related to the tension generated by these muscles and the length of shortening of these muscles (Cafarelli and Bigland-Ritchie, 1979, Gandevia and

McCloskey, 1977). Cafaralli et al. (1979) examined the sensation of perceived voluntary forces at different muscle lengths. The subjects matched a series of static voluntary contractions with simultaneous contractions of the contralateral muscle. Excitatory input was monitored from smoothed rectified electromyograms. The measure for sensation was matching force. They found that when contractions in paired muscles of different maximal strength were matched on the basis of equal sensation, the stronger muscle generated more force. When the length was adjusted so that the tension producing capacity in both muscles was equal, both the reference and the matching forces were nearly the same. They also found that the smoothed rectified EMG was essentially unaffected by length, suggesting that the degree of efferent command was constant under each condition. Cafaralli et al. (1979) found also that the maximum voluntary force decreased as the extent of shortening increased. This was true whether the subjects contracted their muscle voluntarily or by peripheral nerve stimulation. They concluded from the findings that for any degree of activation in a shortened muscle, the force declined but the sensation remain constant. Thus to maintain the initial force at a shorter length required more activation and increased sensation.

We may apply the findings of Cafarelli et al. (1979) to the hypothesis examined in this thesis. We hypothesized that during increased ventilation, as the tidal volume and inspiratory flow increased the capacity of the respiratory muscle to generate force would decrease and the perceived effort increase. We also hypothesized that for a given pressure effort would increase, as the velocity and extent of shortening increase. Thus, the extent of shortening (tidal volume) and the velocity of shortening (inspiratory flow) are seen as important variables contributing to the perceived magnitude of breathlessness, contributing both to an increase in the tension (pressure generated by the inspiratory muscles) and a reduction in the functional strength of these muscles.

As in other skeletal muscles, the maximum force that can be generated by inspiratory muscles decreases with increases in the extent and velocity of shortening. Previous work has established that maximum negative esophageal pressure at FRC (approximately MIP) decreases to recoil pressure of the lung and chest wall as inspired volume approaches TLC, and also decreases by a further 6% for each l/s increase in inspiratory flow at any given volume (Agostoni et al., 1960, Hyatt et al., 1966, Rahn et al., 1949, Ringqvist, 1966, Leblanc, Bowie, Summers, and Killian, 1984) (Fig 2.6).

Extrapolating these fundamental observations of length-tension, and force-velocity of the respiratory muscles to our data the following changes were observed. During exercise without adding any inspiratory loads the predicted maximum inspiratory pressure that can be generated would decrease from 120 cmH2O at FRC to 50 cmH2O at maximum exercise. However, the actual peak pressure generated increased gradually with the increase in volume and flow until it approached the maximum predicted pressure at maximum work load (Fig 3.7, 3.8). During exercise with added resistive loads the predicted changes in maximum inspiratory pressure (at the point of peak inspiratory flow) are less than those in unloaded conditions at maximum exercise because the changes in tidal volume and inspiratory flow were less. The expected maximum pressure decreases from 120 cmH20 to 70, 80, and 90 cmH20 with R1, R2, and R3 respectively at maximum exercise (Fig 3.7). However, the actual peak pressure generated was higher compared to the unloaded condition (to overcome the external added resistance) and also approached the maximum predicted inspiratory pressure at maximum exercise (Fig 3.7). During exercise with added elastic loads the predicted maximum inspiratory pressure (at end inspiration because peak pressure occurs at end inspiration in elastic loading) decreases from 120 to 60, 70 and 80 cmH20 with E1, E2, and E3 respectively at maximum exercise. These reductions in the predicted maximum pressure were less than the reduction in the unloaded condition as the change in volume was small with elastic loading (3.8).

Thus the close rating of breathlessness to maximum in both loaded and unloaded exercise tests at maximum exercise was due to increased tension generated by the inspiratory muscles as well as reduction in tension generating capacity secondary to increased velocity and extent of shortening.

4.3.2 Independent Contribution of Tidal Volume and Inspiratory Flow to Breathlessness

Tidal volume and inspiratory flow rate contribute to the pressure required by the inspiratory muscle to maintain the metabolic demands of the body in the following way:

$$P = (Vt * E) + (\dot{V}i * R)$$

where P is the pressure generated, Vt is the tidal volume, E is the elastance of the system, $\dot{V}$i is the inspiratory flow, and R is the resistance of the system.

To produce the same pressure while breathing against increasing resistance the velocity will fall with increasing resistance. Also, to produce the same pressure while breathing through different elastances, the extent of shortening will be less with increasing elastic loads. Because shortening a muscle fibre (extent and velocity) reduces its capacity to generate force, more effort is required to produce the same pressure with a low resistance compared to a high resistance. Similarly more effort is required to produce the same pressure with a low elastance compared to a high elastance. In the present resistive loading studies, at any given inspiratory pressure the magnitude of breathlessness was higher with the smaller added resistive loads and with increasing velocity of shortening. Similarly, in the elastic loading studies, the perceived magnitude of breathlessness was higher at any given pressure the lower the added elastic load and the higher the extent of shortening. These findings have been further validated by a recent study in our laboratory (El-manshawi, Summers, Campbell, and Killian, 1986). 10 subjects targeted to 3 integrated inspiratory pressures (30, 60, 106 cmH2O.s/breath) whilst breathing through 3 different added inspiratory resistive and 3 elastic loads. The loads were used to provide a wide range of inspiratory flow rates and tidal volumes. Perceived effort increased both as integrated pressure increased and as flow rate increased with resistive loading. Perceived effort increased both as integrated pressure increased and as tidal volume increased. The results of this study indicated that the perceived magnitude of respiratory effort was independently and postively related to the integrated inspiratory pressure, and to the extent and velocity of shortening, and negatively related to the isometric capacity of the inspiratory muscles to generate force (MIP).

4.3.3 Effect of Frequency and Duty Cycle

Peak pressure, duration, duty cycle and frequency all contribute to the perceived magnitude of added inspiratory loads. Killian et al. (1982) derived the following emperical equation that closely reflected the interaction between these variables and the perceived magnitude of added loads:

$$Y = K\ Pm^{1.3} * Ti^{0.56} * fb^{0.28}$$

In those studies all the variables were randomly varied while in the present studies they were not. However, the results of resistive loading studies showed that both an increasing frequency of breathing and an increasing duty cycle contributed to increases in the intensity of breathlessness, independent of the peak inspiratory pressure and inspiratory flow. On the other hand, in elastic loading studies, frequency of breathing contributed to increases in the intensity of breathlessness, independent of the peak inspiratory pressure and tidal volume, while the duty cycle failed to reach significance. The exact mechanisms accounting for the increase in breathlesness with increases in frequency and duty cycle remain ill defined. But they are likely to be closely related to reductions in the capacity to generate pressure and to factors contributing to evolution of fatigue.

4.4 Potential Factors Contributing to Breathlessness

4.4.1 Respiratory Muscle Fatigue and Breathlessness

Roussos and Macklem (1977) suggested that respiratory muscle fatigue plays an essential role in the sensation of breathlessness. Although fatigue, defined as the inability to sustain the required force with continued contractions, may not be a necessary prerequisite to breathlessness, fatigue will intensify the symptom of breathlessness compared to the sensation of effort experienced in absence of fatigue. Bellemare and Grassino (1982) measured transdiaphragmatic pressure to derive a tension-time index (TTDi) - the time integral of pressure, obtained from the product of Pdi/Pdimax * Ti/Ttot. They were able to define the fatigue threshold of the respiratory muscles by identifying the TTDi at which electromyographic evidence of diaphragmatic fatigue occurred. The fatigue threshold occured when TTDi exceeded 0.15. During the present study we did not measure transdiaphragmatic pressure but it is reasonable to assume that the values in our subjects would be considerably smaller under unloaded than loaded condition. Under unloaded conditions, the velocity and extent of contraction are stressed, with modest increases in tension, whereas during loaded conditions the velocity, as in resistive loading, and the extent of shortening, as in elastic loading, are small, but the increases in tension are large. At maximum exercise, the tension-time index of

Bellemare and Grassino would be in the non fatiguing range in the unloaded condition despite the presence of severe breathlessness. During loading, values of TTDi may well have exceeded the fatigue threshold, considering both the high pressure and duty cycle as in resistive loading or high pressure alone as in elastic loading. Yet the subjects were only a little more breathless than under unloaded condition at maximum exercise. Because intensity of breathlessness was a continuum, increasing with ventilation in both loaded and unloaded conditions, the results of the present study suggest that while fatigue may contribute to the intensity of breathlessness, it is not necessarily a prerequisite.

4.4.2 Breathlessness and Oxygen Cost of Breathing

The sense of effort required to lift a weight or perform muscular work increases when the perfusion to the lifting muscle is reduced (Myers and Sullivan, 1968, Jones, 1983). Similarly failure to maintain the metabolic demands of the respiratory muscles by reducing any of the essential substrates including oxygen would be expected to result in a reduction in its capacity to generate force and an increase in the perceived effort. Some authors argued that the oxygen cost of breathing may contribute to a limitation of exercise capacity and development of breathlessness. (Otis et al., 1950; McIlroy, 1954). As all our subjects were limited during loaded studies by breathlessness, it might be expected that the oxygen supply of the respiratory muscles might be a limiting factor.

During cycle ergomtry an increase in oxygen intake is very closely related to an increase in power. As in the present study the power output of the exercising leg muscles was associated also with a wide range of inspiratory muscle power outputs (unloaded, elastic and resistive loads) we may relate the measured V02 to the calculated power output of both muscle groups. We were able to ascertain that the power output of the inspiratory muscles both contributed significantly to the measured oxygen uptake. However, the contribution of the respiratory muscles to V02 was small (8.8 mls/kpm/min). Clearly the excess cost is difficult to estimate under exercise conditions where the oxygen cost of peripheral muscle force approaches 2000 - 4000 ml/min. In this study we cannot confirm or deny that tissue oxygenation of the respiratory muscles contributed to breathlessness.

4.4.3 Breathlessness and End-Tidal C02 and Oxygen Saturation

Reduction in ventilatory responsiveness would serve to reduce effort by decreasing ventilation at a given $\dot{V}$C02. Despite the increased work associated with the elastic or resistive loading ventilation was linearly related to C02 output under all conditions, loaded and unloaded. However, the intercept increased significantly and the slope of the ventilatory response to $\dot{V}$C02 declined significantly as the resistance increased. The net result was a rise in PetCo2 and a reduction in arterial oxygen saturation as respiratory resistance increased and as exercise increased. These observed alterations in control (reduced ventilatory response to $\dot{V}$C02) coupled with the modification of the respiratory pattern contributed to reduce inspiratory effort and breathlessness. Finally as ventilatory demands increase the only adaptation to reduce breathlessness is to terminate exercise. Thus the sensation of breathlessness may act to protect the respiratory muscles from fatigue, and could be one reason why frank fatigue is difficult to demonstrate during exercise. It should be noted that in contrast to resistive loading elastic loading did not significantly alter ventilatory responsiveness to $\dot{V}CO2$. It seems unlikely that the difference occurs at chemoreceptor level but is more likely related to the muscular response and its interaction with the impedance of the system.

4.5 Breathlessness and the Adaptive Responses in Breathing Pattern

For many years two hypotheses have been forwarded for frequency optimization. The first hypothesis suggested that the frequency response is adjusted to minimize the work of breathing (Rohrer, 1925, Otis et al., 1950, Yamashiro and Grodins, 1979). The alternative hypothesis suggested that the frequency response is adjusted to minimize the peak force generated by the inspiratory muscles (Mead, 1960). The derived equations used to predict the frequency response from both mechanical models (Chapter 2, 2.4.3) depend on four main variables; R or the resistance of the respiratory system, C or the compliance of the respiratory system, the alveolar ventilation ($\dot{V}A$), and the dead space (Vd).

These equations predicted that with an increase in R the frequency will be low and with a reduction in C the frequency will be high, assuming that there are no related changes in $\dot{V}A$ and Vd. It has also been demonstrated that frequency of breathing increases and tidal volume decreases when an external elastance is added to normal subjects or when there is an increased elastance of the lungs (reduced C) (West and Alexander, 1959, Burdon, Killian, and Jones, 1979). In contrast the frequency of breathing decreases and tidal volume increases when normal subjects are obliged to breathe through an external resistance or when there is an increase in the resistance of the respiratory system due to obstructive lung diseases (high R) (Cherniack, 1956).

In the present study we were able to examine these two hypotheses under a wide range of metabolic demands and a wide range of elastance (compliances) and resistances. The responses were qualitatively similar to those of the previous studies. However, applying either the criterion of minimization of work (Otis et al., 1951, Yamashiro et al., 1971, 1979) or the criterion of minimization of peak force (Mead, 1960) to our data, large discrepancies were noted. In the unloaded condition the observed frequency of breathing was consistent with the criterion of minimization of peak force and significantly lower than the predicted frequency to minimize work. With the first added resistance (R1) the observed frequency of breathing was consistent with the criterion of minimization of work, and was significantly higher than the predicted frequency to minimize peak force. With the higher added resistive loads (R2,R3) the observed frequency was significantly higher than both predicted frequencies (i.e. inconsistent with both). With all added elastic loads, the observed frequency was much lower than both predicted frequencies. Moreover, both predicted frequencies were in the unphysiologic range. Thus the observed frequency is not consistent with criteria for the minimization of work or the minimization of peak force.

It seems clear to us, viewing these hypotheses at a distance of several years, that they were erected by experiments in the mechanics of breathing, rather than the physiology of muscle since they considered the output of the inspiratory muscles in purely mechanical terms. They appear to neglect the changing capacity of these muscles as ventilation increases. Under given conditions of length and velocity of shortening the force achieved by a muscle contraction is proportionate to the the number of motor units recruited and the intensity of their firing. The motor command is at a functional maximum when all motor units are recruited and firing at maximum and achieving their capacity to generate force. Under any given condition this can be quantified in terms of tension or, in the case of the respiratory system, pressure if the subjects can maximally activate all motor units. Most people appear to be capable of achieving this objective in that supramaximum stimulation directly to the active muscle fails to increase force output (Bellemare and Bigland-Ritchie, 1984).

Under isometric conditions at a given length maximum inspiratory pressure represents maximum functional motor command to the inspiratory muscles. Similarly at any given length, extent and velocity of shortening, maximum achievable pressure or capacity can be experimentally defined. Under dynamic contraction length, extent and velocity reduce the maximum pressure or capacity. Expressing the actual pressures developed as a proportion of the maximum pressure achievable with the pattern of contraction allows a crude estimate of motor command, as a proportion of the maximum functional motor command.

In a recent study from our laboratory it was found that this ratio was higher at end-inspiration rather than at the point of peak pressure, which occurred earlier in the breath (Fig 4.1). As the muscle shortens the motor command required to generate a given pressure increases. The motor command required to generate peak pressure is less than that required to produce end inspiratory pressure largely because peak pressure occurs early in the breath and shortening places a greater demand on motor output than the difference between peak and end inspiratory pressure.

Phrenic discharge starts at the onset of a breath, increases to a maximum at end inspiration and then terminates suddenly. Based on these findings we suggest the following mechanism for the frequency response. Minimization of peak stress on the inspiratory muscles through conscious sensation of effort at end inspiration may be 'the' mechanism which mediates the switch-off. Passage to consciousness may not be obligatory on every breath in that habituation may play the same role in respiration that it plays in peripheral muscular movements. Metabolic demands are customarily met and were met under all circumstances of the present study. Thus it may be the sense of effort, rather than the peak force or work of breathing, that the system minimizes in setting the frequency of breathing during exercise. Conscious behavioural mechanisms and metabolic demands may be the dominant mechanisms determining the pattern response.

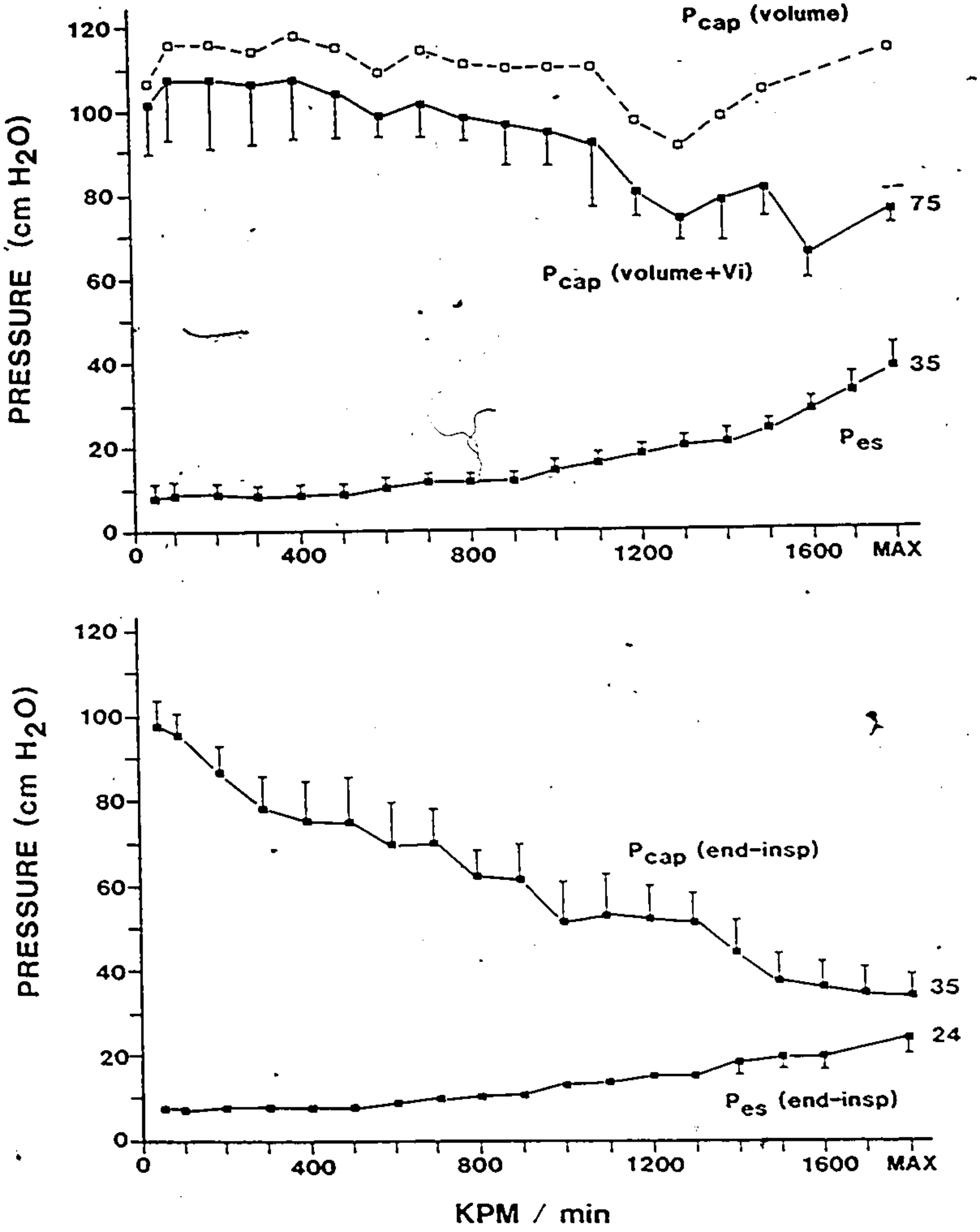

Fig 4.1 The estimated loss in maximum esophageal pressure (Pcap) (at peak inspiratory flow) (4.1A) and at end inspiration (4.1B) and the measured peak and end inspiraton pessure (Pes) generated duing exercise plotted against work loads.

4.6 Neurophysiologic Mechanism of Breathlessness

There is an evolving confluence of opinion that the sensation of muscular effort is mediated centrally as the conscious awareness of the outgoing motor command by corollary discharge (Gandevia and McCloskey, 1977; Gandevia and McCloskey 1977,1982; Matthews,1982; McClosky, 1978). The evidence supporting this opinion is largely circumstantial; collateral discharge within the central nervous system is known to occur (Gandevia, 1982) and the sense of effort increases disproportionately to the developed tension during fatigue (Gandevia et al.,1981), partial neuromuscular blockade, and muscular weakness (Campbell et al., 1980) - all situations in which the motor command is increased. For example, Gandevia et al (1977) examined the appreciation of heaviness in a group of patients with varying degrees of unilateral upper motor neurons weakness without sensory symptoms or signs, and normal subjects during partial curarization of the forearm and the hand. In all experiments both patients and normal subjects weakened with curare judged weights as heavier when lifted by the weakened side. The results of their experiments suggested that there is a perceivable motor command delivered to the muscles which is used in weight and tension estimation. Although the sensory information about the force generated was preserved in both groups, subjects relied on the effort that was put into the contraction than on the peripheral tension achieved (Gandevia et al., 1977). Another example is the study of Gandevia (1982) in patients who suffered a hemiplegia followed by partial recovery of motor function, patients with lower motor neuron paralysis, and patients with spinal transections. Patients with upper motor hemiplegia reported that their attempts to move a completely paralysed limb were not associated with any sensation of effort or heaviness. However, when the first flicker of movement returned, it was associated with the sensation of effort and heaviness. On the other hand, in patients with lower motor neuron paralysis all the attempts to move a completely paralysed limb were associated with the sensation of effort and heaviness, whether the paralysis was recent or longstanding. Even when there was a complete sensory and motor paralysis, as in spinal transection, attempts to move the paralysed limbs were associated with the sensation of effort. All these observations support the concept that the sensation of effort is mediated centrally as the conscious awareness of the outgoing motor command.

The mechanism of the centrally mediated sensation of effort may be ideally suited to mediate the sensation of breathlessness and can account for all circumstances in which breathlessness occurs. The perceived magnitude of breathlessness will be proportional to the magnitude of motor output to the respiratory muscles. Using maximum effort to generate the maximum isometric inspiratory pressure at FRC Bellemare and Bigland-Ritchie (1984) found that the motor output to the respiratory muscle was maximum. Cafarelli et al. (1979) also demonstrated that using same effort to match voluntary isometric forces at different muscle lengths, the tension generated decreased as the muscles shortened. However, the motor output to these muscles was unaffected by length suggesting that the degree of efferent command was constant (Cafarelli et al., 1979). Thus to maintain the same force at shorter length required more activation and inceased sensation. This was illustated in another study (El-manshawi et al., 1986), in which the perceived magnitude of respiratory effort increased as the inspiratory flow (velocity of muscle shortening) and/or tidal volume (extent of muscle shortening) increased for a given pressure generated (Elmenshawi et al., 1986). Thus the maximum pressure that can be generated by the respiratory muscles, taking into account the effect of volume and flow changes, can represent a crude measure of the maximum motor output to the respiratory muscles. The closer the pressure generated to the maximum pressure that can be generated for the given volume and inspiratory flow, the closer is the descending motor output to the maximum output. The same argument may be applied to the perceived magnitude of breathlessness.

In the present study (as illustrated in the graphical analysis of figures 3.7 and 3.8) the pressure generated during exercise tests with and without added inspiratory loads approaches the maximum pressure that can be generated taking into account the effect of volume and inspiratory flow i.e. the motor output to the muscles aproaches maximum with the increases in exercise levels. This was consistent with the increases in the perceived magnitude of breathlessness during exercise with and without added inspiratory loads.

The motor output to the respiratory muscles increases when the muscles are weak or when the ventilation increases or when the impedance of the respiratory system increases. Under all these circumstances the perceived magnitude of breathlessness increased.

The motor commands are converted by the respiratory muscles into force (Pm), velocity (Vi), and shortening (Vt) with a frequency (fb) and duty cycle (Ti/Ttot) determined by the intensity of the motor commands and the impedance of the respiratory system. The ventilatory demands of the body are mediated by chemical control mechanisms but the consquence of these demands on the capacity of the respiratory muscles to generate force is modulated by the conscious sensation of respiratory effort or breathlessness. Thus the selection of a motor output pattern that minimises effort may be no more than a simple learned response.

4.6 Clinical Applications of the Present Study

Breathlessness and leg fatigue are the commonest sensations that limit patients and normal subjects during heavy physical activities. Breathlessness occurs with respiatory muscle weakness, with increased impedance of the respiratory system as with pulmonary fibrosis or airflow obstruction, and increased ventilation as during exercise. The present study provided a comprehensive understanding of the occurrence of breathlessness under different circumstances. The following are some examples to explain the application of the finding in the present study to interpret the occurrence of breathlessness in different conditions.

In normal subjects the occurence of breathlessness with exercise is due to the increased ventilatory demands together with the effect of increased tidal volume and inspiratory flow in reducing the capacity of the inspiratory muscles to generate force. Thus the pressure generated gradually increases as the tidal volume and inspiratory flow increase and approaches the maximum pressure that can be generated for the given volume and flow. This means that the motor output approaches maximum and also the sensation of breathlessness.

In patients with pulmonary diseases the limitation of their physical activity due to beathlessness can be illustrated from the following examples applying the findings of the present study. E.J., a 35 year old man diagnosed as pulmonary fibrosis complained of breathlessness with any physical activity. The subject achieved 90% of his maximum predicted power output during an incremental exercise test. He stopped because of breathlessness with a rate of 9 ("almost maximum") on the Borg scale. The pressure generated during the test ranged between 6 cmH20 at rest and 18 cmH20 at maximum exercise. However, the maximum pressure he was able to generate dropped from 100 cmH20 to 23 cmH20 (using the graphical analysis, as described in the thesis) (Fig 4.2). Thus at the maximum achieved exercise level the pressure generated (18 cmH20) was close to the maximum pressure (23 cmH20), and the motor output was thus close to maximum; the sensation of beathlessness also was close to maximum. If only the pressure generated and the static strength of the respiratory muscles (MIP) were considered, it would have been very difficult to explain the patient's limitation by breathlessness. Such an analysis may be carried out without esophageal pressure measurement if the lung volumes, FRC and TLC, and the maximum inspiratory pressure at FRC are known.

Vt (l)	0.41	1.09	1.09	1.20	1.20	1.21
V̇I (l/s)	0.95	1.30	1.70	1.70	1.80	3.10
BORG S.	0.0	0.0	0.5	3	5	9

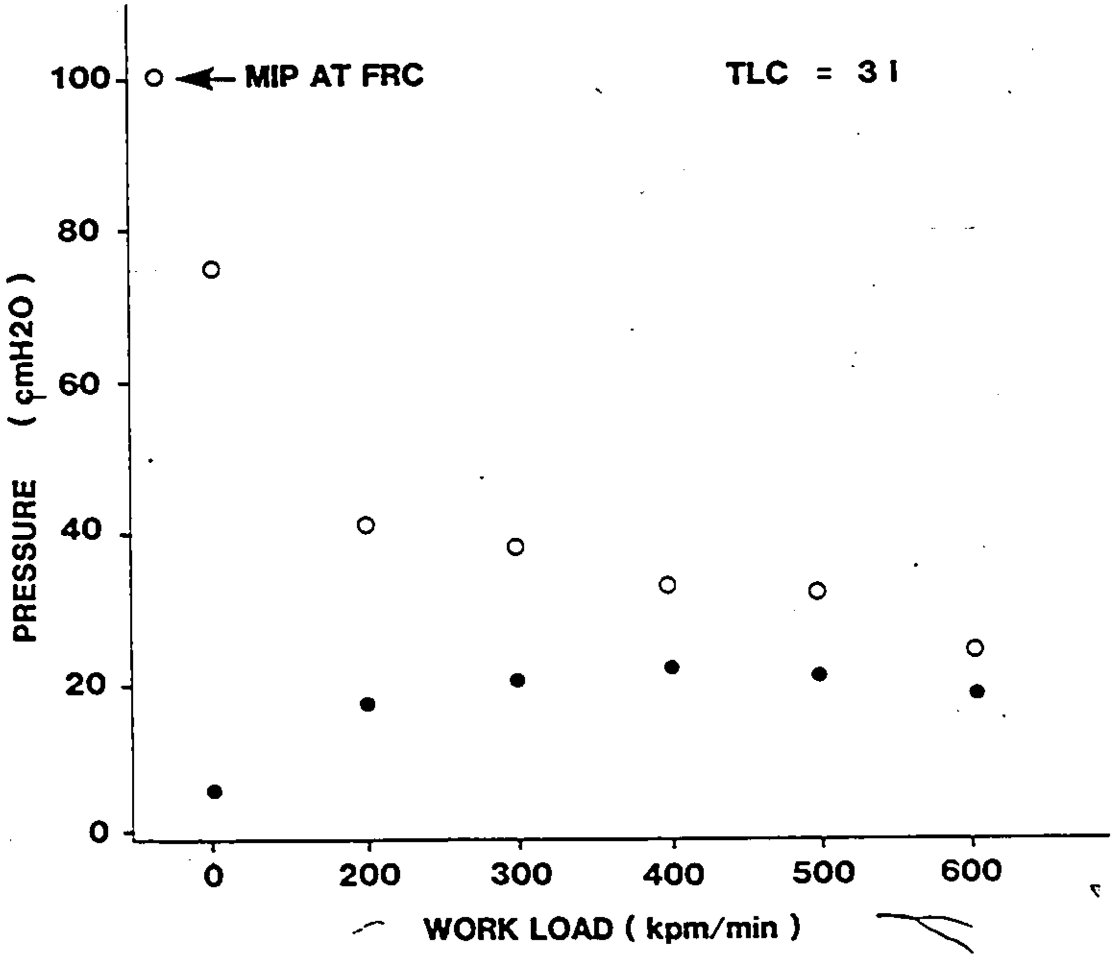

Fig 4.2 Illustrates the measured inspiratory pressure (closed circuit) of the subject E.J. against work load. The figure also illustrates the estimated decline in the maximum inspiratory pressure that can be generated at a given flow and tidal volume (open circuit). At maximum work load both pressures were close. Also illistrated in the figure total lung capacity (TLC), maximum inspiratory pressure at FRC, and the changes in Vt, V̇i, and the rating of breathlessness at different work loads.

CHAPTER 5: SUMMARY AND CONCLUSION

Psychophysical techniques have been used in an attempt to define the factors contributing to breathlessness. Most of the work done so far examined these factors under resting conditions. The results of these studies showed that the sensation is quantitatively related to the force generated by the inspiratory muscles, the duration and frequency of force generation, and the strength of these muscles. These studies suggest that breathlessness may be the perception of respiratory muscle force or tension and may be proportionally related to the output of tendon organs in the inspiratory muscles.

The hypothesis examined in this thesis is that breathlessness in exercise is quantitatively related to inspiratory muscle function. The same factors shown to be important at rest are also important in exercise, with the added factor of a functional weakening of the inspiratory muscle. The functional weakening is associated with both increased extent of shortening and increased velocity of shortening that accompany the increased ventilation of exercise. Thus these factors contribute substantially to the increase in effort required to produce a given tension and thus a given ventilation.

Thus the purpose of this study was to quantify the intensity of breathlessness associated with exercise and respiratory loading; and to isolate the contributions of inspiratory tension, length, velocity, frequency, and duty cycle to the intensity of breathlessness. The intensity of inspiratory muscle tension was quantified by measurement of mouth pressure, the extent of shortening by tidal volume, and the velocity of shortening by inspiratory flow. Normal subjects underwent incremental exercise tests on a cycle ergometer to maximum capacity. The first and last test were unloaded and the intervening tests were performed with external added resistances and elastances in random order. The resistances and elastances were selected to provide a wide range inspiratory pressures, tidal volumes, flows, and patterns of breathing. The inspiratory resistive loads were used mainly to change the velocity of shortening of inspiratory muscles. The inspiratory elastic loads were used mainly to change the extent or length of shortening. At rest and at the end of each min during exercise the subjects estimated the intensity of breathlessness by selecting a number ranging from 0-10 (modified Borg scale), 0 indicating no appreciable breathlessness and 10 the maximum tolerable sensation.

The sensation of breathlessness was found to be a continuum that has a threshold and a slope as with other sensations. The threshold is lowered and the slope is increased as the impedance of the respiratory system increases. The ratings of breathlessness were comparable at maximum exercise in loaded and unloaded conditions suggesting that the velocity and extent of shortening of inspiratory muscles play an important role by reducing the capacity of inspiratory muscles to generate force. Thus the findings of the present study support our hypothesis that not only the pressure generated by the inspiratory muscles, the strength, the frequency and the duration of contraction of these muscles are contributing to the intensity of breathlessness, but also the velocity and extent of contraction contributed independently. Thus when the velocity of shortening was stressed (resistive loading study) the perceived magnitude of breathlessness increased for any given pressure as the inspiratory flow rate increased and as well as the duty cycle increased. When the extent of shortening was stressed (elastic loading study) the perceived magnitude of breathlessness increased for any gived inspiratory pressure as tidal volume increased as well as the frequency of breathing. By making measurements during exercise and with loaded breathing the study established for the first time quantitative relationships between the forces generated by respiratory muscles and the capacity to meet these demands in exercise. Also it established the relative contributions of these factors to the intensity of breathlessness. The perception of the outgoing motor command by means of corollary discharge within the central nervous system is ideally suited to subserve this sensation. Another important finding, which was not an initial intention of the study, was that the pattern of breathing by the subjects did not appear to minimize the work of breathing or the peak force generated by the respiratory muscles. Minimization of respiratory effort appears to be a better explanation for the observed responses; thus what is minimized is a combination of the tension generated in relation to the capacity of the inspiratory muscles to generate a force at a given length and velocity of shortening.

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CHAPTER 7: THE APPANDIX

The contents of this chapter are :

1) The development of the currently used Borg scale.
2) Effect of velocity and extent of shortening on the perceived magnitude of respiratory muscle effort.
3) The raw data of this study.
4) Added inspiratory mechanical loads.
5) Multiple regression analysis.

7.1 The DEVELOPMENT OF THE CURRENTLY USED BORG SCALE

The widespread application of psychophysics in quantifying sensation dates from the middle of the twentieth century. The application to perceived exertion was popularised by Borg at the end of 1950. Over 30 years Borg developed several scales which were used around the world in the clincal lab to evalute exertion in patients and normal subjects.

In this thesis we used the last version of his scale "the ten point category scale with ratio properties". The reasoning behind this scale is presented in the following sections.

7.1.1 Historical Development of Sensory Scales

Fechner (1860) was one of the first investigators to suggest a mathematical relation between sensation and stimulus magnitudes. He came to base his law on the work done by Weber (1834). Weber established that discrimination is relative and for a sensory change to be detected the amount by which the intensity of a stimulus increases or decreases is a constant fraction of the original stimulus intensity. Fechner made detected changes into units by which sensory magnitude could be measured. Thus the increase in magnitude of a physical stimulus required to reach the threshold of detection was measured. This threshold was then rated as one just-noticeable difference (JND). By summing JND's from absolute threshold the sensory magnitude of a stimulus could be estimated. Because the ability to detect a change in a stimulus is dependent on the magnitude of background stimulus (Weber's law), the JND increases in absolute magnitude as a function of the log of the physical magnitude (P): $Y = b + m \log P$ (b is a constant). Fechner's law can be stated as, "Equal JND's" of the stimulus intensity produce equal sensation (subjective) intervals. Most of the subsequent attempts and procedures that were followed to quantify sensation were Fechnerian in nature. They were indirect because the measure of sensory magnitude comes about second hand, via the measurement of the stimulus magnitude necessary to result in a just noticeable change in sensation.

Direct scaling methods were introduced at the end of the ninteenth and early twentieth centuries. Types of direct scaling include direct interval scaling and ratio scaling methods. With the interval scaling method the subject's task is to assign categories to stimuli in such a way that each succeeding category marks off another constant step in sensation. In the ratio scaling (Merkel, 1888), the subject's task was to set a variable stimulus so that the sensation it produced appeared twice as great as that produced by a reference stimulus. Ratio methods had not become popular until 1930s. By the end of the 1950s S.S. Stevens (1946, 1951) had established that man can directly estimate sensory magnitude. His approach was simple in that he controlled the magnitude of the stimulus and requested the subjects to estimate the perceived magnitude. The subjects were free to select any number but were constrained to use the numbers in direct ratio relationship to the perceived magnitude of the stimulus. The use of open magnitude scaling resulted in discovery of a new psychophysical law in which the subjective and the objective magnitude of the stimulus are related by a power function, such that

$Y = KO^n$ where Y is the sensory magnitude, K is a constant and O is the physical magnitude, and n is the power function. This relatioship remains constant over most of the operating range, departing at very low magnitudes.

7.1.2 Psychophysical Scales and general rules of measurements

Psychophysical scales used to measure the perceived magnitude of sensory modalities are not different from any other physical measurement scales. Measurement is defined as the assigning of numbers to objects or events in accordance with a systematic rule. For each measurement there is similarity between the relations among the objects and the relations among numbers. The measurement is considered to be valid if the rules are obeyed. The rules of scaling are hierarchical in nature; 1. Nominal; 2. Ordinal; 3. Interval; 4. Ratio.

When measurement is nominal it is merely used to distinguish one object or event from another. An example is the numbering of football players - the number specifically denotes a player. With ordinal scaling objects or events are scaled in ascending magnitude. As the magnitude increases the scale increases. Differences between objects or events carry no meaning, for example the I.Q. scale. An individual scoring 80 on an I.Q. test is not half as intelligent as an individual scoring 160. Intervals or ratios have no unique meaning on ordinal scale. The scale is not valid if ascending order is not maintained. The third type of scales, the interval scale, implies that the differences between objects or events bear a constant relationship with the differences in the scale. A good example of an interval scales is the temperature in F or C. The difference between a temperature of 20 - 30 C is the same as the difference between 40 - 50 C. If the differences on an interval scale do not correspond to comparable differences in objects or events it is invalid. An interval scale does not imply ratio properties. For example an object with temperature of 40 C is not twice as hot as an object with a temperature of 20 C. This applies only to measurement of absolute temperature. The fourth type of scales, the ratio scale, implies an absolute zero and ratio properties being preserved, for example metric measurement of distances. Thus a road which is scaled 20 meter on a ratio scale is twice as great as that scaled 10 meter. If the ratios are not preserved the scale is invalid.

The same rules are applied to sensory measurement as to any other measurement. The application of these rules on sensory measurement requires the identification of the factors contributing to the sensation (input parameter or the parameter of the stimulus), a technique to apply the rules to measure the evoked sensation, and a mathematical method to quantify the relationship between the input parameter (the stimulus) and the output parameter (the evoked sensation). The most used scales in sensory measurement nowadays are interval scales and ratio scales.

The category scales are the most used interval scales. As all interval scales, they are based on the Fechnerian theory. On using the category scaling method the subject is given several instructions. He is told to judge the relative magnitudes of a variety of stimulus intensities that will be presented to him. He is given a set of categories and told to place the weakest of the stimuli into the first and the strongest into the highest category, and he may even be shown examples of these stimului. He is then told that he is to distribute the stimuli among the categories in such a way that the sensation level difference between categories is constant. The curve discribing the relationship between the sensory scaling and the physical stimulus scaling is concave downward. This relationship is found to be logarithmic. This means that the sensation intensity equals the logarithm of the stimulus intensity multiplied by a constant. Although the results of using category scales are reproduceble, sensory scaling of the stimuli depends on the spacing of the stimuli.

Ratio scales are based on Stevens theory that the perceived magnitude of evoked sensation is related to the physical stimulus by a power function. Several methods of ratio scaling are used - Magnitude estimation, magnitude production, ratio estimation, and ratio production are among the most common (Stevens, 1971). In magnitude estimation the subjected is presented with a series of stimuli in irregular order and is told to assign numbers to them. He is told to assign any number to the first stimulus that seems appropriate to him. For the following stimuli he should assign numbers in proportion to the number assigned to the first stimulus depending upon the subjective perception of the magnitude of stimuli. In magnitude production, the experimenter presents the numbers one at a time in irregular order, and the subject adjusts the stimulus to produce an apparent match. In ratio estimation, the subject is asked to match numerical ratios to apparent stimulus ratios. The stimuli are presented in pairs and the apparent ratios are estimated. In ratio production, the subject is asked to produce the stimulus that seems to stand in a prescribed relation to a standard stimulus. All the magnitude scales, when ploted against the stimulus intensity, are power functions. In contrast to category scaling, magnitude scaling is independent of the spacing of the stimuli. This suggests that the magnitude values are attached to the stimuli by the subject, where as with category scaling values are attached to the stimulus-within-the-context of the display in which it appears. The ratio scaling methods seem to give better representation of the relative perceptual variation than any other scaling methods (Borg, 1982). However, the ratio methods only give relative intensities and no subjective "level" for immediate interindividual comparisons. In ratio scaling, the subjective intensities are compared with one another in relation to some arbitrarily chosen subjective unit and not in absolute sense. With category scaling direct level estimate may be made, whether they are strong or weak according to the long life experience of the individuals or fundamental psychophysiological responses.

The relationships between category scaling and magnitude scaling for different sensory modalities has been examined (Stevens, 1957). When the category scales were plotted against the magnitude scales for different sensory modalities the curves were parallel and curvelinear--with negative acceleration. This was true regardless of the sensory contimuum examined. The difference between the two scales is due to the attachement of the category scale to the stimulus-within-the-context of the display in which it appears. Also imposing a limit on scaling leads to altered estimates of the percieved magnitude. Another important factor is the dependance of category scales on discrimination principles. In assigning the categories noticeable differences become bigger due to the effect of Weber's law with the increase in the intensity of the applied stimulus.

The validity of the psychophysical scales can be tested by the compliance to the preset rules for the measurement in combination with their reproduceability. A secondary support for the validity of these scales is cross-modality matching method. In this method the subject is asked to match the intensity of a sensory stimulus using the intensity of a sensory modality of a known exponent such as the force of handgrip. The results show that the subjects are able to estimate the magnitude of the stimuli presented to them, a consistant manner across sensory modalities. The results also confirm the earlier findings where the numerical estimation had been used (Stevens, 1966). Other ancillary support is the neuropsychophysiological studies which show a strong relationship between the neural responses and the perceived magnitude of the evoked sensation (Borg, 1967, Stevens, 1970).

Variability exists as tit does in all measurements. The most important components contributing to the variabilty in psychophysical scaling appear to be the following (Stevens, 1958): 1) Variability due the obsever's modulus to choose the level of matching intensities; 2) Variabilty due to the observer's conception of a subjective ratio; 3) Variablity due to differing sense-organ operating characteristics; 4) Variability due to the observer's motivation. All these factors can be reduced by careful study design, detailed explanation of the scaling technique to the observers, and preliminary training experiment for the naive subjects.

7.1.3 Development of Borg Scale

The development of the currently used Borg category scale with ratio properties took several steps. Borg applied open magnitude scaling to the sensation of perceived exertion and in keeping with other sensory modalities found that it confirmed to a power function. The sensory magnitude increased three fold when the physical magnitude increased two fold (exponent 1.6). There were practical problems in using the results of this scale particularly comparing sensory magnitude across groups or individuals. He drew attention to the fact that the physical magnitude of the stimulus was finite and varied from zero to the maximum work capacity that the subject could develope and 'de facto' there must be a finite range of sensory magnitude. He then suggested that man has a perception of sensory magnitude in an absolute sense from minimum to maximum and thus comparison is possible. From these considerations he developed his range theory. Both the physical and sensory continuums were limited and the rate at which sensory magnitude grows at submaximum levels of stimulation is also known. Using these facts he constructed a number scale ranging from zero to maximum. His next step was the addition of simple verbal expressions denoting - very, very slight; very slight; slight; moderate; somewhat severe; severe; very severe; very, very severe; and maximal. He placed these verbal expression in relationship to the numbers such that the known ratio properties were preserved.

7.1.3.1 Ratio scales and the Perceived Intensity of the Physical Work

Borg (1960) was the first to quantify the perception of exertion during rhythmic exercise of short duration (less than 1 min on a cycle ergometer). These experiments employed the direct pyschophysical methods established by Stevens (1958) of magnitude estimation and magnitude production. The perceived intensity was seen to grow with the physical intensity (kpm/min) and was mathematically explained by a postive accelerating power function with an exponent of about 1.6. This exponent for dynamic cycling exercise was quite similar to that determined by Stevens, Mack, and Stevens, (1960) for the perceived force of static handgrip exercise. Borg (1962) also evaluated his results using other ratio estimation and production methods for cycling exercise of brief duration and for longer exercise durations (each of an attempt of 6 min durations). The exponent was 1.6 for these experiments. The main issues revealed by these experiments included; 1. the significance of the range; 2. justification for starting from the subject's statments concerning numerical ratio to obtain subjective ratio scales; 3. ratio scaling was too awkward for average persons to use; 4. impossible to compare the intensity of perceptions across individuals; 5. difficulty in validating comparison across the same individuals studied at different times. Basically, Stevens method provided valid ratio scales but gave no indication of absolute intensity.

7.1.3.2 Development of the Range Theory

In order to solve the problem of interindividual comparisons

Borg (1961) proposed that the perceptual range from minimal to a maximal subjective intensity is the same for all individuals inspite of the fact that the stimulus range may vary considerably. By arbitrary setting the perceptal range equal for all subjects, individual functions may be drawn in the same coordinates and interindividual comparison made (Fig 7.1.1).

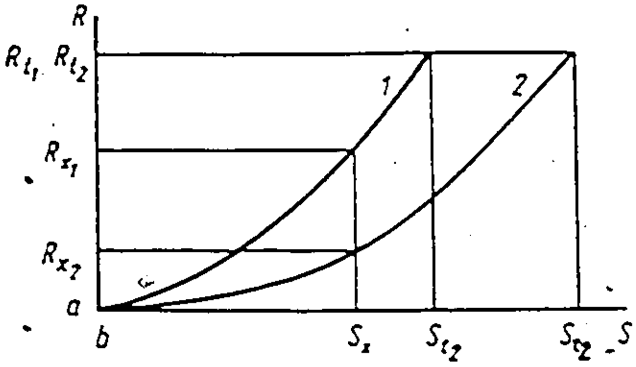

Fig 7.1.1 Variation of perceived exertion (R according to a ratio scale) with the physical work load (S in watt) during exercise on a bicycle ergometer. The curves represent two individuals, subjects 1 and 2, and are drawn in the same diagram according to the "range theory" (see text) (From Borg, 1961, 1970).

7.1.3.3 Development of the Category Perceived Exertion Scales

After a period of trial and error to overcome the difficulties associated with the ratio scaling methods, Borg developed a twenty-one point graded category scale (Borg, 1962). Adverbs and adjectives were anchored to the odd numbers on this scale starting from 3 "extremely light" to 19 "extremely laborious" (Table 7.1.1). Heart rate was used as a measure of the physical magnitude of the stimulus (Borg, 1962, 1972). The ratings according to the scale gave a high correlations with heart rate, e.g. in group of healthy people correlations between 0.80 and 0.90 if work intensity was varied from light to heavy work. However, the correlation coefficients between ratings and heart rate at each work load were approximately r = 0.40. This 21-point scale was used extensively in evaluation of exercise performance and perceived exertion of individuals in various age, arterial hypertension, and vasoregulatory asthenia (Borg and Limderholm, 1970).

1		11	Neither light nor laborious
2		12	
3	Extremly light	13	Rather laborious
4		14	
5	Very light	15	Laborious
6		16	
7	Light	17	Very laborious
8		18	
9	Rather light	19	Extremely laborious
10		20	
		21	

Table 7.1.1: The 21-point category scale for rating of perceived exertion (Borg, 1962)

To increase the linearity between the rating and the heart rate the scale was later changed to a fifteen-point graded category scale by Borg (1970) (Table 7.1.2). This scale was numbered from 6 to 20 with every odd number anchored by verbal experssions such as "very, very light" at 7 and "very, very hard" at 19. This scale was constructed in such a way that for healthy middle-age men doing moderate to hard work on bicycle ergometer or treadmill, the heart rate should be about ten times the rate of perceived exertion (60 to 200).

6		16	
7	Very, very light	17	Very hard
8		18	
9	Very light	19	Very, Very hard
10		20	
11	Fairly light		
12			
13	Somewhat hard		
14			
15	Hard		

Table 7.1.2: The 15-point category scale for ratings of perceived exertion (Borg, 1970)

The 15-point scale developed by Borg was the most popular scale for determining the rating of perceived exertion (RPE).

7.1.3.4 Development of the Category Scale with Ratio Properties

In 1980 Borg introduced a new category scale with ratio properties permitting interprocess comparisons. The rationale underlying the construction of the new scale was based on several considerations. The first was the acceptance of Stevens ratio scales as the best ones for general descriptions of the perceptual variation. The second consideration was the range theory. For direct interindividual comparisons the perceptual ranges must be the same for all individuals. For comparisons across sensory modalities it was assumed that the ranges were roughly the same or close enough.

to justify the use of one and the same scale in most practical situations. The third consideration was that adjectives and adverbs may define the level of certain perceptual intensity and how more intense one perception is than another. These adjectives and adverbs have interpretation and precision. The interpretation is the subjective intensity behind the expression and the precision is the relative dispersion - how people agree on the intensity level of the expression. In a series of experiments Borg et al. (Borg, 1964; Borg and Hosman, 1970; Borg and Lindblad, 1976) determined the metric properties of several verbal expressions as well as the subjective intensities of many different and frequently used adjectives and adverbs in descriptions of subjective symptoms.

To obtain a category scale with ratio properties the expressions of the RPE-scale were plotted to ratio scale and their relative intensity levels on the ratio scale were determined. The verbal expressions of the category scales were rearranged till they gain the same power function of open magnitude estimation of the physical work. This was done taking into account that the relation between the RPE-scale and physical work load is linear and the ratio data between perceived exertion and work load has a power function with an exponent of 1.6. A 20-point scale from 0, equal to no exertion at all, to 20, equal to maximal exertion was first constructed. This scale was tested for transient work (less than a minute) on a bicycle ergometer and the exponent of about 1.6 was obtained. To achieve the goal of greater simplicity a more limited range of numbers was used 0 to 10. However, the verbal expressions were chosen to cover the same range of perceived intensity covered in the 20-point scale. They were placed on the scale ratings such as somwhat severe were found to be twice slight. The advantage of this scale over the open magnitude scale was that it allows the interindividual comparisons at levels of sensation and was not confined arbitrarily numbers chosen by different subjects.

The Borg scale may not be strictly valid but is reproducible, stable and easy to use. If the subjects are asked to adjust the level of exercise so that the intensity of effort was either double or halved, the exercise intensity might not precisely coincide with the values predicted from more valid ratio scales. This discrepancy can be expected, because the subjects are confined to a closed scale and are inclined to bias their responses to the defined categories. These systematic departures from validity are outweighted by the ability to compare across subjects and to indicate the absolute magnitude.

The pragmatic utility of this scale is supported by the frequency with which it is used in answering sensory questions of a diverse nature. In our own experience in clinical exercise testing and psychophysical studies the scale has proved rugged. In the present study this scale is used because it combines the characteristics of both category and ratio scales, it allows comparisons across individual subjects and within individual subjects, it is simple to use in that numbers are anchored to verbal expression which are easily understod by most people, and finally, it covers the whole sensory continuum for any given sensation (zero to maximum).

To understand the relationship between subjective sensations (symptom) and the stimulus giving rise to these sensations a method for the measurement of sensory intensities is obligatory. To be generally useful these methods should be applicaple to most people regardless of gender, age, circumstances, and national origin. The Borg scale fulfills most of these criterion.

7.2 EFFECT OF VELOCITY AND EXTENT OF SHORTENING ON THE PERCEIVED MAGNITUDE OF RESPIRATORY MUSCLE EFFORT.

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The purpose of this study was to estimate the effect of velocity and extent of shortening on the perceived magnitude of respiratory effort. 10 normal subjects breathed through 3 linear inspiratory resistive loads (29, 57, 195 cmH2O/l/sec) and 3 inspiratory elastic loads (25, 42, 73 cmH2O/l) while targeting to integrated pressures of 33, 60, & 106 cmH2O.sec/breath with each inspiratory load. For example to generate an integrated pressure of 60 cmH2O.sec subjects had to inspire with the following inspiratory flows ($\dot{V}i$) (velocity of shortening): 1.1, 0.5, 0.3 l/sec, and tidal volumes (Vt) (extent of shortening): 1.6, 0.7, 0.2 l in R1, R2, and R3 respectively (Fig 7.2.1&2). Each trial consisted of 3 consecutive breaths and subjects rated their respiratory effort at the end of the third breath using a Borg scale. Inspiratory time and duty cycle were constant. Loads were used to provide a wide range of velocity ($\dot{V}i$) (0.2 to 1.9 l/sec) and extent of shortening (Vt) (0.2 to 2.7 l/breath). The perceived magnitude of respiratory effort required to produce 60 & 106 cmH2O.sec was significantly higher as flow rate and volume increased ($\dot{V}i$, $P<0.01$, Vt, $P<0.001$) (Fig 7.2.3). There was no significant difference between the perceived

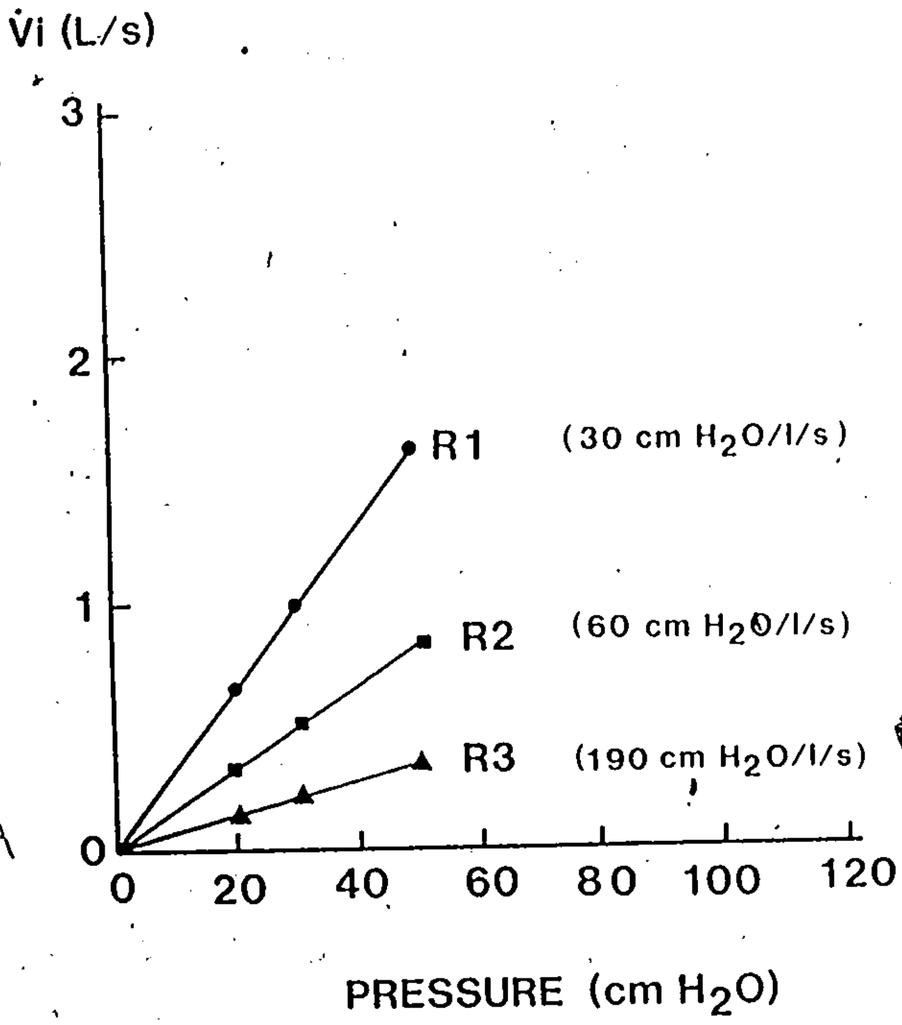

Fig 7.2.2 Inspiratory flow (functional velocity of shortening) plotted against inspiratory pressure to illustrate the generation of different flows for a given pressure using 3 different resistances.

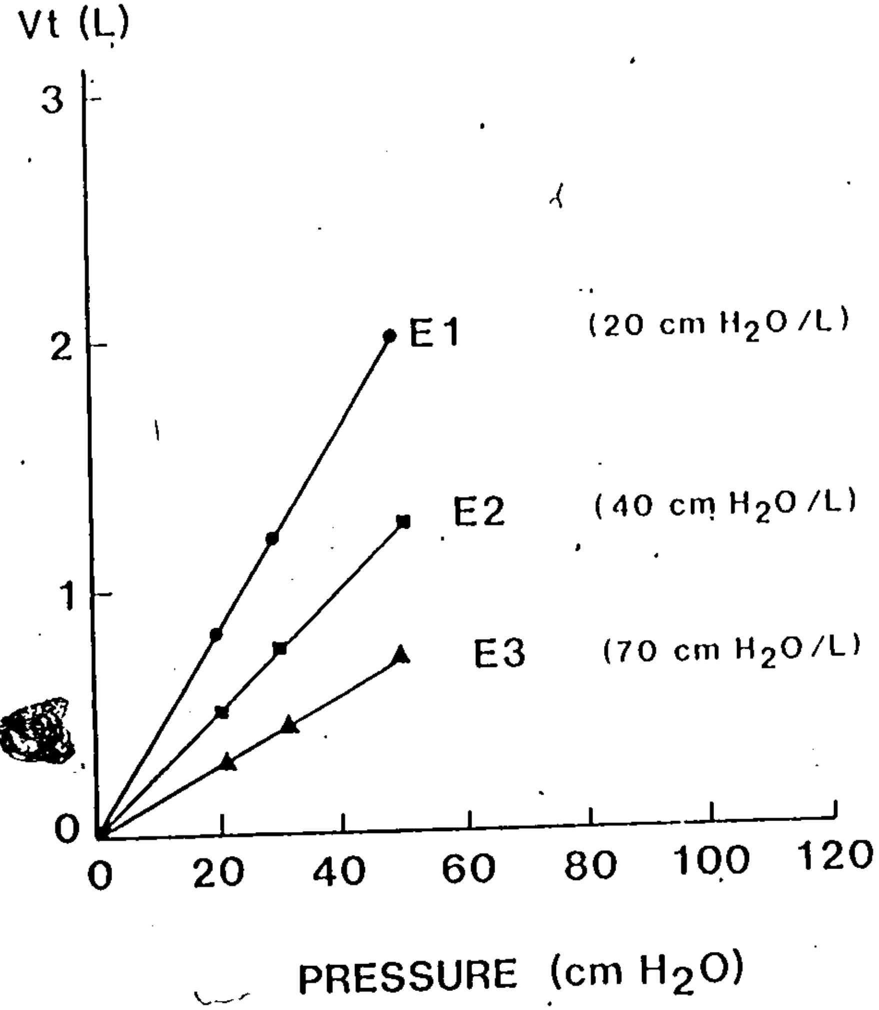

Fig 7.2.3 Tidal volume (functional extent of shortening) plotted against inspiratory pressure to illustrate generation of different tidal volumes for a given pressure using 3 elastances.

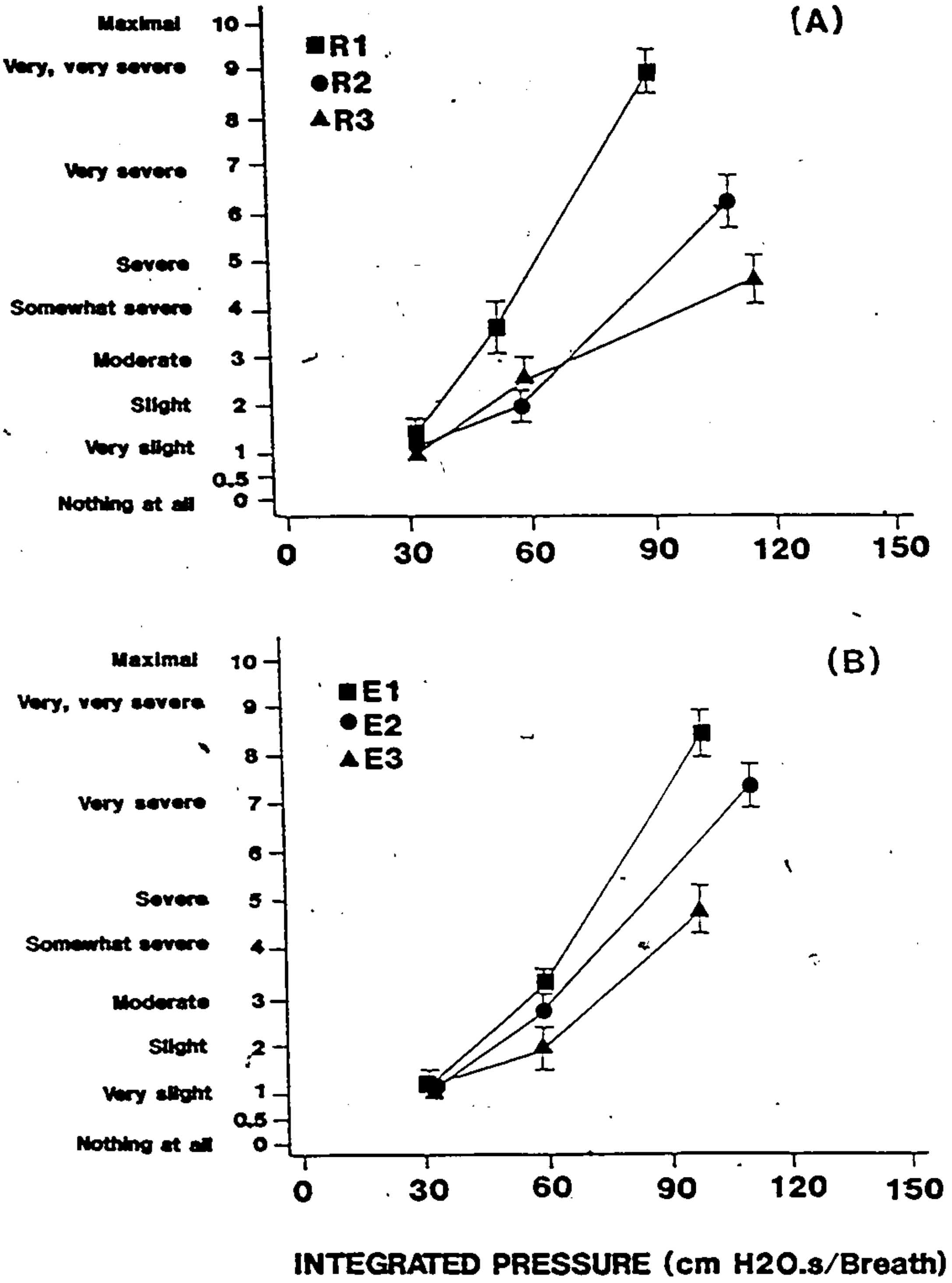

Fig 7.2.3 Rating of breathlessness plotted against integrated pressure with resistances (4A) and elastances (4B).

magnitude of respiratory effort as flow and volume required to produce the lowest integrated pressure (33 cmH2O.sec) increased. The perceived magnitude of respiratory effort was found to be significantly and positively related to the integrated mouth pressure ($P<0.01$), the velocity of shortening ($P<0.01$), the extent of shortening ($P<0.01$), and negatively related to the capacity of inspiratory muscle to generate force (MIP) ($P<0.05$). These factors independently and collectively contributed to perceived respiratory effort:

$$\text{Perceived Effort} = 0.22 + 0.05\,\text{IntPm} + 1.42\,\text{Vt} + 0.43\,\dot{\text{V}}\text{i} - 0.01\,\text{MIP}$$

($r=0.80$, $P<0.01$). Thus the perceived effort required to produce a given integrated pressure is related to the velocity and degree of shortening and the capacity of the inspiratory muscles and is independent of the quality of the inspired load.

7.3 TABLES OF THE RAW DATA

The following tables (1-48) are the measured variables of each subjects. The Tables consisted of a set of 8 i.e. from table 1 to 8 are the measured variables of the first subject during unloaded (first control), R1, R2, R3, E1, E2, E3, and last unloaded or second control exercise tests. This sequence is fixed for all subjects.

The main symbols of these tables are :

Dflag	The record number in the work file
Code	Subject I.D. number
KPM	Kilopound meter/min on the cycle ergometer
Borg	Borg scale (0-10)
P-mouth	The pressure measured at the mouth (cmH20)
Vt (21)	Tidal volume meaured using MMC Horizon system (1)
$\dot{V}i$	Inspiratory flow rate (l/s)
FB	Frequency of breathing (Br/min)
TTOT	Total time of respiratory cycle
Ti	Inspiratory time
Ti/Ttot	Duty cycle
TE	Expiratory Time
P*Time	The integrated pressure at the mouth
Vt (6)	Tidal volume measured from the intigration of the inspiratory flow
$\dot{V}E$	Minute ventilation (l/min)

$\dot{V}$CO2	Carbon dioxide output (l/min)
$\dot{V}$O2	Oxygen uptake (l/min)
PEtCO2	End-tidal CO2 (mmHg)
PECO2	Mixed expired CO2 (mmHg)
SaO2%	Arterial oxygen saturation (%)
HR	Heart rate (Beat/min)

Dflag	CODE 1	KPM 4	cor borg 29	P-MOUTH 20	VT 21	VI 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 1:	1.0000	0.0000	0.0000	2.4000	0.9500	0.6000	8.3400	6.3000	2.7000	0.3492	4.1000
♦ 2:	1.0000	100.000	0.0000	2.7000	1.0400	0.9000	16.3300	4.1300	2.0700	0.5012	2.0600
♦ 3:	1.0000	200.000	0.0000	3.1000	1.2100	1.0000	14.3300	3.5300	1.6800	0.4759	1.8500
♦ 4:	1.0000	300.000	0.0000	2.3000	1.2900	1.0300	15.2000	4.5000	2.2300	0.4956	2.2700
♦ 5:	1.0000	400.000	0.0000	3.1000	1.3100	1.1500	17.9000	3.6000	1.7500	0.4861	1.8500
♦ 6:	1.0000	500.000	0.5000	3.9700	1.4900	1.3000	17.6300	3.3500	1.7000	0.5075	1.6500
♦ 7:	1.0000	600.000	0.5000	3.7800	1.7300	1.5000	16.3500	3.7000	1.7000	0.4595	2.0000
♦ 8:	1.0000	700.000	0.7500	4.5400	1.9300	1.8000	15.4000	3.6000	1.7000	0.4722	1.9000
♦ 9:	1.0000	800.000	0.7500	5.7600	2.0300	1.7000	17.8000	3.7000	1.8700	0.5054	1.8300
♦ 10:	1.0000	900.000	1.2500	7.9700	2.2100	2.5000	18.2800	2.6000	1.3000	0.5000	1.3000
♦ 11:	1.0000	1000.00	1.2500	10.7000	2.1800	2.7000	21.3000	2.8000	1.2600	0.4500	1.5400
♦ 12:	1.0000	1100.00	1.7500	9.7000	2.2200	2.6000	22.6500	2.8000	1.2600	0.4500	1.5400
♦ 13:	1.0000	1200.00	2.0000	10.9600	2.2000	3.2000	25.1800	2.6000	0.9700	0.3731	1.6300
♦ 14:	1.0000	1300.00	3.0000	14.4000	2.3100	3.4000	25.3800	2.2000	1.0300	0.4682	1.1700
♦ 15:	1.0000	1400.00	3.2500	13.4000	2.3900	3.6000	27.4000	2.1000	0.9400	0.4476	1.1600
♦ 16:	1.0000	1500.00	3.5000	13.9900	2.4400	3.7000	29.1500	1.9000	0.8000	0.4211	1.1000
♦ 17:	1.0000	1600.00	3.5000	19.5000	2.5200	4.1000	30.5500	1.8000	0.7000	0.3889	1.1000
♦ 18:	1.0000	1700.00	4.2500	22.2000	2.5600	4.5000	33.7500	1.8000	0.7000	0.3889	1.1000
♦ 19:	1.0000	1800.00	5.5000	24.6000	2.6700	4.6000	39.1500	1.3500	0.5000	0.3704	0.8500

Dflag	CODE 1	KPM 4	P*TIME 22	VT 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 1:	1.0000	0.0000	0.0000	0.8000	7.9900	0.2700	0.3300	40.0000	29.3000	95.0000	78.0000
♦ 2:	1.0000	100.000	0.0000	1.0500	17.0300	0.6100	0.6500	40.0000	31.1000	95.0000	90.0000
♦ 3:	1.0000	200.000	0.0000	1.0300	17.0800	0.6400	0.7500	40.0000	32.5000	95.0000	90.0000
♦ 4:	1.0000	300.000	38.0000	1.4000	19.4300	0.7400	0.8900	41.0000	33.2000	95.0000	96.0000
♦ 5:	1.0000	400.000	0.0000	1.4000	23.2300	0.8900	1.0500	42.0000	33.2000	94.0000	102.000
♦ 6:	1.0000	500.000	88.2000	1.5800	26.3300	1.0500	1.2200	42.0000	34.6000	95.0000	108.000
♦ 7:	1.0000	600.000	81.8000	1.6000	27.8300	1.1300	1.2600	43.0000	35.4000	95.0000	108.000
♦ 8:	1.0000	700.000	96.3000	1.9000	29.6800	1.2800	1.4300	45.0000	36.8000	94.0000	114.000
♦ 9:	1.0000	800.000	89.0000	2.1500	36.1000	1.5300	1.6300	46.0000	36.8000	95.0000	126.000
♦ 10:	1.0000	900.000	137.300	2.2000	40.2000	1.7300	1.8600	40.0000	38.2000	94.0000	138.000
♦ 11:	1.0000	1000.00	170.400	2.4000	46.4000	1.9700	2.0600	45.0000	36.8000	95.0000	144.000
♦ 12:	1.0000	1100.00	169.900	2.4000	50.2000	2.1400	2.1900	46.0000	36.8000	95.0000	150.000
♦ 13:	1.0000	1200.00	189.000	2.4000	55.4000	2.3100	2.3100	44.0000	36.1000	95.0000	156.000
♦ 14:	1.0000	1300.00	190.000	2.5000	58.3800	2.4500	2.4500	47.0000	36.7000	95.0000	162.000
♦ 15:	1.0000	1400.00	205.500	2.4000	65.5300	2.7000	2.6500	46.0000	36.8000	95.0000	168.000
♦ 16:	1.0000	1500.00	219.000	2.4000	71.1800	2.9300	2.8400	46.0000	36.5000	94.0000	168.000
♦ 17:	1.0000	1600.00	244.800	2.5000	77.1500	3.2000	3.0400	45.0000	36.1000	94.0000	174.000
♦ 18:	1.0000	1700.00	338.000	2.5000	88.7500	3.4700	3.2500	45.0000	34.6000	92.0000	180.000
♦ 19:	1.0000	1800.00	392.000	2.6000	104.600	3.9800	3.5400	42.0000	33.9000	90.0000	186.000

Tab 7.3.1.1 Individual data of subject 1, Cl.

	CODE	KPM	cor borg	P-MOUTH	VT	VI	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
♦ 112:	1.0000	0.0000	0.5000	7.6700	0.8600	0.5300	7.9600	6.8000	3.1000	0.4559	3.2000
♦ 113:	1.0000	100.000	0.5000	4.5000	1.1300	0.4000	12.2000	7.7000	3.8000	0.4935	3.9000
♦ 114:	1.0000	200.000	0.5000	6.0000	1.4400	0.6000	6.6000	12.1000	6.1000	0.5041	6.0000
♦ 115:	1.0000	300.000	0.7500	8.5000	2.1900	0.7500	5.6000	8.0500	4.8500	0.6025	3.2000
♦ 116:	1.0000	400.000	0.7500	10.0000	2.5200	0.9000	5.9000	8.2000	4.1000	0.5000	4.1000
♦ 117:	1.0000	500.000	1.0000	11.5000	2.2800	0.9000	8.3000	7.3500	4.4000	0.5986	2.9500
♦ 118:	1.0000	600.000	1.2500	15.0000	2.4000	1.2000	8.4000	8.9000	4.0000	0.4494	4.9000
♦ 119:	1.0000	700.000	1.2500	16.7000	2.1400	1.2300	11.4000	4.7000	2.8000	0.5957	1.9000
♦ 120:	1.0000	800.000	1.5000	19.6700	2.2700	1.4000	13.6000	3.7700	2.3000	0.6101	1.4700
♦ 121:	1.0000	900.000	2.0000	41.3000	2.5100	1.7000	11.8000	3.9000	2.0300	0.5205	1.8700
♦ 122:	1.0000	1000.00	2.7500	43.0000	2.3400	1.7300	15.1000	3.7000	2.0600	0.5568	1.6400
♦ 123:	1.0000	1100.00	3.0000	46.7000	2.3300	1.8300	16.9000	2.8000	1.6700	0.5964	1.1300
♦ 124:	1.0000	1200.00	3.2500	53.3000	2.0800	2.0300	20.8000	2.5700	1.6700	0.6498	0.9000
♦ 125:	1.0000	1300.00	3.5000	57.3000	2.1300	2.1700	22.4000	2.1300	1.7000	0.7981	0.4300
♦ 126:	1.0000	1400.00	4.0000	59.0000	2.2200	2.2000	21.9000	2.3000	1.6700	0.7261	0.6300
♦ 127:	1.0000	1500.00	5.5000	62.0000	2.1000	2.3000	26.5000	2.2000	1.5000	0.6818	0.7000
♦ 128:	1.0000	1600.00	8.2500	66.7000	2.1400	2.4000	27.5000	2.0000	1.4000	0.7000	0.6000

	CODE	KPM	P*TIME	VT	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	18
♦ 112:	1.0000	0.0000	61.5000	1.1700	6.8800	0.2400	0.3500	40.0000	30.6000	97.0000	72.0000
♦ 113:	1.0000	100.000	106.500	1.3000	13.9000	0.4900	0.5900	39.0000	32.0000	97.0000	90.0000
♦ 114:	1.0000	200.000	127.400	2.5000	9.4000	0.3900	0.6000	44.0000	36.3000	96.0000	90.0000
♦ 115:	1.0000	300.000	108.100	2.3000	12.2000	0.5200	0.8300	43.0000	37.7000	97.0000	96.0000
♦ 116:	1.0000	400.000	148.680	2.8000	14.8000	0.6700	0.9700	45.0000	39.1000	96.0000	104.000
♦ 117:	1.0000	500.000	200.300	2.7000	19.0000	0.8600	1.1700	45.0000	39.8000	96.0000	108.000
♦ 118:	1.0000	600.000	259.400	3.0000	20.1000	0.9300	1.1900	47.0000	40.5000	96.0000	108.000
♦ 119:	1.0000	700.000	309.600	2.5000	24.0000	1.1200	1.3900	46.0000	40.5000	96.0000	114.000
♦ 120:	1.0000	800.000	367.200	2.2700	30.9000	1.3900	1.5900	46.0000	39.1000	96.0000	132.000
♦ 121:	1.0000	900.000	614.900	2.4700	29.7000	1.4300	1.7000	46.0000	40.0000	96.0000	138.000
♦ 122:	1.0000	1000.00	796.500	2.4000	35.3000	1.7000	1.9100	48.0000	42.0000	96.0000	138.000
♦ 123:	1.0000	1100.00	782.500	2.0700	39.3000	1.9100	2.0800	47.0000	42.0000	96.0000	144.000
♦ 124:	1.0000	1200.00	896.500	2.1000	43.3000	2.1000	2.2400	48.0000	42.0000	95.0000	150.000
♦ 125:	1.0000	1300.00	1167.00	2.1300	47.7000	2.3000	2.4300	48.0000	42.0000	95.0000	150.000
♦ 126:	1.0000	1400.00	1066.53	2.0000	48.6000	2.4300	2.5400	50.0000	43.4000	94.0000	162.000
♦ 127:	1.0000	1500.00	1317.00	1.9800	55.6000	2.7800	2.7800	50.0000	43.4000	92.0000	168.000
♦ 128:	1.0000	1600.00	1324.50	2.0300	10000.0	3.1000	2.8900	50.0000	43.4000	91.0000	174.000

Tab 7.3.1.2 Individual data of subject 1, R1.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 194:	1.0000	0.0000	1.0000	13.0000	1.2600	0.3500	5.4300	10.4000	5.5000	0.5288	4.9000
♦ 195:	1.0000	100.000	1.0000	8.0000	1.4900	0.4800	7.2000	5.7000	4.0000	0.7018	1.7000
♦ 196:	1.0000	200.000	1.2500	10.0000	1.5800	0.5300	7.7200	10.5000	6.2000	0.5905	4.3000
♦ 197:	1.0000	300.000	1.2500	14.6700	2.0800	0.6700	7.0800	7.8000	5.2000	0.6667	2.6000
♦ 198:	1.0000	400.000	1.5000	19.6700	1.9100	0.8000	9.1700	6.3000	4.2000	0.6667	2.1000
♦ 199:	1.0000	500.000	2.0000	23.3000	2.3800	0.9700	7.2200	7.6000	4.5500	0.5987	3.0500
♦ 200:	1.0000	600.000	2.5000	32.6700	2.5500	1.1000	8.0700	6.5000	3.8000	0.5846	2.7000
♦ 201:	1.0000	700.000	3.0000	31.0000	2.5300	1.1300	9.0400	6.4000	3.9500	0.6172	2.4500
♦ 202:	1.0000	800.000	3.7500	38.0000	2.3200	1.2700	12.1400	4.9000	3.0000	0.6122	1.9000
♦ 203:	1.0000	900.000	6.2500	68.6700	2.2300	1.3300	13.3900	4.2500	2.6500	0.6235	1.6000
♦ 204:	1.0000	1000.00	9.0000	78.0000	1.9700	1.6000	16.7400	3.8000	2.9500	0.7763	0.8500
♦ 205:	1.0000	1100.00	10.0000	79.1700	1.8600	1.6300	19.9200	2.9000	2.2000	0.7586	0.7000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 194:	1.0000	0.0000	66.3000	1.4000	6.8400	0.2400	0.3480	39.0000	31.9000	97.0000	72.0000
♦ 195:	1.0000	100.000	56.9000	1.5000	10.7500	0.4000	0.5300	38.0000	32.6000	97.0000	88.0000
♦ 196:	1.0000	200.000	122.800	1.8500	12.2000	0.4800	0.7300	40.0000	34.0000	95.0000	96.0000
♦ 197:	1.0000	300.000	275.400	2.0000	14.7000	0.6200	0.9300	42.0000	36.1000	95.0000	90.0000
♦ 198:	1.0000	400.000	462.400	2.0700	17.5000	0.7500	1.0400	44.0000	36.8000	95.0000	108.000
♦ 199:	1.0000	500.000	447.100	2.6000	17.1800	0.7900	1.1000	46.0000	40.0000	95.0000	114.000
♦ 200:	1.0000	600.000	786.600	2.5300	20.5500	0.9700	1.2900	45.3300	39.5000	94.0000	114.000
♦ 201:	1.0000	700.000	860.340	2.5300	22.8800	1.1000	1.4000	46.6700	40.0000	95.0000	120.000
♦ 202:	1.0000	800.000	1155.40	2.1700	28.1500	1.3300	1.5900	48.0000	41.1000	94.0000	150.000
♦ 203:	1.0000	900.000	2364.50	2.0000	29.8500	1.4700	1.7300	50.0000	42.2000	92.0000	138.000
♦ 204:	1.0000	1000.00	2917.60	1.8300	32.9500	1.6900	1.9200	51.0000	43.9000	93.0000	144.000
♦ 205:	1.0000	1100.00	3334.80	1.7500	37.0500	1.9300	2.0800	51.5000	44.6000	91.0000	148.000

Tab 7.3.1.3 Individual data of subject 1, R2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 258:	1.0000	0.0000	1.2500	10.0000	1.5580	0.3000	4.7700	13.2000	8.5000	0.6439	4.7000
• 259:	1.0000	100.000	1.2500	24.0000	1.9800	0.4500	5.3000	6.0000	3.6000	0.6000	2.4000
• 260:	1.0000	200.000	1.2500	19.8000	2.4600	0.4000	4.9000	11.4000	7.9000	0.6930	3.5000
• 261:	1.0000	300.000	1.7500	30.0000	2.1300	0.5000	6.5000	12.3000	7.9500	0.6463	4.3500
• 262:	1.0000	400.000	3.0000	38.0000	2.6400	0.7000	6.2000	10.5000	6.8000	0.6476	3.7000
• 263:	1.0000	500.000	3.7500	44.0000	2.2300	0.7000	8.9000	9.3000	6.1000	0.6559	3.2000
• 264:	1.0000	600.000	4.5000	56.0000	2.1200	0.8000	10.1000	7.7000	5.0300	0.6532	2.6700
• 265:	1.0000	700.000	5.5000	63.0000	2.0400	0.9300	12.4000	6.4500	4.2500	0.6589	2.2000
• 266:	1.0000	800.000	7.7500	75.5000	1.9000	1.0000	15.4000	4.2300	3.1300	0.7400	1.1000
• 267:	1.0000	900.000	10.0000	78.0000	1.4600	1.2400	15.4000	3.0000	2.3000	0.7667	0.7000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 258:	1.0000	0.0000	263.000	1.3700	7.4000	0.3200	0.4200	40.0000	34.8000	97.0000	72.0000
• 259:	1.0000	100.000	548.000	1.1500	10.6000	0.4600	0.6400	40.0000	35.2000	97.0000	90.0000
• 260:	1.0000	200.000	418.500	1.9200	12.1000	0.5600	0.8100	42.0000	38.4000	96.0000	96.0000
• 261:	1.0000	300.000	739.700	2.4000	14.0000	0.6800	0.9600	45.0000	40.5000	95.0000	102.000
• 262:	1.0000	400.000	781.200	2.5000	16.3000	0.8200	1.1000	47.0000	42.0000	95.0000	108.000
• 263:	1.0000	500.000	1199.30	2.5000	19.6000	1.0300	1.2800	48.0000	42.0000	94.0000	114.000
• 264:	1.0000	600.000	1514.20	2.6700	21.5000	1.1500	1.3800	50.0000	43.0000	95.0000	126.000
• 265:	1.0000	700.000	1741.50	2.3500	25.3000	1.3800	1.6200	50.0000	44.0000	94.0000	132.000
• 266:	1.0000	800.000	1859.60	2.0000	29.2000	1.5700	1.6500	50.0000	45.0000	93.0000	138.000
• 267:	1.0000	900.000	1859.60	1.4400	22.2000	1.3200	1.2900	54.0000	46.9000	92.0000	144.000

Tab 7.3.1.4 Individual data of subject 1, R3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 308:	1.0000	0.0000	0.5000	10.4800	0.7900	0.8400	12.1900	4.7000	1.7000	0.3617	3.0000
• 309:	1.0000	100.000	0.5000	16.2500	1.1200	0.9600	10.7700	6.6000	3.3000	0.5000	3.3000
• 310:	1.0000	200.000	0.7500	18.2500	1.4900	1.1000	11.1100	4.8000	2.1000	0.4375	2.7000
• 311:	1.0000	300.000	0.7500	21.1700	1.5500	1.2000	10.6000	5.4000	2.0300	0.3759	3.3700
• 312:	1.0000	400.000	1.0000	23.6000	1.7500	1.6000	10.6000	4.9000	1.9000	0.3878	3.0000
• 313:	1.0000	500.000	1.2500	28.4300	1.8600	1.8000	11.4000	4.9000	1.6000	0.3265	3.3000
• 314:	1.0000	600.000	1.2500	27.8600	1.9200	1.8700	15.4000	4.6000	1.5400	0.3348	3.0600
• 315:	1.0000	700.000	1.7500	31.3600	2.1200	2.1000	13.9100	4.9000	1.5300	0.3122	3.3700
• 316:	1.0000	800.000	2.7500	32.4800	2.1300	2.4000	14.4200	3.2000	1.1400	0.3562	2.0600
• 317:	1.0000	900.000	3.2500	30.0000	1.9600	2.6000	21.2800	3.3000	1.1500	0.3485	2.1500
• 318:	1.0000	1000.00	4.0000	29.5000	2.0300	3.0000	19.6000	2.7000	0.8800	0.3259	1.8200
• 319:	1.0000	1100.00	4.5000	31.0000	2.0400	2.8000	23.3000	3.2000	1.0300	0.3219	2.1700
• 320:	1.0000	1200.00	5.5000	30.4400	2.0400	3.1000	22.6100	2.2000	0.8300	0.3773	1.3700
• 321:	1.0000	1300.00	6.2500	34.4000	2.0300	3.0000	26.2400	2.5000	0.9300	0.3720	1.5700
• 322:	1.0000	1400.00	7.2500	35.8400	2.0900	3.1000	26.8000	2.2000	0.8000	0.3636	1.4000
• 323:	1.0000	1500.00	8.2500	35.4200	2.1100	3.5000	28.7000	2.0100	0.7700	0.3831	1.2400
• 324:	1.0000	1600.00	9.0000	36.1300	2.1700	3.9000	30.7300	1.8700	0.7300	0.3904	1.1400
• 325:	1.0000	1700.00	9.5000	36.4700	2.2100	4.6000	33.9800	1.6800	0.7000	0.4167	0.9800
• 326:	1.0000	1800.00	10.0000	36.6400	2.2300	4.2000	37.7000	1.5000	0.5800	0.3867	0.9200

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 308:	1.0000	0.0000	249.900	0.8000	9.6600	0.3300	0.3800	38.0000	29.8000	97.0000	78.0000
• 309:	1.0000	100.000	447.500	1.1500	12.0300	0.4600	0.4700	40.0000	33.3000	96.0000	84.0000
• 310:	1.0000	200.000	366.400	1.3500	16.5500	0.6300	0.7000	38.0000	32.6000	96.0000	102.000
• 311:	1.0000	300.000	469.000	1.4000	16.4000	0.6600	0.8200	40.0000	36.2000	95.0000	102.000
• 312:	1.0000	400.000	498.800	1.6000	18.5500	0.8300	1.0400	42.0000	38.0000	95.0000	108.000
• 313:	1.0000	500.000	553.000	1.8000	21.2000	0.9900	1.1400	44.0000	39.0000	95.0000	114.000
• 314:	1.0000	600.000	544.400	1.9000	29.5800	1.2900	1.3500	42.0000	39.0000	95.0000	120.000
• 315:	1.0000	700.000	631.700	2.1000	29.4400	1.3600	1.4200	46.0000	41.0000	95.0000	126.000
• 316:	1.0000	800.000	643.800	1.9000	30.6500	1.4600	1.5500	44.0000	40.0000	95.0000	132.000
• 317:	1.0000	900.000	678.400	1.9000	41.6500	1.8600	1.8600	46.0000	39.0000	95.0000	156.000
• 318:	1.0000	1000.00	679.600	1.8000	39.7500	1.9000	1.9700	44.0000	40.0000	95.0000	144.000
• 319:	1.0000	1100.00	693.100	2.0000	47.5800	2.2000	2.1500	46.0000	40.0000	95.0000	150.000
• 320:	1.0000	1200.00	679.000	1.9000	47.3000	2.2100	2.1800	46.0000	40.4000	94.0000	150.000
• 321:	1.0000	1300.00	732.900	2.1000	53.1000	2.4000	2.3500	44.0000	39.0000	95.0000	162.000
• 322:	1.0000	1400.00	674.900	1.9800	56.1000	2.5500	2.4800	44.0000	39.7000	94.0000	162.000
• 323:	1.0000	1500.00	712.500	2.0000	60.4800	2.7000	2.8500	45.0000	39.2000	94.0000	168.000
• 324:	1.0000	1600.00	712.500	2.1000	66.7300	3.0800	2.8500	45.0000	40.0000	93.0000	168.000
• 325:	1.0000	1700.00	768.600	2.1000	74.8500	3.3500	3.0200	45.0000	40.0000	93.0000	174.000
• 326:	1.0000	1800.00	808.500	1.7000	84.3000	3.7100	3.2200	46.0000	38.3000	89.0000	186.000

Tab 7.3.1.5 Individual data of subject 1, El.

	CODE	KPM	cor Borg	P-MOUTH	Vt	$\dot{V}$I	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
• 413:	1.0000	0.0000	1.2500	19.8000	0.5600	0.6000	13.0600	4.5000	1.5000	0.3333	3.0000
• 414:	1.0000	100.000	1.7500	27.8000	0.7900	0.7300	14.1000	4.1000	1.6000	0.3902	2.5000
• 415:	1.0000	200.000	1.7500	32.6000	1.0800	0.9700	12.2600	4.3000	2.1000	0.4884	2.2000
• 416:	1.0000	300.000	2.2500	43.1000	1.1900	1.1000	13.3100	5.0000	1.8000	0.3600	3.2000
• 417:	1.0000	400.000	2.5000	43.5000	1.2600	1.1300	14.7900	4.1000	1.6000	0.3902	2.5000
• 418:	1.0000	500.000	3.5000	49.2000	1.5500	1.9000	12.6900	4.6000	1.7000	0.3696	2.9000
• 419:	1.0000	600.000	3.5000	50.7000	1.4500	1.8000	16.4100	3.4000	1.3000	0.3824	2.1000
• 420:	1.0000	700.000	3.7500	54.6000	1.6200	2.2000	17.1500	3.2000	1.2000	0.3750	2.0000
• 421:	1.0000	800.000	4.5000	55.1000	1.6800	2.1000	17.1000	3.1000	1.1000	0.3548	2.0000
• 422:	1.0000	900.000	5.5000	56.0000	1.7100	2.7000	19.7700	3.1000	1.0000	0.3226	2.1000
• 423:	1.0000	1000.00	6.2500	58.6000	1.7400	2.4000	22.3000	2.4000	1.0000	0.4167	1.4000
• 424:	1.0000	1100.00	7.7500	59.3000	1.6800	2.6000	25.1900	2.2000	0.9000	0.4091	1.3000
• 425:	1.0000	1200.00	9.5000	60.9000	1.6200	2.9000	27.3600	2.2000	0.8000	0.3636	1.4000
• 426:	1.0000	1300.00	10.0000	61.5000	1.6800	3.4000	31.2200	1.8000	0.7000	0.3889	1.1000
• 427:	1.0000	1400.00	10.0000	61.5000	1.7700	3.5000	36.4900	1.5000	0.6000	0.4000	0.9000

	CODE	KPM	P=TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	10
• 413:	1.0000	0.0000	481.200	0.5000	7.3200	0.2200	0.3500	36.0000	27.7000	95.0000	90.0000
• 414:	1.0000	100.000	709.600	0.7000	11.1000	0.4200	0.6200	38.0000	32.6000	95.0000	96.0000
• 415:	1.0000	200.000	1039.50	0.9000	13.3000	0.5300	0.7800	40.0000	34.7000	93.0000	108.000
• 416:	1.0000	300.000	1404.10	1.1500	15.8800	0.6600	0.9700	42.0000	36.2000	94.0000	108.000
• 417:	1.0000	400.000	1246.60	1.1800	18.5800	0.7900	1.1000	48.0000	37.2000	96.0000	120.000
• 418:	1.0000	500.000	1417.50	1.5500	19.6300	0.9100	1.2600	46.0000	41.1000	93.0000	120.000
• 419:	1.0000	600.000	1450.50	1.3000	23.8300	1.1100	1.4200	46.0000	40.4000	95.0000	132.000
• 420:	1.0000	700.000	1227.30	1.5000	27.7000	1.2800	1.5700	48.0000	40.4000	94.0000	132.000
• 421:	1.0000	800.000	1472.60	1.6000	28.6500	1.3800	1.6600	50.0000	41.8000	94.0000	144.000
• 422:	1.0000	900.000	1615.20	1.6000	33.7500	1.6300	1.9400	50.0000	41.8000	94.0000	150.000
• 423:	1.0000	1000.00	1646.50	1.5000	38.8000	1.8500	2.1400	47.0000	41.1000	94.0000	156.000
• 424:	1.0000	1100.00	1606.70	1.6000	42.2300	2.0700	2.2600	49.0000	42.3000	92.0000	162.000
• 425:	1.0000	1200.00	1865.40	1.5000	44.2800	2.1900	2.3400	50.0000	42.5000	92.0000	168.000
• 426:	1.0000	1300.00	1698.30	1.6000	52.4500	2.5000	2.5600	48.0000	41.6000	91.0000	174.000
• 427:	1.0000	1400.00	1638.00	1.6000	64.6000	2.9200	2.8300	46.0000	39.0000	89.0000	168.000

Tab 7.3.1.6 Individual data of subject 1, E2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 498:	1.0000	0.0000	1.5000	23.9800	0.6100	0.4700	12.6100	4.8000	1.6000	0.3333	3.2000
♦ 499:	1.0000	100.000	1.5000	38.9600	0.8200	0.6800	15.7100	4.0800	1.6700	0.4093	2.4100
♦ 500:	1.0000	200.000	1.5000	35.9800	0.8900	0.7400	15.5400	4.2300	1.3800	0.3262	2.8500
♦ 501:	1.0000	300.000	1.5000	45.4000	1.0300	0.9600	14.0600	3.6000	1.4000	0.3889	2.2000
♦ 502:	1.0000	400.000	1.7500	53.9000	1.0800	1.1000	16.4700	3.4200	1.2200	0.3567	2.2000
♦ 503:	1.0000	500.000	2.7500	61.8900	1.1700	1.4000	17.9000	3.6300	1.1200	0.3085	2.5100
♦ 504:	1.0000	600.000	4.0000	63.6900	1.3700	1.5000	18.2200	3.1300	1.0400	0.3323	2.0900
♦ 505:	1.0000	700.000	5.0000	64.3500	1.3900	1.7000	19.7200	2.9200	1.0800	0.3699	1.8400
♦ 506:	1.0000	800.000	6.0000	70.6300	1.4500	1.9000	20.7600	2.6700	0.9800	0.3670	1.6900
♦ 507:	1.0000	900.000	7.2500	69.5400	1.4800	2.0500	24.1100	2.3000	0.9300	0.4043	1.3700
♦ 508:	1.0000	1000.00	8.7500	73.0200	1.5200	2.2600	25.7300	2.1700	0.8100	0.3733	1.3600
♦ 509:	1.0000	1100.00	9.5000	73.1700	1.5700	2.7000	28.8500	2.0300	0.7900	0.3892	1.2400
♦ 510:	1.0000	1200.00	9.5000	71.1500	1.5600	2.8000	32.5300	1.9000	0.7600	0.4000	1.1400
♦ 511:	1.0000	1300.00	9.5000	73.7100	1.4400	2.7000	36.2700	1.8500	0.7400	0.4000	1.1100
♦ 512:	1.0000	1400.00	10.0000	71.8400	1.5300	2.7000	38.0500	1.5900	0.6300	0.3962	0.9600
* 513:	1.0000	1500.00	10.0000	72.9400	1.6100	2.7000	38.0500	1.6100	0.7000	0.4348	0.9100

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 498:	1.0000	0.0000	388.000	0.3800	7.6500	0.3300	0.3700	36.0000	29.8000	97.0000	72.0000
♦ 499:	1.0000	100.000	758.400	0.5200	12.8200	0.5400	0.6400	38.0000	33.3000	96.0000	80.0000
♦ 500:	1.0000	200.000	709.300	0.6000	13.9000	0.5400	0.7200	40.0000	35.5000	96.0000	90.0000
♦ 501:	1.0000	300.000	900.800	0.8000	14.5300	0.6100	0.8700	42.0000	36.9000	95.0000	95.0000
♦ 502:	1.0000	400.000	1011.60	0.8200	17.7000	0.7700	0.9800	42.0000	37.6000	95.0000	98.0000
♦ 503:	1.0000	500.000	1157.40	0.9700	20.9300	0.9400	1.1600	44.0000	40.4000	95.0000	105.000
♦ 504:	1.0000	600.000	1344.80	0.9800	25.0500	1.1800	1.3700	45.0000	41.1000	95.0000	112.000
♦ 505:	1.0000	700.000	1292.40	1.0400	27.3500	1.3100	1.4700	45.0000	42.4000	95.0000	126.000
♦ 506:	1.0000	800.000	1220.80	1.1500	30.2000	1.4900	1.6200	46.0000	42.9000	95.0000	144.000
♦ 507:	1.0000	900.000	1537.40	1.1600	35.6800	1.8000	1.9200	48.0000	43.3000	93.0000	150.000
♦ 508:	1.0000	1000.00	1516.30	1.1400	39.2000	2.0000	2.0800	49.0000	44.0000	91.0000	150.000
♦ 509:	1.0000	1100.00	1538.40	1.3000	45.2300	2.2700	2.2600	49.0000	42.5000	92.0000	156.000
♦ 510:	1.0000	1200.00	1562.40	1.4000	48.7500	2.4300	2.3400	47.0000	40.4000	90.0000	156.000
♦ 511:	1.0000	1300.00	1697.10	1.2000	52.3000	2.2100	2.0900	44.0000	37.6000	92.0000	150.000
♦ 512:	1.0000	1400.00	1530.60	1.1000	58.2300	2.3100	2.3200	44.0000	36.9000	91.0000	156.000
* 513:	1.0000	1500.00	1457.90	1.2000	61.3000	2.3100	2.2100	44.0000	36.9000	90.0000	162.000

Tab 7.3.1.7 Individual data of subject 1, E3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}I$ 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 575:	1.0000	0.0000	0.0000	1.3000	0.8300	0.8300	9.2700	5.6300	1.7600	0.3126	3.8700
• 576:	1.0000	100.000	0.0000	1.9300	1.0800	1.0200	13.9200	6.2500	2.5200	0.4032	3.7300
• 577:	1.0000	200.000	0.0000	2.1800	0.9700	1.2800	12.8900	3.4400	1.3700	0.3983	2.0700
• 578:	1.0000	300.000	0.0000	1.4800	1.1400	1.2300	12.9100	5.3000	2.6300	0.4962	2.6700
• 579:	1.0000	400.000	0.0000	2.2800	1.2600	1.4400	14.6000	4.7700	2.1300	0.4465	2.6400
• 580:	1.0000	500.000	0.2500	3.0800	1.6800	1.7200	11.8200	5.0500	2.1000	0.4158	2.9500
• 581:	1.0000	600.000	0.2500	4.2000	1.5600	1.8000	16.1200	3.8200	1.6000	0.4188	2.2200
• 582:	1.0000	700.000	0.5000	2.7600	1.5800	1.8300	16.7500	4.3600	2.0000	0.4587	2.3600
• 583:	1.0000	800.000	0.7500	4.7000	1.8000	2.1800	16.8800	3.8300	1.5900	0.4151	2.2400
• 584:	1.0000	900.000	1.2500	5.1700	1.7400	2.5500	19.3500	3.1300	1.2900	0.4121	1.8400
• 585:	1.0000	1000.00	1.2500	6.5600	1.9200	2.8900	19.5900	2.7900	1.1600	0.4158	1.6300
• 586:	1.0000	1100.00	1.7500	6.9600	1.9100	3.0100	23.5800	2.4000	1.0400	0.4333	1.3600
• 587:	1.0000	1200.00	2.0000	7.8400	1.9100	3.3900	25.3800	2.3100	0.9200	0.3983	1.3900
• 588:	1.0000	1300.00	2.5000	8.9000	1.9800	3.4900	24.1400	2.2900	0.9800	0.4279	1.3100
• 589:	1.0000	1400.00	3.0000	9.4000	2.0300	3.6900	26.3100	2.1200	0.9000	0.4245	1.2200
• 590:	1.0000	1500.00	4.0000	9.9400	2.0300	4.1500	29.4700	1.9100	0.8300	0.4346	1.0800
• 591:	1.0000	1600.00	4.5000	11.4000	2.0900	4.1300	34.3300	1.6800	0.6600	0.3929	1.0200
• 592:	1.0000	1700.00	5.5000	12.9200	2.1300	4.7800	37.8600	1.4400	0.5500	0.3819	0.8900

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}E$ 9	$\dot{V}CO2$ 13	$\dot{V}O2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 575:	1.0000	0.0000	6.9900	0.8000	7.7100	0.2500	0.3700	37.0000	28.4000	97.0000	66.0000
• 576:	1.0000	100.000	19.4800	1.3600	11.7800	0.4200	0.5800	40.0000	32.0000	96.0000	96.0000
• 577:	1.0000	200.000	20.4800	1.0500	13.5300	0.4900	0.7200	38.0000	31.2000	96.0000	96.0000
• 578:	1.0000	300.000	20.4800	1.7800	14.8500	0.5800	0.8800	40.0000	34.1000	95.0000	102.000
• 579:	1.0000	400.000	32.7700	1.8600	18.3500	0.7300	1.0600	41.0000	34.1000	96.0000	108.000
• 580:	1.0000	500.000	42.1800	2.3200	19.9000	0.8600	1.2200	42.0000	36.9000	95.0000	120.000
• 581:	1.0000	600.000	42.1600	1.8800	25.1800	1.0300	1.3200	41.0000	35.5000	96.0000	114.000
• 582:	1.0000	700.000	47.1400	2.2000	26.4500	1.1000	1.3500	43.0000	36.2000	96.0000	126.000
• 583:	1.0000	800.000	52.2200	2.4200	30.4300	1.2900	1.6200	44.0000	36.9000	96.0000	132.000
• 584:	1.0000	900.000	88.8700	2.3500	33.6300	1.5000	1.8900	46.0000	38.3000	95.0000	138.000
• 585:	1.0000	1000.00	94.0100	2.4300	37.7000	1.7200	2.0600	48.0000	39.1000	94.0000	144.000
• 586:	1.0000	1100.00	97.4500	2.3300	44.9800	1.9700	2.1800	46.0000	38.3000	95.0000	150.000
• 587:	1.0000	1200.00	117.960	2.3800	48.5300	2.13[illegible]	2.3400	44.0000	37.6000	95.0000	156.000
• 588:	1.0000	1300.00	144.000	2.4800	47.7800	2.2100	2.4500	45.0000	39.8000	94.0000	168.000
• 589:	1.0000	1400.00	165.000	2.5400	53.2800	2.5000	2.6600	48.0000	40.5000	94.0000	168.000
• 590:	1.0000	1500.00	177.690	2.5700	59.9000	2.8800	2.8800	49.0000	41.2000	93.0000	174.000
• 591:	1.0000	1600.00	211.720	2.0800	71.6800	3.3300	3.1100	48.0000	39.8000	92.0000	180.000
• 592:	1.0000	1700.00	322.950	2.0700	80.7000	3.6600	3.3100	48.0000	39.1000	91.0000	180.000

Tab 7.3.1.8 Individual data of subject 1, C2.

Dflag	CODE 1	KPH 4	cor Rorg 29	P-MOUTH 20	Vt 21	V̇I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 75	TE 28
0:	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	
20:	7.0000	0.0000	0.0000	7.0000	0.6500	0.8000	13.5400	4.8000	1.6800	0.3500	3.1200
21:	2.0000	100.000	0.0000	2.0000	0.9500	1.2000	16.7700	4.7000	1.5700	0.3340	3.1300
22:	7.0000	200.000	0.5000	7.0000	1.2200	1.4800	15.2500	5.5000	2.0800	0.3787	3.4200
23:	2.0000	300.000	1.0000	2.0000	1.2900	1.0000	13.2800	5.0000	1.7800	0.3560	3.2200
24:	2.0000	400.000	1.2500	2.3000	1.3700	1.3000	14.5800	4.5600	1.9800	0.4342	2.5800
25:	2.0000	500.000	1.2500	3.0000	1.5400	1.7300	14.9000	4.4700	1.9000	0.4251	2.5700
26:	2.0000	600.000	1.7500	4.3000	1.5200	1.1300	17.0400	3.5200	1.4200	0.4034	2.1000
27:	2.0000	700.000	2:0000	4.0000	1.7900	1.9600	17.2000	3.9000	1.6500	0.4231	2.7500
28:	7.0000	800.000	2.5000	3.7500	1.9300	1.8700	17.9400	2.7700	1.2000	0.4332	1.5700
29:	2.0000	900.000	3.2500	5.0000	2.2100	2.5000	18.9000	3.3000	1.5700	0.4758	1.7300
30:	2.0000	1000.00	3.5000	5.5000	2.2900	2.5800	20.1100	2.7000	1.7500	0.4430	1.4500
31:	2.0000	1100.00	4.5000	5.3000	2.8700	2.5300	17.2900	3.6000	1.8200	0.5056	1.7800
32:	7.0000	1200.00	4.5000	6.3000	3.0300	2.8000	17.2800	3.8700	1.9300	0.4987	1.9400
33:	2.0000	[illegible]	6.0000	7.0000	3.3000	3.1000	16.9800	3.5000	1.7500	0.5000	1.7500
34:	2.0000	[illegible]	6.0000	8.8000	3.0800	3.5000	21.0000	2.6500	1.4000	0.5283	1.7500
35:	2.0000	1500.00	7.2500	8.6000	3.2900	3.5000	22.1100	2.5000	1.2600	0.5040	1.2400
36:	2.0000	1600.00	8.5000	10.0000	3.3400	4.0300	25.1000	2.2000	1.1200	0.5091	1.0800
37:	2.0000	1700.00	9.0000	10.1600	3.2300	4.1200	29.7800	1.8800	0.9100	0.4840	0.9700
38:	2.0000	1800.00	9.0000	12.6700	3.3100	4.5000	33.6600	1.6500	0.7700	0.4447	0.8800

Dflag	CODE 1	KPH 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
0:	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	
20:	2.0000	0.0000	10.1000	0.8100	8.8000	0.2500	0.3700	40.0000	25.6000	95.0000	66.0000
21:	2.0000	100.000	28.1000	1.0800	15.4300	0.5700	0.7200	44.0000	29.1000	96.0000	84.0000
22:	2.0000	200.000	23.1000	1.8000	18.6000	0.6500	0.8300	43.0000	30.5000	96.0000	78.0000
23:	2.0000	300.000	27.1000	1.4500	17.1300	0.6300	0.8300	44.0000	32.0000	95.0000	78.0000
24:	2.0000	400.000	28.3000	1.7000	19.9800	0.7600	1.0300	44.0000	37.7000	95.0000	84.0000
25:	2.0000	500.000	52.4000	2.0600	22.9500	0.9000	1.1700	46.0000	34.1000	94.0000	84.0000
26:	2.0000	600.000	54.5000	1.5700	25.9000	1.0400	1.3000	46.0000	34.8000	95.0000	90.0000
27:	2.0000	700.000	65.2000	2.2700	30.7800	1.2700	1.5600	44.0000	35.5000	94.0000	96.0000
28:	7.0000	800.000	73.8000	1.6300	34.6300	1.4500	1.7000	46.0000	36.2000	95.0000	102.000
29:	2.0000	900.000	75.6000	2.7300	41.7800	1.7400	1.9600	47.0000	36.3000	96.0000	108.000
30:	2.0000	1000.00	100.100	2.5000	46.0500	1.9100	2.1100	47.0000	36.2000	95.0000	114.000
31:	2.0000	1100.00	106.000	3.0000	49.6700	2.1100	2.2200	48.0000	36.9000	95.0000	170.000
32:	2.0000	1200.00	97.9000	3.6000	52.3500	2.2800	2.4300	49.0000	37.6000	94.0000	170.000
33:	2.0000	1300.00	109.000	3.7500	56.6300	7.4400	2.5500	48.0000	37.6000	94.0000	176.000
34:	2.0000	1400.00	102.100	3.2800	64.6800	2.6800	2.7000	46.0000	34.7000	94.0000	139.000
35:	2.0000	1500.00	149.700	3.2600	77.7300	3.0300	2.9500	47.0000	34:2000	94.0000	144.000
36:	2.0000	1600.00	162.400	3.2500	83.8300	3.3700	3.1800	47.0000	34.6000	94.0000	150.000
37:	2.0000	1700.00	180.100	7.8900	96.2000	3.6100	3.3800	44.0000	37.7000	94.0000	147.000
38:	2.0000	1800.00	233.600	3.0300	111.400	3.9900	3.6700	44.0000	31.2000	94.0000	168.000

Tab 7.3.2.1 Individual data of subject 2, CI.

Oflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 0:	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	
• 129:	2.0000	0.0000	3.0000	33.1000	1.1100	0.9800	15.0400	3.4600	1.7000	0.4913	1.7600
• 130:	2.0000	100.000	3.2500	33.5000	1.0400	0.9000	18.8700	3.1200	0.9800	0.3141	2.1400
• 131:	2.0000	200.000	3.7500	29.4000	1.3700	0.8400	17.2300	3.2800	1.9800	0.6037	1.3000
• 132:	2.0000	300.000	4.7500	30.5000	1.2500	1.0200	21.9800	2.5200	1.4800	0.5873	1.0400
• 133:	2.0000	400.000	5.0000	35.8000	1.4000	1.0400	21.4800	2.8300	1.7000	0.6007	1.1300
• 134:	2.0000	500.000	5.2500	35.7000	1.2800	0.9800	21.1200	3.0000	1.9600	0.6533	1.0400
• 135:	2.0000	600.000	6.2500	32.8000	1.2600	1.1300	18.5300	3.3000	1.5000	0.4545	1.8000
• 136:	2.0000	700.000	6.7500	34.9000	1.3000	1.0600	21.1500	3.1400	1.7800	0.5669	1.3600
• 137:	2.0000	800.000	7.0000	39.7000	1.6000	1.3200	19.6400	3.0000	1.7000	0.5667	1.3000
• 138:	2.0000	900.000	7.7500	44.8000	1.7400	1.3200	19.9400	3.0500	2.0500	0.6721	1.0000
• 139:	2.0000	1000.00	8.0000	58.6000	1.6000	1.7800	25.8900	2.1000	1.4000	0.6667	0.7000
• 140:	2.0000	1100.00	8.2500	55.7000	1.5400	1.6900	28.5200	2.1000	1.5900	0.7571	0.5100
• 141:	2.0000	1200.00	9.0000	58.4000	1.6800	1.7700	30.5400	2.0000	1.5100	0.7550	0.4900
• 142:	2.0000	1300.00	10.0000	61.9000	1.6100	1.9000	33.9100	1.7800	1.2500	0.7022	0.5300

Oflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 0:	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	10000.0	
• 129:	2.0000	0.0000	359.600	1.0800	16.7100	0.3900	0.3700	28.0000	20.4000	97.0000	84.0000
• 130:	2.0000	100.000	476.000	1.3300	19.6800	0.5500	0.6500	30.0000	24.7000	97.0000	84.0000
• 131:	2.0000	200.000	719.300	1.2400	23.5300	0.7000	0.8300	32.0000	26.2000	98.0000	90.0000
• 132:	2.0000	300.000	693.600	1.0000	27.5300	0.7800	0.8800	30.0000	24.8000	98.0000	84.0000
• 133:	2.0000	400.000	850.000	1.2800	30.0800	0.8800	0.9900	32.0000	26.2000	98.0000	84.0000
• 134:	2.0000	500.000	802.600	1.3300	26.9800	0.8500	1.0500	34.0000	27.6000	98.0000	90.0000
• 135:	2.0000	600.000	868.500	1.1000	23.3500	0.8200	1.1300	40.0000	30.4000	99.0000	84.0000
• 136:	2.0000	700.000	752.900	1.2500	27.5500	1.0100	1.3100	40.0000	31.4000	97.0000	90.0000
• 137:	2.0000	800.000	928.000	1.4700	31.4800	1.2200	1.5300	42.0000	33.2000	97.0000	96.0000
• 138:	2.0000	900.000	1109.80	1.8800	34.6000	1.4100	1.7000	43.0000	35.4000	97.0000	102.000
• 139:	2.0000	1000.00	1352.10	1.6300	41.3000	1.6700	1.8600	43.0000	34.6000	97.0000	108.000
• 140:	2.0000	1100.00	1339.20	1.5500	43.8500	1.7900	1.9800	46.0000	35.4000	97.0000	108.000
• 141:	2.0000	1200.00	1768.50	1.5800	51.2300	2.1000	2.2000	45.0000	36.1000	97.0000	120.000
• 142:	2.0000	1300.00	1633.73	1.5200	54.6000	2.2400	2.3300	44.0000	36.1000	98.0000	120.000

Tab 7.3.2.2 Individual data of subject 2, R1.

	CODE	KPM	cor Borg	P-MOUTH	Vt	V̇I	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
+ 206:	2.0000	0.0000	3.5000	43.3000	0.8200	0.8000	14.7900	5.5000	2.5000	0.4545	3.0000
+ 207:	2.0000	100.000	3.7500	36.0000	0.8800	0.6600	16.9900	3.6700	2.6200	0.7139	1.0500
+ 208:	2.0000	200.000	3.7500	42.0000	0.9900	0.7300	15.5300	4.3000	3.0700	0.7140	1.2300
+ 209:	2.0000	300.000	4.2500	44.0000	0.8800	0.7300	17.5200	3.0500	2.4500	0.8033	0.6000
+ 210:	2.0000	400.000	4.5000	39.0000	1.0300	0.5600	17.7900	2.9500	1.7000	0.5763	1.2500
+ 211:	2.0000	500.000	5.5000	43.3000	1.1500	0.6700	19.2200	4.0500	3.5000	0.8647	0.5500
+ 212:	2.0000	600.000	6.0000	47.0000	1.2100	0.8000	19.4800	3.2500	2.8500	0.8769	0.4000
+ 213:	2.0000	700.000	6.2500	57.2000	1.2300	0.9000	20.7300	2.5000	1.8500	0.7400	0.6500
+ 214:	2.0000	800.000	8.2500	61.8000	1.2600	1.0000	23.2600	2.1000	1.5000	0.7143	0.6000
+ 215:	2.0000	900.000	9.5000	66.5000	1.1300	1.2000	30.2100	1.7000	1.4300	0.8412	0.2700

	CODE	KPM	P*TIME	Vt	V̇E	V̇CO2	V̇O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	10
+ 206:	2.0000	0.0000	676.080	0.9000	12.0700	0.3300	0.3600	32.0000	25.5000	99.0000	66.0000
+ 207:	2.0000	100.000	650.100	0.9600	14.9500	0.4600	0.5700	36.0000	26.7000	98.0000	72.0000
+ 208:	2.0000	200.000	632.300	1.0000	15.3000	0.5300	0.7300	38.0000	29.8000	97.0000	78.0000
+ 209:	2.0000	300.000	814.300	1.0000	15.3800	0.5800	0.8800	40.0000	31.9000	96.0000	78.0000
+ 210:	2.0000	400.000	923.400	0.9300	18.2800	0.7000	1.0000	42.0000	32.6000	97.0000	84.0000
+ 211:	2.0000	500.000	1230.80	1.5500	22.0500	0.8900	1.1700	42.0000	34.7000	98.0000	84.0000
+ 212:	2.0000	600.000	1398.60	1.5000	23.5300	0.9800	1.2200	44.0000	36.2000	97.0000	84.0000
+ 213:	2.0000	700.000	1606.40	1.4000	25.5500	1.1500	1.2800	44.0000	36.9000	97.0000	96.0000
+ 214:	2.0000	800.000	1515.50	1.0000	29.7500	1.2600	1.5400	47.0000	37.6000	98.0000	104.000
+ 215:	2.0000	900.000	1871.30	1.1000	34.2300	1.4700	1.7100	46.0000	37.6000	96.0000	104.000

Tab 7.3.2.3 Individual data of subject 2, R2.

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         CODE     KPM      cor Borg  P-MOUTH  Vt       V̇I       FR       TTOT     TI       Ti/Ttot  TE
Dflag       1        4        29       20       21        8        7        5        19       25       28
-------------------------------------------------------------------------------------------------------
+ 268:   2.0000   0.0000   6.2500   78.9000  0.7900   0.9000   14.8400  3.1000   1.6000   0.5161   1.5000
+ 269:   2.0000 100.000    6.7500   80.9000  1.0300   0.8300   14.6600  3.6000   1.5500   0.4306   2.0500
+ 270:   2.0000 200.000    7.2500   72.7000  1.0800   0.8300   14.7800  4.5500   1.8000   0.3956   2.7500
+ 271:   2.0000 300.000    8.7500   59.5000  1.2700   0.8300   15.0900  4.0000   2.1300   0.5325   1.8700
+ 272:   2.0000 400.000    8.7500   85.9000  1.2900   1.2300   17.2300  3.6700   2.0300   0.5531   1.6400
+ 273:   2.0000 500.000   10.0000   83.5000  1.2500   1.1200   20.0400  3.0000   1.0700   0.3567   1.9300
-------------------------------------------------------------------------------------------------------
         CODE     KPM      P*TIME   Vt       V̇E       V̇CO2     V̇O2      PETCO2   PECO2    SAO2     HR
Dflag       1        4       .22       6        9        13       14       11       36       12       10
-------------------------------------------------------------------------------------------------------
+ 268:   2.0000   0.0000 1883.20    0.7300  11.6900   0.3800   0.4200  38.0000  31.3800  97.0000  84.0000
+ 269:   2.0000 100.000  1773.80    0.7000  15.0300   0.7000   0.8000  40.0000  32.0000  97.0000  78.0000
+ 270:   2.0000 200.000   708.800   1.0000  15.9300   0.6300   0.8000  40.0000  34.1000  96.0000  84.0000
+ 271:   2.0000 300.000  1095.90    1.0300  19.2000   0.8000   1.0400  44.0000  36.3000  97.0000  90.0000
+ 272:   2.0000 400.000  1290.00    1.0800  22.2500   0.9600   1.1600  44.0000  37.3000  96.0000  90.0000
+ 273:   2.0000 500.000  1268.30    1.0400  25.0500   1.1000   1.3600  46.0000  38.4000  96.0000  90.0000
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Tab 7.3.2.4 Individual data of subject 2, R3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TF 28
♦ 327:	2.0000	0.0000	2.2500	23.5000	1.4800	1.3300	13.7800	5.0800	1.5000	0.2953	3.5800
♦ 328:	2.0000	100.000	2.5000	39.5000	2.0100	1.5800	13.5300	4.8900	1.5100	0.3088	3.3800
♦ 329:	2.0000	200.000	2.7500	30.0000	1.9600	1.4000	12.7300	4.9000	1.6500	0.3367	3.2500
♦ 330:	2.0000	300.000	2.7500	34.9000	1.8800	1.9500	10.6300	7.0300	1.3000	0.1849	5.7300
♦ 331:	2.0000	400.000	3.0000	32.5000	2.1500	1.3000	10.1200	[illegible].9000	1.8700	0.2710	5.0300
♦ 332:	2.0000	500.000	3.5000	35.9000	2.3300	1.1500	10.1200	[illegible].0500	2.1000	0.3471	3.9500
♦ 333:	2.0000	600.000	3.5000	36.3000	2.4200	1.2500	12.2100	5.0800	1.9000	0.3740	3.1800
♦ 334:	2.0000	700.000	4.2500	39.7200	2.2000	1.9300	14.2100	4.5000	1.7300	0.3844	2.7700
♦ 335:	2.0000	800.000	5.0000	43.8000	2.5400	2.2600	16.4000	3.3500	1.6000	0.4776	1.7500
♦ 336:	2.0000	900.000	5.0000	33.5000	2.1900	1.7300	17.7000	3.6800	1.6500	0.4484	2.0300
♦ 337:	2.0000	1000.00	6.0000	41.3000	2.2800	2.1200	19.8000	3.0300	1.4000	0.4620	1.6300
♦ 338:	2.0000	1100.00	8.0000	38.6000	2.5000	2.5800	19.6000	2.8500	1.2800	0.4491	1.5700
♦ 339:	2.0000	1200.00	8.2500	41.5000	2.3800	2.7000	22.5300	2.6500	1.3500	0.5094	1.3000
♦ 340:	2.0000	1300.00	8.7500	40.6000	2.4200	2.9000	25.2300	2.3300	1.1500	0.4936	1.1800
♦ 341:	2.0000	1400.00	8.7500	43.0000	2.5000	3.1500	25.4400	2.2500	1.1000	0.4889	1.1500
♦ 342:	2.0000	1500.00	9.0000	43.5000	2.5600	2.9800	25.8100	2.2700	1.1300	0.4978	1.1400
♦ 343:	2.0000	1600.00	9.5000	45.3000	2.7700	3.7000	26.9400	2.1000	1.0000	0.4762	1.1000
♦ 344:	2.0000	1700.00	10.0000	46.5700	2.8500	3.8000	30.3100	1.8800	0.9000	0.4787	0.9800

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
♦ 327:	2.0000	0.0000	291.000	1.3300	20.4400	0.5000	0.4500	28.0000	20.6000	98.0000	78.0000
♦ 328:	2.0000	100.000	445.000	2.0900	27.2300	0.7300	0.7000	32.0000	23.5000	98.0000	84.0000
♦ 329:	2.0000	200.000	454.000	1.7700	24.9800	0.7100	0.7800	34.0000	24.9000	98.0000	84.0000
♦ 330:	2.0000	300.000	334.300	1.9400	19.9500	0.6400	0.8500	36.0000	27.7000	98.0000	78.0000
♦ 331:	2.0000	400.000	456.300	1.9500	21.7800	0.7700	1.0800	42.0000	31.3000	97.0000	84.0000
♦ 332:	2.0000	500.000	563.700	2.2400	23.5800	0.9000	1.2700	40.0000	33.4000	97.0000	90.0000
♦ 333:	2.0000	600.000	546.200	2.0000	29.5300	1.1500	1.4000	42.0000	34.1000	97.0000	90.0000
♦ 334:	2.0000	700.000	612.200	2.2000	31.2000	1.2300	1.4300	40.0000	34.1000	98.0000	96.0000
♦ 335:	2.0000	800.000	871.300	2.5200	41.6000	1.6100	1.7900	40.0000	33.4000	98.0000	116.000
♦ 336:	2.0000	900.000	711.800	1.8800	38.7800	1.6100	1.8100	44.0000	36.3000	97.0000	104.000
♦ 337:	2.0000	1000.00	662.900	2.2900	45.2300	1.9300	2.1600	44.0000	37.0000	97.0000	108.000
♦ 338:	2.0000	1100.00	763.400	2.3400	49.0300	2.1000	2.2300	46.5000	37.0000	97.0000	132.000
♦ 339:	2.0000	1200.00	840.700	2.3200	53.6500	2.3000	2.4100	44.0000	37.7000	96.0000	128.000
♦ 340:	2.0000	1300.00	989.400	2.2000	61.0300	2.5000	2.5600	46.0000	36.3000	97.0000	120.000
♦ 341:	2.0000	1400.00	920.100	2.3900	63.6800	2.6000	2.6600	44.0000	36.8000	97.0000	128.000
♦ 342:	2.0000	1500.00	978.800	2.4200	66.1500	2.8500	2.8400	46.0000	37.7000	97.0000	140.000
♦ 343:	2.0000	1600.00	1127.60	2.4700	74.5500	3.2100	3.0300	45.0000	37.7000	97.0000	148.000
♦ 344:	2.0000	1700.00	1119.20	2.6600	86.5300	3.5000	3.2000	43.0000	35.6000	97.0000	156.000

Tab 7.3.2.5 Individual data of subject 2, El.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 428:	2.0000	0.0000	4.5000	45.4500	1.2300	1.2700	13.2500	3.7000	1.0000	0.2703	2.7000
♦ 429:	2.0000	100.000	4.5000	56.9200	1.4100	1.6700	10.9900	5.0300	1.0000	0.1988	4.0300
♦ 430:	2.0000	200.000	4.7500	61.9700	1.4400	1.6400	10.7100	5.4000	1.2000	0.2222	4.2000
♦ 431:	2.0000	300.000	5.2500	62.8800	1.4900	1.4800	12.6300	5.6000	1.4000	0.2500	4.2000
♦ 432:	2.0000	400.000	5.5000	69.9200	1.6500	1.4800	15.0800	5.0000	1.3000	0.2600	3.7000
♦ 433:	2.0000	500.000	6.0000	74.3100	1.8700	1.8600	14.6100	4.3500	1.1500	0.2644	3.2000
♦ 434:	2.0000	600.000	6.2500	7.4300	1.7300	1.7000	16.3000	4.2500	1.3000	0.3059	2.9500
♦ 435:	2.0000	700.000	6.2500	66.1400	1.5000	1.5100	22.6100	2.8800	1.1800	0.4897	1.7000
♦ 436:	2.0000	800.000	7.2500	63.2000	1.6600	1.5500	21.2200	2.7500	1.2200	0.4436	1.5300
♦ 437:	2.0000	900.000	9.0000	69.8200	1.6200	1.8100	25.3600	2.2300	1.1200	0.5022	1.1100
♦ 438:	2.0000	1000.00	9.7500	70.9000	1.6400	2.0000	28.8400	1.9600	0.9300	0.4745	1.0300
♦ 439:	2.0000	1100.00	10.0000	67.1100	1.6000	2.1000	31.1300	1.8100	0.9100	0.5028	0.9800
♦ 440:	2.0000	1200.00	10.0000	71.8800	1.4800	2.9400	39.1000	1.4900	0.7500	0.5034	0.7400

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 428:	2.0000	0.0000	424.200	0.8500	16.2900	0.4000	0.3900	33.0000	21.2000	96.0000	78.0000
♦ 429:	2.0000	100.000	405.900	1.1000	15.5300	0.4600	0.5800	38.0000	26.2000	97.0000	78.0000
♦ 430:	2.0000	200.000	545.200	1.2100	15.4500	0.5300	0.7300	42.0000	29.7000	97.0000	90.0000
♦ 431:	2.0000	300.000	634.400	1.2600	18.8300	0.7000	0.9700	46.0000	32.5000	95.0000	84.0000
♦ 432:	2.0000	400.000	721.700	1.3700	24.8000	0.9200	1.1400	44.0000	32.5000	96.0000	96.0000
♦ 433:	2.0000	500.000	833.600	1.4200	27.2500	1.0800	1.3100	47.0000	34.6000	96.0000	96.0000
♦ 434:	2.0000	600.000	882.800	1.4400	28.1300	1.1300	1.3300	49.0000	34.6000	95.0000	90.0000
♦ 435:	2.0000	700.000	1044.60	1.2300	33.8000	1.3900	1.5500	48.0000	35.7000	96.0000	102.000
♦ 436:	2.0000	800.000	1237.30	1.2200	35.1800	1.5200	1.7100	50.0000	37.5600	95.0000	102.000
♦ 437:	2.0000	900.000	1350.90	1.3500	40.9500	1.8000	1.9500	49.0000	37.7000	96.0000	120.000
♦ 438:	2.0000	1000.00	1352.50	1.3500	47.2300	2.0600	2.1300	50.0000	37.8000	96.0000	120.000
♦ 439:	2.0000	1100.00	1412.40	1.1000	49.9000	2.2100	2.2500	50.0000	38.2000	96.0000	126.000
♦ 440:	2.0000	1200.00	1361.80	1.2300	58.0000	2.4600	2.4600	49.0000	36.8000	96.0000	126.000

Tab 7.3.2.6 Individual data of subject 2, E2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TF 28
• 514:	2.0000	0.0000	4.5000	42.0000	0.9000	0.9780	15.2400	5.1300	1.7000	0.2339	3.9300
• 515:	2.0000	100.000	4.7500	53.5000	1.1600	1.2500	15.6700	4.1500	1.2500	0.3012	2.9000
• 516:	2.0000	200.000	5.0000	54.0000	1.0500	1.3700	15.3300	4.7000	1.3700	0.2915	3.3300
• 517:	2.0000	300.000	5.5000	52.3000	1.2000	1.3000	16.8400	3.2200	1.1700	0.3634	2.0500
• 518:	2.0000	400.000	6.2500	56.0000	1.1900	1.5500	20.7100	2.8000	1.0500	0.3750	1.7500
• 519:	2.0000	500.000	7.0000	57.3000	1.2600	1.7000	22.2100	2.7500	0.9300	0.3382	1.8200
• 520:	2.0000	600.000	8.2500	56.0000	1.3100	1.7800	22.7400	2.3800	1.0000	0.4202	1.3800
• 521:	2.0000	700.000	8.7500	63.0000	1.3900	2.1000	24.7000	2.4000	0.9300	0.3875	1.4700
• 522:	2.0000	800.000	9.5000	52.8000	1.2500	2.2000	30.1400	1.6800	0.7300	0.4345	0.9500
* 523:	2.0000	900.000	10.0000	50.3000	1.0000	2.1000	30.1400	1.4000	0.6000	0.4286	0.8000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 514:	2.0000	0.0000	388.000	0.9000	13.7000	0.3800	0.4200	30.0000	23.4000	97.0000	72.0000
• 515:	2.0000	100.000	736.400	1.2000	18.1000	0.5800	0.6900	36.0000	28.3000	97.0000	84.0000
• 516:	2.0000	200.000	705.000	1.2700	16.0800	0.5600	0.7200	40.0000	30.1000	97.0000	90.0000
• 517:	2.0000	300.000	858.300	1.1300	20.2300	0.7500	1.0000	40.0000	32.5000	97.0000	90.0000
• 518:	2.0000	400.000	990.400	1.1500	24.7000	0.9100	1.1100	40.0000	31.9000	97.0000	90.0000
• 519:	2.0000	500.000	958.000	1.1800	27.9300	1.0600	1.2700	41.0000	33.3000	97.0000	90.0000
• 520:	2.0000	600.000	1115.50	1.1600	29.6800	1.1400	1.3700	42.0000	33.4000	97.0000	96.0000
• 521:	2.0000	700.000	1226.90	1.3700	34.4000	1.3300	1.5400	43.0000	34.0000	97.0000	96.0000
• 522:	2.0000	800.000	1232.50	1.0500	37.7500	1.4900	1.7300	42.0000	34.7000	97.0000	108.000
* 523:	2.0000	900.000	1164.00	1.0000	30.1400	1.4900	1.3000	42.0000	33.3000	97.0000	96.0000

Tab 7.3.2.7 Individual data of subject 2, E3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 593:	2.0000	0.0000	0.0000	1.5000	0.6300	0.7000	13.2700	5.1500	1.8800	0.3650	3.2700
• 594:	2.0000	100.000	0.0000	2.2000	1.0500	0.8500	17.2700	5.2000	2.4000	0.4615	2.8000
• 595:	2.0000	200.000	0.5000	3.0000	1.0400	1.0300	14.3800	4.8000	1.9500	0.4063	2.8500
• 596:	2.0000	300.000	0.7500	3.1000	1.2400	1.1500	15.7000	4.4500	2.0000	0.4494	2.4500
• 597:	2.0000	400.000	1.7500	3.8000	1.2800	1.3800	17.5300	3.6800	1.5000	0.4076	2.1800
• 598:	2.0000	500.000	1.2500	2.9000	1.5600	1.2400	16.5000	4.1500	1.7800	0.4289	2.3700
• 599:	2.0000	600.000	1.7500	3.3000	1.4900	1.5200	18.1700	3.3500	1.4200	0.4239	1.9300
• 600:	2.0000	700.000	2.7500	3.8000	1.6800	1.9000	17.5400	3.8000	1.6200	0.4263	2.1800
• 601:	2.0000	800.000	3.2500	4.6000	1.9000	1.8200	17.0400	3.9700	1.8700	0.4710	2.1000
• 602:	2.0000	900.000	3.7500	4.0000	1.8700	2.1100	19.5500	3.3400	1.5000	0.4491	1.8400
• 603:	2.0000	1000.00	4.0000	4.8000	2.3200	2.3700	19.6200	3.3600	1.5000	0.4464	1.8600
• 604:	2.0000	1100.00	4.5000	5.5000	2.5300	2.3800	19.0400	3.1400	1.4600	0.4650	1.6800
• 605:	2.0000	1200.00	5.2500	6.2000	2.7700	2.6700	17.9300	3.1000	1.3700	0.4419	1.7300
• 606:	2.0000	1300.00	5.7500	6.5000	2.5900	2.7900	21.1100	2.8900	1.2800	0.4429	1.6100
• 607:	2.0000	1400.00	6.7500	7.3000	2.8300	3.0900	20.4400	2.9600	1.3400	0.4527	1.6200
• 608:	2.0000	1500.00	7.2500	9.1000	3.0800	3.4600	22.8100	2.6600	1.4000	0.5263	1.2600
• 609:	2.0000	1600.00	8.2500	11.1000	3.3300	4.0300	23.8000	2.3200	1.0300	0.4440	1.2900
• 610:	2.0000	1700.00	9.0000	10.9000	3.3800	4.2100	27.4500	2.2500	0.9600	0.4267	1.2900
• 611:	2.0000	1800.00	10.0000	16.3000	3.4800	5.6600	32.3400	1.7100	0.8000	0.4678	0.9100
• 612:	2.0000	1900.00	10.0000	15.8000	3.3800	5.7200	39.7000	1.4300	0.7000	0.4895	0.7300

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 593:	2.0000	0.0000	20.8600	0.6500	8.3500	0.2600	0.3500	40.0000	26.8000	97.0000	66.0000
• 594:	2.0000	100.000	31.3000	1.1400	18.0500	0.6000	0.8600	40.0000	29.0000	97.0000	78.0000
• 595:	2.0000	200.000	34.0600	1.4300	14.9500	0.5500	0.7500	42.0000	31.8000	97.0000	84.0000
• 596:	2.0000	300.000	25.7300	1.6300	19.5000	0.7500	1.0400	42.0000	33.2000	96.0000	84.0000
• 597:	2.0000	400.000	32.7700	1.4500	22.4300	0.8700	1.1300	43.0000	33.2000	96.0000	90.0000
• 598:	2.0000	500.000	30.6800	1.5800	25.6500	1.0100	1.3300	44.0000	33.9000	97.0000	90.0000
• 599:	2.0000	600.000	44.5400	1.5200	27.0300	1.0900	1.3200	44.0000	34.6000	97.0000	96.0000
• 600:	2.0000	700.000	47.0700	1.8800	29.3800	1.2100	1.3900	44.0000	35.3000	97.0000	102.000
• 601:	2.0000	800.000	57.9000	2.4700	32.3800	1.3700	1.5700	45.0000	38.8000	97.0000	102.000
• 602:	2.0000	900.000	58.4800	2.3200	36.5500	1.6000	1.8200	46.0000	37.4000	97.0000	120.000
• 603:	2.0000	1000.00	73.7900	2.5400	45.4800	1.9600	2.0500	46.0000	36.7000	97.0000	120.000
• 604:	2.0000	1100.00	79.3800	2.5000	48.1300	2.0800	2.1500	46.0000	36.7000	97.0000	120.000
• 605:	2.0000	1200.00	102.730	2.8000	49.6800	2.1700	2.2000	45.0000	37.2000	96.0000	120.000
• 606:	2.0000	1300.00	105.730	2.5400	54.5800	2.3400	2.3500	46.0000	38.1000	96.0000	126.000
• 607:	2.0000	1400.00	112.860	2.9900	57.8500	2.4600	2.4200	44.0000	36.7000	96.0000	138.000
• 608:	2.0000	1500.00	161.580	3.1800	70.3300	2.8600	2.6900	44.0000	36.0000	97.0000	144.000
• 609:	2.0000	1600.00	226.570	3.3100	79.1300	3.1500	2.8900	43.0000	34.6000	97.0000	150.000
• 610:	2.0000	1700.00	191.750	3.1100	92.7000	3.4800	3.1400	44.0000	33.9000	97.0000	156.000
• 611:	2.0000	1800.00	340.600	3.4000	112.340	3.9500	3.4600	42.0000	31.8000	97.0000	168.000
• 612:	2.0000	1900.00	344.160	2.9000	134.250	4.5300	3.7200	40.0000	29.7000	97.0000	174.000

Tab 7.3.2.8 Individual data of subject 2, C2.

Dflag	CODE	KPM	cor Berg	P-MOUTH	Vt	V̇I	FB	TTOT	TI	Ti/Ttot	TE
	1	4	29	20	21	8	7	5	19	25	28
• 39:	3.0000	0.0000	0.0000	1.4000	0.9500	0.9000	11.8100	4.9000	1.4000	0.2857	3.5000
• 40:	3.0000	100.000	0.0000	3.0000	1.1200	0.9300	17.4000	5.4000	2.4000	0.4444	3.0000
• 41:	3.0000	200.000	1.0000	2.6000	1.3900	0.9200	10.0100	4.9000	2.4000	0.4898	2.5000
• 42:	3.0000	300.000	1.0000	2.5000	1.3400	1.1000	12.0600	3.0200	1.2000	0.3974	1.8200
• 43:	3.0000	400.000	1.0000	2.6000	1.6700	1.3000	12.1000	4.1000	1.8000	0.4390	2.3000
• 44:	3.0000	500.000	1.7500	3.4000	1.7400	1.3000	13.2900	4.7000	2.7000	0.4681	2.5000
• 45:	3.0000	600.000	1.7500	2.5000	2.0600	1.6000	17.8100	5.1000	2.6000	0.5098	2.5000
• 46:	3.0000	700.000	1.7500	3.2000	1.9500	1.7000	15.5000	4.6000	2.1000	0.4565	2.5000
• 47:	3.0000	800.000	2.7500	3.6000	2.2000	1.7000	14.9700	4.4000	2.1000	0.4773	2.3000
• 48:	3.0000	900.000	3.7500	3.9000	2.7100	2.1000	14.1200	3.6000	1.7000	0.4772	1.9000
• 49:	3.0000	1000.00	3.7500	4.1000	2.3900	2.3000	18.6400	3.4000	1.5000	0.4412	1.9000
• 50:	3.0000	1100.00	4.5000	5.0000	2.5500	2.6000	18.8900	3.1000	1.4000	0.4516	1.7000
• 51:	3.0000	1200.00	4.5000	5.6000	2.4200	2.8000	22.7300	2.8000	1.3000	0.4643	1.5000
• 52:	3.0000	1300.00	6.2500	6.1000	2.5600	3.2000	23.1900	2.2000	1.0000	0.4545	1.2000
• 53:	3.0000	1400.00	7.2500	6.9000	2.5200	3.5000	26.9200	2.2000	1.1000	0.5000	1.1000
• 54:	3.0000	1500.00	7.2500	7.3000	2.4800	3.6000	29.2100	2.1000	0.9300	0.4429	1.1700
• 55:	3.0000	1600.00	8.2500	8.7000	2.7600	3.8000	28.0000	2.2000	0.9600	0.4364	1.2400
• 56:	3.0000	1700.00	9.0000	8.9000	2.7400	4.3000	31.4000	1.7800	0.8300	0.4663	0.9500

Dflag	CODE	KPM	P*TIME	Vt	V̇E	V̇CO2	V̇O2	PETCO2	PECO2	SAO2	HR
	1	4	22	6	9	13	14	11	36	17	18
• 39:	3.0000	0.0000	4.8200	1.1000	11.1900	0.3400	0.4700	34.0000	24.8000	96.0000	84.0000
• 40:	3.0000	100.000	6.1200	1.5000	13.9500	0.4700	0.4200	38.0000	29.8000	97.0000	90.0000
• 41:	3.0000	200.000	6.4000	1.6000	13.9500	0.5100	0.4600	40.0000	31.9000	97.0000	78.0000
• 42:	3.0000	300.000	4.3000	1.3000	16.1800	0.5900	0.8000	39.0000	31.8000	97.0000	84.0000
• 43:	3.0000	400.000	39.2000	1.9000	20.3800	0.7900	1.0400	42.0000	34.0000	97.0000	96.0000
• 44:	3.0000	500.000	45.9000	2.0000	23.1000	0.9100	1.1400	40.0000	34.7000	96.0000	96.0000
• 45:	3.0000	600.000	30.6000	2.5000	26.3500	1.0600	1.2500	40.0000	35.4000	97.0000	108.000
• 46:	3.0000	700.000	40.0000	2.3000	30.1500	1.2200	1.4100	42.0000	35.1000	96.0000	108.000
• 47:	3.0000	800.000	37.7000	2.7000	34.0800	1.4300	1.6000	44.0000	37.6000	97.0000	120.000
• 48:	3.0000	900.000	58.3000	3.1000	38.2000	1.6500	1.8000	44.0000	36.9000	96.0000	120.000
• 49:	3.0000	1000.00	81.6000	2.9000	44.6500	1.8800	1.9700	44.0000	36.5000	97.0000	138.000
• 50:	3.0000	1100.00	80.3000	2.9000	48.1800	2.0200	2.0900	45.0000	36.2000	96.0000	144.000
• 51:	3.0000	1200.00	87.4000	2.8000	55.0500	2.2800	2.3100	44.0000	36.2000	0.9700	150.000
• 52:	3.0000	1300.00	112.100	2.5000	59.3000	2.4600	2.4900	44.0000	35.2000	97.0000	142.000
• 53:	3.0000	1400.00	112.300	2.8000	67.7300	2.7300	2.6700	42.0000	34.5000	96.0000	168.000
• 54:	3.0000	1500.00	119.400	2.8000	72.5000	2.8900	2.8200	44.0000	34.3000	96.0000	174.000
• 55:	3.0000	1600.00	153.000	3.0000	77.3500	3.0800	2.9600	42.0000	34.3000	96.0000	180.000
• 56:	3.0000	1700.00	213.400	2.8000	85.9300	3.3200	3.1200	42.0000	33.3000	96.0000	180.000

Tab 7.3.3.1 Individual data of subject 3, Cl.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}I$ 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 143:	3.0000	0.0000	3.7500	12.3300	1.2300	0.4000	6.7500	8.2000	4.0300	0.4915	4.1700
♦ 144:	3.0000	100.000	5.5000	16.0000	1.4500	0.5000	7.7400	7.5000	4.3000	0.5733	3.2000
♦ 145:	3.0000	200.000	5.5000	19.0000	1.6100	0.6000	7.8400	7.8000	3.6000	0.4615	4.2000
♦ 146:	3.0000	300.000	6.2500	26.0000	2.5300	0.9000	5.3800	11.0000	5.5000	0.5000	5.5000
♦ 147:	3.0000	400.000	8.2500	34.0000	2.1000	1.3000	9.4500	7.2000	3.5000	0.4861	3.7000
♦ 148:	3.0000	500.000	8.2500	36.3000	1.2200	1.3000	17.2100	4.8000	3.0000	0.6250	1.8000
♦ 149:	3.0000	600.000	8.2500	42.0000	2.0200	1.4000	13.1500	4.0000	2.1000	0.5250	1.9000
♦ 150:	3.0000	700.000	9.0000	41.0000	2.2000	1.3500	13.0200	5.7000	3.2000	0.5614	2.5000
♦ 151:	3.0000	800.000	10.0000	50.0000	2.6400	1.6300	12.0800	4.3000	2.4000	0.5581	1.9000
♦ 152:	3.0000	900.000	10.0000	54.5000	2.4400	1.8700	14.4500	4.4000	2.8500	0.6477	1.5500
♦ 153:	3.0000	1000.00	10.0000	46.6700	3.0800	1.5000	12.8500	3.8000	2.6000	0.6842	1.2000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}E$ 9	$\dot{V}CO2$ 13	$\dot{V}O2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 143:	3.0000	0.0000	279.700	1.1000	8.3100	0.2800	0.3500	31.0000	29.0000	96.0000	72.0000
♦ 144:	3.0000	100.000	428.500	1.5000	11.2000	0.4300	0.5500	36.0000	33.4000	96.0000	78.0000
♦ 145:	3.0000	200.000	312.800	1.0000	12.6500	0.5100	0.7500	36.0000	33.0000	96.0000	90.0000
♦ 146:	3.0000	300.000	513.600	2.5000	13.6300	0.5900	0.8700	44.0000	36.9000	95.0000	96.0000
♦ 147:	3.0000	400.000	734.300	2.1000	19.8500	0.8400	1.1300	44.0000	37.6000	96.0000	102.000
♦ 148:	3.0000	500.000	1209.90	1.9000	21.0600	0.9200	1.2900	47.0000	39.1000	95.0000	108.000
♦ 149:	3.0000	600.000	963.400	1.9000	26.5700	1.2000	1.4900	46.0000	39.1000	95.0000	108.000
♦ 150:	3.0000	700.000	1301.70	2.6000	28.5800	1.3200	1.5700	48.0000	40.5000	95.0000	126.000
♦ 151:	3.0000	800.000	1188.70	2.4000	31.9380	1.5400	1.7500	49.0000	41.9000	95.0000	138.000
♦ 152:	3.0000	900.000	1875.00	3.0000	37.6300	1.8000	1.9700	48.0000	41.2000	94.0000	138.000
♦ 153:	3.0000	1000.00	1207.50	2.1000	39.5300	1.9700	2.1100	51.0000	43.5000	93.0000	144.000

Tab 7.3.3.2 Individual data of subject 3, R1.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 28	Vt 21	$\dot{V}$I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 216:	3.0000	0.0000	1.7500	20.9000	0.9300	0.4700	8.5700	7.0000	3.9600	0.5077	3.8400
♦ 217:	3.0000	100.000	1.7500	29.3000	0.9500	0.5800	10.8100	5.0200	2.0000	0.3984	3.0200
♦ 218:	3.0000	200.000	1.7500	32.4000	1.2000	0.6000	10.8400	5.4000	2.6000	0.4815	2.8000
♦ 219:	3.0000	300.000	2.7500	38.6300	1.4300	0.7500	10.1600	5.8000	3.1000	0.5345	2.7000
♦ 220:	3.0000	400.000	4.5000	45.3200	1.6200	0.9200	10.5700	5.4500	2.9700	0.5450	2.4800
♦ 221:	3.0000	500.000	5.5000	38.1000	2.1100	0.6300	7.9900	8.2000	5.2000	0.6341	3.0000
♦ 222:	3.0000	600.000	7.2500	48.3300	2.0800	0.9000	9.0200	6.4000	4.3000	0.6719	2.1000
♦ 223:	3.0000	700.000	6.2500	47.0000	2.4600	0.6300	8.9900	7.3000	4.9000	0.6712	2.4000
♦ 224:	3.0000	800.000	8.2500	63.2400	2.4500	1.2000	11.1200	5.1000	3.4000	0.6667	1.7000
♦ 225:	3.0000	900.000	10.0000	67.8300	2.5500	1.2000	13.1400	4.0000	3.1000	0.7750	0.9000
♦ 226:	3.0000	1000.00	10.0000	67.4200	1.9500	1.1800	13.8000	3.7000	2.7000	0.7297	1.0000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}CO_2$ 13	$\dot{V}O_2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 216:	3.0000	0.0000	408.800	0.9700	7.9000	0.2900	0.3500	37.0000	32.6000	97.0000	66.0000
♦ 217:	3.0000	100.000	497.900	0.6700	10.3000	0.4200	0.5300	40.0000	35.5000	95.0000	90.0000
♦ 218:	3.0000	200.000	667.300	1.0000	12.9800	0.5500	0.7500	42.0000	36.7000	93.0000	96.0000
♦ 219:	3.0000	300.000	702.600	1.1000	14.5300	0.6500	0.9200	45.0000	38.3000	94.0000	107.000
♦ 220:	3.0000	400.000	1030.70	1.3300	17.1500	0.8000	1.1000	46.0000	40.4000	94.0000	108.000
♦ 221:	3.0000	500.000	906.700	1.9700	16.8300	0.8400	1.1300	48.0000	43.0000	93.0000	114.000
♦ 222:	3.0000	600.000	1098.30	1.7800	18.7300	1.0000	1.3400	50.0000	45.0000	93.0000	126.000
♦ 223:	3.0000	700.000	1195.80	2.2000	22.0800	1.2000	1.4700	50.0000	44.0000	92.0000	176.000
♦ 224:	3.0000	800.000	1677.30	2.1500	27.2000	1.5000	1.7500	52.0000	46.0000	93.0000	138.000
♦ 225:	3.0000	900.000	2141.20	1.9400	33.5000	1.8200	1.9700	50.0000	44.0000	92.0000	138.000
♦ 226:	3.0000	1000.00	2141.20	1.9300	26.6000	1.8200	1.8000	51.0000	46.0000	92.0000	150.000

Tab 7.3.3.3 Individual data of subject 3, R2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 274:	3.0000	0.0000	2.2500	20.3000	0.8600	0.5000	8.1000	7.0000	3.6000	0.5143	3.4000
• 275:	3.0000	100.000	2.7500	30.2000	1.0800	0.6000	9.8000	6.5000	3.7000	0.5692	2.8000
• 276:	3.0000	200.000	3.2500	32.9000	1.0800	0.7000	11.2000	5.9000	4.0000	0.6780	1.9000
• 277:	3.0000	300.000	3.7500	35.1000	1.7000	0.7000	8.3000	7.7000	4.8000	0.6234	2.9000
• 278:	3.0000	400.000	4.5000	44.5000	1.3300	0.8000	11.1000	6.6000	4.4000	0.6667	2.2000
• 279:	3.0000	500.000	6.2500	54.9000	1.5400	1.0000	12.1000	4.1000	2.7000	0.6585	1.4000
• 280:	3.0000	600.000	8.2500	55.6000	2.0300	1.0000	10.9000	6.7000	4.6000	0.6866	2.1000
• 281:	3.0000	700.000	10.0000	59.8000	2.3400	1.0000	9.0000	5.4000	3.7000	0.6852	1.7000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 274:	3.0000	0.0000	472.400	0.7000	6.9600	0.2500	0.3200	40.0000	32.4000	96.0000	66.0000
• 275:	3.0000	100.000	642.000	0.9000	10.6000	0.4300	0.5600	42.0000	36.2000	96.0000	84.0000
• 276:	3.0000	200.000	929.800	1.3000	12.0000	0.5300	0.7600	44.0000	38.3000	96.0000	90.0000
• 277:	3.0000	300.000	1067.20	1.6000	14.1000	0.6600	0.9800	47.0000	40.5000	95.0000	102.000
• 278:	3.0000	400.000	13203.0	1.7000	14.8000	0.7400	1.0700	48.0000	44.0000	95.0000	108,000
• 279:	3.0000	500.000	1588.10	1.4000	18.6000	0.9600	1.2600	48.0000	44.7000	95.0000	114.000
• 280:	3.0000	600.000	1797.60	2.1000	22.1000	1.1700	1.4600	50.0000	46.2000	94.0000	120.000
• 281:	3.0000	700.000	1945.30	2.1000	21.2000	1.1800	1.4900	50.0000	48.3000	92.0000	126.000

Tab 7.3.3.4 Individual data of subject 3, R3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
+ 345:	3.0000	0.0000	1.5000	17.3000	0.9200	0.9900	7.6000	8.3700	2.4000	0.2867	5.9700
+ 346:	3.0000	100.000	2.2500	21.0000	0.9300	1.4700	11.8300	5.3500	1.5000	0.2804	3.8500
+ 347:	3.0000	200.000	3.2500	26.7000	1.3300	1.9000	10.6300	5.2500	1.4500	0.2762	3.8000
+ 348:	3.0000	300.000	3.5000	27.8000	1.6100	1.7500	9.2800	6.0000	1.7000	0.2833	4.3000
+ 349:	3.0000	400.000	4.2500	29.6000	1.3900	1.9800	10.2000	3.6700	1.2500	0.3406	2.4200
+ 350:	3.0000	500.000	4.2500	30.0000	1.4800	1.9800	15.8000	2.9600	1.1800	0.3986	1.7800
+ 351:	3.0000	600.000	4.7500	28.5000	1.2300	1.8800	20.2800	3.3500	1.2800	0.3821	2.0700
+ 352:	3.0000	700.000	4.7500	30.9000	1.5200	2.2000	17.1300	3.2000	1.2000	0.3750	2.0000
+ 353:	3.0000	800.000	5.2500	30.1000	1.4400	2.0200	20.3300	2.9000	1.2800	0.4414	1.6200
+ 354:	3.0000	900.000	8.0000	29.7000	1.6300	2.2400	22.1800	2.6200	1.1200	0.4275	1.5000
+ 355:	3.0000	1000.00	8.0000	31.3000	1.5300	2.5400	27.4500	2.4400	1.1000	0.4508	1.3400
+ 356:	3.0000	1100.00	9.0000	31.4000	1.6600	2.6400	28.5000	2.1200	0.9900	0.4670	1.1300
+ 357:	3.0000	1200.00	9.0000	35.9000	1.7900	2.7300	27.3300	2.4200	1.0600	0.4380	1.3600
+ 358:	3.0000	1300.00	9.0000	35.3000	1.8400	2.8500	28.7800	1.8000	0.8800	0.4889	0.9200
+ 359:	3.0000	1400.00	10.0000	51.6000	1.9600	2.5700	27.6300	2.4700	0.9300	0.3765	1.5400

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
+ 345:	3.0000	0.0000	369.100	1.0300	6.9800	0.2700	0.3200	40.0000	33.4000	96.0000	66.0000
+ 346:	3.0000	100.000	377.400	1.3700	10.5000	0.4400	0.5600	44.0000	36.0000	95.0000	84.0000
+ 347:	3.0000	200.000	502.800	1.5500	13.5500	0.6100	0.7900	48.0000	38.8000	94.0000	90.0000
+ 348:	3.0000	300.000	696.000	1.7000	15.0300	0.7200	0.9700	50.0000	41.0000	94.0000	90.0000
+ 349:	3.0000	400.000	654.100	1.4500	17.6900	1.0200	1.1900	45.0000	38.0000	94.0000	96.0000
+ 350:	3.0000	500.000	551.400	1.3400	23.0800	1.0800	1.2500	50.0000	40.5000	94.0000	108.000
+ 351:	3.0000	600.000	683.000	1.5000	26.2300	1.1800	1.2900	50.0000	38.8000	95.0000	102.000
+ 352:	3.0000	700.000	637.200	1.6500	26.1000	1.2500	1.3900	49.0000	41.0000	94.0000	108.000
+ 353:	3.0000	800.000	715.600	1.6400	30.7800	1.4600	1.5800	50.0000	41.7000	94.0000	120.000
+ 354:	3.0000	900.000	756.300	1.6600	36.1200	1.7300	1.7800	57.0000	41.3000	93.0000	137.000
+ 355:	3.0000	1000.00	875.700	1.6000	41.5300	1.9600	1.9500	51.0000	41.0000	94.0000	138.000
+ 356:	3.0000	1100.00	775.200	1.6100	47.1300	2.1000	2.0700	50.0000	40.2000	94.0000	138.000
+ 357:	3.0000	1200.00	912.800	1.7300	49.0000	2.3000	2.1900	50.0000	41.0000	93.0000	150.000
+ 358:	3.0000	1300.00	774.200	1.6800	53.0300	2.4500	2.3900	51.0000	41.0000	92.0000	150.000
+ 359:	3.0000	1400.00	1072.00	1.5000	53.9000	2.4000	2.3700	56.0000	41.7000	90.0000	156.000

Tab 7.3.3.5 Individual data of subject 3, El.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
+ 441:	3.0000	0.0000	2.2500	24.5300	0.5600	0.8300	10.3400	4.7000	1.3000	0.2766	3.4000
+ 442:	3.0000	100.000	2.7500	31.4800	0.6300	1.0600	13.8800	3.5000	1.1000	0.3143	2.4000
+ 443:	3.0000	200.000	2.7500	41.4300	0.7800	1.3600	15.0600	3.6000	1.1000	0.3056	2.5000
+ 444:	3.0000	300.000	3.7500	40.2000	0.8500	1.4500	16.3900	3.5000	1.1000	0.3143	2.4000
+ 445:	3.0000	400.000	4.5000	47.3800	0.9300	1.5800	16.9200	3.7000	1.1000	0.2973	2.6000
+ 446:	3.0000	500.000	5.5000	41.2100	0.9200	1.4500	20.0200	2.9800	1.1000	0.3691	1.8800
+ 447:	3.0000	600.000	5.5000	39.9000	0.8200	1.7200	24.2700	2.2000	0.8000	0.3636	1.4000
+ 448:	3.0000	700.000	5.5000	46.7000	0.9500	1.9100	24.9300	2.5000	0.9000	0.3600	1.6000
+ 449:	3.0000	800.000	6.2500	48.1400	1.0900	1.8300	27.7600	2.3000	0.8700	0.3783	1.4300
+ 450:	3.0000	900.000	7.7500	52.4000	1.0900	2.0000	27.7000	2.2000	0.9000	0.4091	1.3000
+ 451:	3.0000	1000.00	9.5000	55.5800	1.2800	2.2900	28.2500	2.0000	0.8800	0.4400	1.1200
* 452:	3.0000	1100.00	10.0000	56.9100	1.3000	2.4800	28.2500	1.7000	0.7700	0.4529	0.9300

Dflag	CODE 1	KPM 4	P*TIME 22	VI 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
+ 441:	3.0000	0.0000	634.600	0.5800	5.8200	0.2800	0.3600	40.0000	38.0000	95.0000	84.0000
+ 442:	3.0000	100.000	604.300	0.7600	8.6300	0.4300	0.5700	44.0000	40.0000	93.0000	102.000
+ 443:	3.0000	200.000	948.800	0.9400	11.6800	0.6100	0.8400	46.0000	41.0000	93.0000	90.0000
+ 444:	3.0000	300.000	864.480	0.9800	13.8500	0.7400	0.9800	45.0000	40.0000	94.0000	108.000
+ 445:	3.0000	400.000	897.600	1.1200	15.6500	0.8800	0.9800	45.0000	39.0000	94.0000	120.000
+ 446:	3.0000	500.000	932.100	0.9600	18.4300	1.0700	1.7700	46.0000	40.2000	93.0000	120.000
+ 447:	3.0000	600.000	950.200	0.9600	19.9000	1.1400	1.3800	50.0000	43.5000	92.0000	126.000
+ 448:	3.0000	700.000	1113.30	1.0900	23.6300	1.3400	1.5100	50.0000	44.0000	92.0000	137.000
+ 449:	3.0000	800.000	1098.00	1.1100	30.1200	1.5600	1.6800	50.0000	43.8000	94.0000	144.000
+ 450:	3.0000	900.000	1224.70	1.7100	30.0500	1.7700	1.9000	54.0000	46.0000	92.0000	150.000
+ 451:	3.0000	1000.80	1393.30	1.3400	35.8500	2.1400	2.1700	54.0000	49.0000	92.0000	150.000
* 457:	3.0000	1100.00	1386.00	1.2900	36.4000	2.1400	2.1000	51.0000	43.8000	93.0000	156.000

Tab 7.3.3.6 Individual data of subject 3, E2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TF 28
♦ 524:	3.0000	0.0000	3.7500	29.2100	0.6400	0.5900	12.3400	4.2300	1.1700	0.2766	3.0400
♦ 525:	3.0000	100.000	3.7500	44.1200	0.7600	0.8000	14.9300	4.0300	1.1300	0.2804	2.9000
♦ 526:	3.0000	200.000	4.5000	44.6600	0.8200	0.9000	16.1500	3.4000	1.0000	0.2941	2.4000
♦ 527:	3.0000	300.000	4.5000	49.4300	0.7700	0.9400	19.1300	3.7300	1.1800	0.3164	2.5500
♦ 528:	3.0000	400.000	4.5000	45.9500	0.8800	1.2500	19.9700	2.3800	0.8400	0.3529	1.5400
♦ 529:	3.0000	500.000	6.2500	57.4900	0.9800	1.5500	20.5400	2.8600	0.8800	0.3077	1.9800
♦ 530:	3.0000	600.000	7.2500	56.9900	1.0500	1.4700	21.3500	2.5800	0.9000	0.3488	1.6800
♦ 531:	3.0000	700.000	8.2500	67.2600	1.1200	1.7300	23.8300	2.1700	0.8800	0.4055	1.2900
♦ 532:	3.0000	800.000	8.7500	64.7800	1.3700	1.4900	24.5100	2.5800	1.0600	0.4109	1.5200
♦ 533:	3.0000	900.000	10.0000	68.7800	1.3600	1.5900	27.7200	1.9600	0.9000	0.4592	1.0600
▪ 534:	3.0000	1000.00	10.0000	68.8000	1.3800	1.9700	27.7000	1.6800	0.7800	0.4643	0.9000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 524:	3.0000	0.0000	602.800	0.4000	7.8700	0.2900	0.3700	42.0000	32.5000	96.0000	66.0000
♦ 525:	3.0000	100.000	704.000	0.6100	11.3200	0.4500	0.6100	43.0000	34.6000	96.0000	90.0000
♦ 526:	3.0000	200.000	1152.60	0.6800	13.2000	0.5400	0.7400	46.0000	35.7000	96.0000	90.0000
♦ 527:	3.0000	300.000	1051.00	0.6400	14.7800	0.6300	0.8200	46.0000	37.5000	95.0000	90.0000
♦ 528:	3.0000	400.000	1087.50	0.5400	17.5800	0.7810	1.0000	47.0000	38.9000	96.0000	96.0000
♦ 529:	3.0000	500.000	1372.40	0.8400	20.0300	0.9100	1.1200	48.0000	39.2000	94.0000	108.000
♦ 530:	3.0000	600.000	1579.40	0.7700	22.4800	1.0400	1.2000	50.0000	39.6000	95.0000	90.0000
♦ 531:	3.0000	700.000	1927.40	0.8900	26.7500	1.2600	1.4400	50.0000	41.0000	93.0000	114.000
♦ 532:	3.0000	800.000	1944.90	0.9300	33.4500	1.6300	1.7500	52.0000	42.1000	93.0000	132.000
♦ 533:	3.0000	900.000	1442.90	0.9900	37.8300	1.9300	2.0100	52.0000	43.8000	93.0000	138.000
▪ 534:	3.0000	[illegible]00.00	1901.10	1.0300	28.5300	1.9300	1.8500	52.0000	44.5000	91.0000	144.000

Tab 7.3.3.7 Individual data of subject 3, E3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 613:	3.0000	0.0000	0.0000	2.8900	0.7000	1.1600	11.6500	2.9900	0.9900	0.3311	2.0000
• 614:	3.0000	100.000	0.0000	2.2500	0.9500	1.3300	17.2000	4.7400	1.6600	0.3502	3.0800
• 615:	3.0000	200.000	0.0000	3.2000	1.0700	1.6000	14.8200	3.6200	1.2800	0.3536	2.3400
• 616:	3.0000	300.000	0.5000	3.0800	1.5900	1.4800	11.7800	4.8800	2.2200	0.4549	2.6600
• 617:	3.0000	400.000	0.5000	3.0300	1.3800	1.5000	16.8100	4.8500	2.1000	0.4330	2.7500
• 618:	3.0000	500.000	0.5000	3.0800	1.7700	1.7300	14.4100	4.8500	2.3800	0.4907	2.4700
• 619:	3.0000	600.000	1.0000	3.2300	1.9100	2.0100	14.1600	4.1800	1.8800	0.4498	2.3000
• 620:	3.0000	700.000	1.0000	3.9000	2.1600	2.1300	14.5700	4.2000	2.0800	0.4952	2.1200
• 621:	3.0000	800.000	1.7500	3.7300	1.9100	2.3200	18.8900	3.3000	1.4900	0.4515	1.8100
• 622:	3.0000	900.000	2.7500	5.0000	2.1400	2.7500	20.8700	2.6200	1.3200	0.5038	1.3000
• 623:	3.0000	1000.00	2.7500	5.4400	2.2600	2.9100	21.5200	2.9200	1.3800	0.4726	1.5400
• 624:	3.0000	1100.00	2.7500	6.1900	2.2800	3.0800	22.2500	2.7000	1.2000	0.4444	1.5000
• 625:	3.0000	1200.00	2.7500	6.1100	2.2900	3.2700	24.1700	2.4000	1.0700	0.4458	1.3300
• 626:	3.0000	1300.00	3.2500	5.8600	2.3000	3.2700	22.8000	2.5700	1.2000	0.4669	1.3700
• 627:	3.0000	1400.00	3.7500	6.8300	2.3200	3.7000	27.9600	2.0800	1.0000	0.4808	1.0800
• 628:	3.0000	1500.00	4.5000	7.8900	2.4700	4.0600	29.3900	1.8700	0.8900	0.4759	0.9800
• 629:	3.0000	1600.00	6.2500	9.0400	2.6100	4.3300	30.3600	2.0100	0.9800	0.4876	1.0300
• 630:	3.0000	1700.00	7.2500	10.4100	2.4300	4.6800	34.4000	1.7800	0.8000	0.4494	0.9800

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 613:	3.0000	0.0000	16.2900	0.6100	8.1800	0.2700	0.3400	37.0000	30.5000	96.0000	66.0000
• 614:	3.0000	100.000	17.5400	1.4000	11.5300	0.4100	0.5400	38.0000	30.5000	96.0000	72.0000
• 615:	3.0000	200.000	24.7800	1.5200	15.8300	0.5800	0.8000	38.0000	30.5000	95.0000	90.0000
• 616:	3.0000	300.000	23.5100	2.1000	18.7300	0.7300	1.0500	40.0000	34.1000	95.0000	90.0000
• 617:	3.0000	400.000	31.0900	2.3500	23.2000	0.8910	1.1700	40.0000	34.8000	95.0000	102.000
• 618:	3.0000	500.000	41.7100	2.5000	25.5000	1.0400	1.2900	41.0000	36.1000	95.0000	102.000
• 619:	3.0000	600.000	54.2900	2.6800	27.0500	1.1400	1.3900	41.0000	36.2000	95.0000	108.000
• 620:	3.0000	700.000	58.9700	2.6000	31.5000	1.3400	1.5500	42.0000	36.9000	95.0000	114.000
• 621:	3.0000	800.000	69.0900	2.7000	36.3000	1.5200	1.7300	44.0000	36.2000	95.0000	126.000
• 622:	3.0000	900.000	78.6200	2.5100	44.6000	1.8700	2.0400	44.0000	36.2000	96.0000	132.000
• 623:	3.0000	1000.00	80.7100	2.8500	48.5800	2.0500	2.1600	44.0000	36.2000	96.0000	144.000
• 624:	3.0000	1100.00	121.390	2.8600	50.6800	2.1600	2.2500	44.0000	36.9000	96.0000	144.000
• 625:	3.0000	1200.00	130.110	2.5200	55.3500	2.3400	2.3500	44.0000	34.8000	96.0000	138.000
• 626:	3.0000	1300.00	127.280	2.9700	52.5000	2.1500	2.1900	41.0000	34.8000	96.0000	150.000
• 627:	3.0000	1400.00	159.070	2.9900	64.8600	2.6000	2.6400	42.0000	34.8000	96.0000	174.000
• 628:	3.0000	1500.00	172.730	2.8900	72.7000	2.9100	2.8400	41.0000	34.1000	96.0000	168.000
• 629:	3.0000	1600.00	223.530	3.2900	79.3300	3.1400	3.0000	43.0000	34.1000	96.0000	174.000
• 630:	3.0000	1700.00	47.3600	3.0200	83.6000	3.3600	3.7000	43.0000	34.8000	93.0000	180.000

Tab 7.3.3.8 Individual data of subject 3, C2.

	CODE	KPM	cor Borg	P-MOUTH	Vt	VI	FB	TTOT	TI	Ti/Ttot	TE
D+lag	1	4	29	20	21	8	7	5	19	25	28
+ 58:	4.0000	0.0000	0.0000	2.0000	0.5500	0.7100	16.5500	3.4700	0.9700	0.2795	2.5000
+ 59:	4.0000	100.000	0.0000	2.0000	0.7000	0.6000	14.5000	4.0000	1.5000	0.3750	2.5000
+ 60:	4.0000	200.000	0.0000	2.0000	0.7400	1.0300	18.6900	3.6300	1.2700	0.3499	2.3600
+ 61:	4.0000	300.000	0.5000	2.7000	0.8400	1.3000	17.5000	3.6000	1.3500	0.3750	2.2500
+ 62:	4.0000	400.000	1.0000	2.3000	1.1600	1.1300	15.6700	5.2000	1.6000	0.3077	3.6000
+ 63:	4.0000	500.000	1.2500	2.6000	1.2000	1.3000	17.9800	4.3500	1.2500	0.2874	3.1000
+ 64:	4.0000	600.000	1.7500	3.0000	1.3400	1.3800	17.2400	3.2700	1.6000	0.4893	1.6700
+ 65:	4.0000	700.000	2.2500	3.0000	1.4500	1.6500	17.8300	3.4300	1.4000	0.4082	2.0300
+ 66:	4.0000	800.000	2.2500	3.0000	1.5600	1.6000	18.1400	3.5000	1.4000	0.4000	2.1000
+ 67:	4.0000	900.000	3.2500	3.7500	1.8100	1.8300	18.5400	3.5200	1.4000	0.3977	2.1200
+ 68:	4.0000	1000.00	3.5000	3.8000	2.0500	2.0400	16.9700	3.4000	1.5000	0.4412	1.9000
+ 69:	4.0000	1100.00	3.7500	3.8000	1.8400	2.1000	21.6000	3.0000	1.2800	0.4267	1.7200
+ 70:	4.0000	1200.00	3.7500	4.0000	2.1300	2.2500	18.7800	3.1500	1.4800	0.4698	1.6700
+ 71:	4.0000	1300.00	5.0000	4.6000	2.1900	2.4000	18.7400	2.7500	1.4300	0.5200	1.3200
+ 72:	4.0000	1400.00	7.7500	5.8000	2.2400	2.8000	20.5100	2.6500	1.2000	0.4528	1.4500
+ 73:	4.0000	1500.00	7.7500	6.6700	1.9900	2.8500	25.1200	2.5300	1.2000	0.4743	1.3300
+ 74:	4.0000	1600.00	8.2500	8.0700	2.0100	3.4400	26.3300	2.1600	0.9600	0.4444	1.2000
+ 75:	4.0000	1700.00	8.7500	9.8800	2.1700	3.9400	28.8000	1.7800	0.8300	0.4663	0.9500
+ 76:	4.0000	1800.00	9.5000	10.3000	2.2000	3.8200	29.0000	1.4000	0.6800	0.4857	0.7200

	CODE	KPM	P*TIME	Vt	V̇E	V̇CO2	V̇O2	PETCO2	PECO2	SAO2	HR
D+lag	1	4	22	6	9	13	14	11	36	12	10
+ 58:	4.0000	0.0000	0.0000	0.5300	9.1000	0.3000	0.3900	38.0000	30.6000	96.0000	88.0000
+ 59:	4.0000	100.000	14.6000	0.3500	10.1500	0.5900	0.8400	42.0000	32.7000	96.0000	114.000
+ 60:	4.0000	200.000	0.0000	0.9100	13.8300	0.5900	0.8400	43.0000	34.5000	95.0000	100.000
+ 61:	4.0000	300.000	25.1000	1.5000	14.7000	0.6500	0.9000	44.0000	34.8000	95.0000	100.000
+ 62:	4.0000	400.000	0.0000	1.6000	18.1800	0.7600	1.0100	44.0000	37.7000	95.0000	104.000
+ 63:	4.0000	500.000	14.6000	1.4800	21.5800	0.9200	1.1700	47.0000	37.7000	96.0000	115.000
+ 64:	4.0000	600.000	17.6000	1.2500	23.1000	1.0400	1.2600	45.0000	39.1000	96.0000	120.000
+ 65:	4.0000	700.000	44.4000	1.7500	25.8500	1.1400	1.3700	48.0000	39.8000	97.0000	128.000
+ 66:	4.0000	800.000	27.6000	1.7000	28.3000	1.3300	1.5700	47.0000	41.2000	96.0000	136.000
+ 67:	4.0000	900.000	49.3000	1.9400	33.5500	1.6700	1.8600	48.0000	40.9000	96.0000	137.000
+ 68:	4.0000	1000.00	66.6000	2.1300	34.6800	1.6400	1.8200	48.8000	42.0000	95.0000	144.000
+ 69:	4.0000	1100.00	56.1000	2.1400	39.7500	1.9800	2.1600	50.0000	42.0000	96.0000	150.000
+ 70:	4.0000	1200.00	93.2000	2.3900	40.0000	2.0700	2.1700	50.5000	42.5000	96.0000	163.000
+ 71:	4.0000	1300.00	96.9000	2.3100	41.0300	2.2000	2.3600	49.6000	42.5000	95.0000	164.000
+ 72:	4.0000	1400.00	80.9000	2.3900	45.9400	2.4800	2.5400	50.2000	42.6000	96.0000	167.000
+ 73:	4.0000	1500.00	115.400	2.4600	49.9800	2.6700	2.6600	49.9000	43.3000	95.0000	176.000
+ 74:	4.0000	1600.00	115.300	2.4900	52.9300	2.7600	2.6900	49.5000	43.7000	95.0000	188.000
+ 75:	4.0000	1700.00	188.600	2.4200	62.5000	3.2900	2.9200	48.0000	41.2000	95.0000	188.000
+ 76:	4.0000	1800.00	146.600	2.3200	62.5000	3.2900	2.9200	45.4000	38.4000	94.0000	188.000

Tab 7.3.4.1 Individual data of subject 4, Cl.

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	CODE	KPM	cor Borg	P-MOUTH	Vt	V̇I	FB	TTOT	TI	Ti/Ttot	TE
Dflag.	1	4	29	20	21	8	7	5	19	25	28
• 154:	4.0000	0.0000	1.7500	10.0000	0.8700	0.3500	8.6600	7.7000	3.2000	0.4156	4.5000
• 155:	4.0000	100.000	1.7500	22.5000	1.0800	0.7500	10.2100	12.8000	6.1000	0.4766	6.7000
• 156:	4.0000	200.000	2.0000	19.4000	1.0800	0.5000	10.6400	8.7000	4.5000	0.5172	4.2000
• 157:	4.0000	300.000	2.2500	25.0000	1.4700	0.7300	9.7400	8.8000	5.2000	0.5909	3.6000
• 158:	4.0000	400.000	2.7500	27.1000	1.1800	0.8500	13.6700	7.1000	3.5000	0.4930	3.6000
• 159:	4.0000	500.000	3.7500	30.5000	1.6400	0.9300	11.1000	5.8000	3.0000	0.5172	2.8000
• 160:	4.0000	600.000	4.5000	34.7000	1.5800	1.0500	13.6600	5.1000	3.0000	0.5882	2.1000
• 161:	4.0000	700.000	4.0000	34.3000	1.5800	1.1000	14.5900	5.5000	3.0000	0.5455	2.5000
• 162:	4.0000	800.000	4.5000	37.5000	1.8100	1.1000	15.1400	4.2000	2.5000	0.5952	1.7000
• 163:	4.0000	900.000	5.0000	47.7000	1.9600	1.3000	15.5300	4.0000	2.5000	0.6250	1.5000
• 164:	4.0000	1000.00	6.2500	50.3000	1.9100	1.4000	18.7200	3.1000	2.0500	0.6613	1.0500
• 165:	4.0000	1100.00	7.2500	48.8000	1.9900	1.4800	19.4700	3.1000	2.2000	0.7097	0.9000
• 166:	4.0000	1200.00	10.0000	53.6000	2.1200	1.4600	20.2600	2.7000	1.8000	0.6667	0.9000

	CODE	KPM	P*TIME	Vt	V̇E	V̇CO2	V̇O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	27	6	9	13	14	11	36	12	10
• 154:	4.0000	0.0000	345.000	0.5000	7.5400	0.2800	0.3800	36.0000	32.6000	96.0000	78.0000
• 155:	4.0000	100.000	258.800	1.6000	10.9800	0.4500	0.6200	40.0000	34.7000	95.0000	102.000
• 156:	4.0000	200.000	301.800	1.5000	11.1800	0.4900	0.7500	40.0000	37.6000	95.0000	107.000
• 157:	4.0000	300.000	380.800	1.7000	14.3000	0.5000	1.0000	44.0000	39.0000	94.0000	108.000
• 158:	4.0000	400.000	515.200	1.7500	16.1300	0.7700	1.1000	44.0000	40.0000	95.0000	114.000
• 159:	4.0000	500.000	577.900	1.6000	18.1800	0.9400	1.2300	46.0000	42.0000	95.0000	120.000
• 160:	4.0000	600.000	778.900	1.9300	21.5800	1.1400	1.4100	48.0000	43.0000	95.0000	126.000
• 161:	4.0000	700.000	655.700	1.7000	23.0500	1.2800	1.5100	50.0000	45.0000	95.0000	126.000
• 162:	4.0000	800.000	935.100	1.9000	27.3300	0.1530	1.7600	52.0000	46.0000	94.0000	132.000
• 163:	4.0000	900.000	1118.20	2.0000	30.4300	1.4400	1.9200	54.0000	48.0000	94.0000	150.000
• 164:	4.0000	1000.00	1338.50	1.9000	35.8000	2.0990	2.1900	56.0000	50.3000	93.0000	156.000
• 165:	4.0000	1100.00	1321.90	1.9500	38.7000	2.3200	2.3500	56.0000	50.0000	92.0000	156.000
• 166:	4.0000	1200.00	1489.60	1.9000	42.8500	2.5800	2.5500	56.0000	50.0000	89.0000	168.000

Tab 7.3.4.2 Individual data of subject 4, RI.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 227:	4.0000	0.0000	2.7500	19.5000	0.8900	0.4000	7.9400	9.7500	5.5000	0.5641	4.2500
♦ 228:	4.0000	100.000	3.2500	19.2000	1.2500	0.4800	7.1600	7.0000	4.1000	0.5857	2.9000
♦ 229:	4.0000	200.000	4.0000	18.8000	1.0700	0.3500	9.2100	6.9000	5.0500	0.7319	1.8500
♦ 230:	4.0000	300.000	5.0000	30.6000	1.5000	0.6000	8.2100	5.4500	3.8000	0.6972	1.6500
♦ 231:	4.0000	400.000	5.5000	38.2000	1.6700	0.6300	8.6500	6.1000	4.3300	0.7098	1.7700
♦ 232:	4.0000	500.000	6.2500	38.3000	1.5000	0.5500	10.5500	6.0700	3.1000	0.5107	2.9700
♦ 233:	4.0000	600.000	7.5000	47.2000	1.4100	0.7300	12.6100	5.8300	3.8700	0.6638	1.9600
♦ 234:	4.0000	700.000	8.7500	48.0000	1.2600	0.7800	18.7100	3.0300	1.8000	0.5941	1.2300
♦ 235:	4.0000	800.000	9.5000	43.8000	1.1900	0.7800	20.5100	3.4800	2.6800	0.7701	0.8000
♦ 236:	4.0000	900.000	10.0000	65.0000	1.4000	1.0000	21.0000	3.1000	1.9300	0.6226	1.1700

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 227:	4.0000	0.0000	695.940	1.1000	7.1000	0.2800	0.3800	41.0000	35.6000	97.0000	84.0000
♦ 228:	4.0000	100.000	554.900	1.0000	8.9500	0.4000	0.5300	45.0000	38.4000	96.0000	96.0000
♦ 229:	4.0000	200.000	652.990	0.9000	9.8800	0.4500	0.6700	46.0000	39.1000	96.0000	96.0000
♦ 230:	4.0000	300.000	684.700	1.2300	12.2800	0.5800	0.8600	49.0000	41.7000	95.0000	114.000
♦ 231:	4.0000	400.000	1001.67	1.5000	14.4000	0.7100	1.0400	50.0000	44.1000	95.0000	114.000
♦ 232:	4.0000	500.000	1243.90	1.2000	15.8800	0.8500	1.1500	51.0000	46.0000	94.0000	114.000
♦ 233:	4.0000	600.000	1534.60	1.5400	17.7800	1.0100	1.3100	56.0000	49.1000	94.0000	126.000
♦ 234:	4.0000	700.000	1210.50	1.0300	23.4800	1.2600	1.5000	53.0000	46.2000	94.0000	132.000
♦ 235:	4.0000	800.000	1880.80	1.1700	24.3500	1.3600	1.5800	58.0000	48.4000	93.0000	138.000
♦ 236:	4.0000	900.000	2118.70	1.4800	29.4000	1.4000	1.3500	57.0000	51.2000	93.0000	1[illegible].000.

Tab 7.3.4.3 Individual data of subject 4, R2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 282:	4.0000	0.0000	2.2500	5.5000	0.8400	0.3000	7.0500	9.8000	5.0500	0.5153	4.7500
• 283:	4.0000	100.000	2.7500	17.5000	1.5500	0.6500	6.2200	8.3000	4.3000	0.5181	4.0000
• 284:	4.0000	200.000	3.0000	18.2000	1.6100	0.4500	6.0400	9.2000	4.2000	0.4565	5.0000
• 285:	4.0000	300.000	3.2500	24.0000	1.5500	0.6500	8.8700	6.7500	3.6500	0.5407	3.1000
• 286:	4.0000	400.000	3.7500	29.3000	2.0100	0.7000	6.6800	8.4500	5.2500	0.6213	3.2000
• 287:	4.0000	500.000	4.5000	40.9000	2.1300	0.6700	8.4500	7.2000	4.4700	0.6208	2.7300
• 288:	4.0000	600.000	5.5000	43.6000	1.9200	0.6300	9.2800	6.5000	4.6300	0.7123	1.8700
• 289:	4.0000	700.000	6.2500	49.6000	2.0700	0.8600	10.7300	4.8300	3.8000	0.7867	1.0300
• 290:	4.0000	800.000	8.2500	63.1000	1.9500	0.8800	12.7700	4.7000	3.9000	0.8298	0.8000
• 291:	4.0000	900.000	10.0000	63.2000	1.9000	1.0700	12.8000	3.1600	2.5500	0.8070	0.6100

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9.	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 282:	4.0000	0.0000	121.900	0.9000	5.8900	0.2800	0.3800	44.0000	36.7000	95.0000	78.0000
• 283:	4.0000	100.000	326.500	1.4500	9.6300	0.4900	0.5800	44.0000	41.7000	96.0000	102.000
• 284:	4.0000	200.000	296.700	1.6500	9.7300	0.6600	0.8500	47.0000	43.1000	95.0000	102.000
• 285:	4.0000	300.000	594.800	1.8000	12.5300	0.7400	0.9400	49.0000	45.2000	97.0000	108.000
• 286:	4.0000	400.000	584.500	2.1000	13.4500	1.0600	1.3700	50.0000	46.0000	96.0000	120.000
• 287:	4.0000	500.000	1111.80	2.0000	17.9500	1.0600	1.4300	55.0000	48.0000	95.0000	126.000
• 288:	4.0000	600.000	979.500	1.7000	17.7200	1.1000	1.3800	58.0000	50.0000	94.0000	126.000
• 289:	4.0000	700.000	1364.60	1.6000	22.1000	1.3800	1.6200	57.0000	52.0000	95.0000	138.000
• 290:	4.0000	800.000	2028.10	1.9000	24.8000	1.6100	1.8000	60.0000	52.8000	93.0000	144.000
• 291:	4.0000	900.000	2202.90	1.8500	24.1000	1.6100	1.5500	60.0000	53.0000	90.0000	144.000

Tab 7.3.4.4 Individual data of subject 4, R3.

	CODE	KPM	cor Borg	P-MOUTH	Vt	VI	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
• 360:	4.0000	0.0000	0.5000	8.3500	0.5300	0.6500	17.8500	3.7500	1.0300	0.2747	2.7200
• 361:	4.0000	100.000	0.5000	16.6000	0.7200	1.5800	18.1000	3.6400	0.9300	0.2555	2.7100
• 362:	4.0000	200.000	1.0000	22.4000	0.8800	1.3200	18.4000	2.8700	0.8000	0.2787	2.0700
• 363:	4.0000	300.000	1.0000	19.0200	0.9200	1.1300	17.3000	3.2000	0.9500	0.2969	2.2500
• 364:	4.0000	400.000	1.0000	22.5000	0.9800	1.3800	20.1000	2.9800	1.0300	0.3552	1.8700
• 365:	4.0000	500.000	1.2500	28.3000	1.1300	1.6000	19.0000	3.6000	1.1300	0.3139	2.4700
• 366:	4.0000	600.000	1.7500	27.2000	1.2900	1.8000	18.9000	3.4000	1.0300	0.3029	2.3700
• 367:	4.0000	700.000	2.2500	30.1000	1.4100	1.8000	19.2000	3.2500	1.0000	0.3077	2.2500
• 368:	4.0000	800.000	2.7500	31.8000	1.4300	1.9800	21.3000	3.0000	1.0000	0.3333	2.0000
• 369:	4.0000	900.000	2.7500	35.6000	1.7400	2.2000	19.7000	3.1000	1.1000	0.3548	2.0000
• 370:	4.0000	1000.00	3.0000	36.4000	1.7100	2.2800	22.2000	2.7000	0.9600	0.3556	1.7400
• 371:	4.0000	1100.00	3.2500	40.5000	1.8100	2.5000	22.7000	3.0000	0.9300	0.3100	2.0700
• 372:	4.0000	1200.00	3.5000	40.1000	2.0100	2.8600	22.1000	2.9000	0.8500	0.2931	2.0500
• 373:	4.0000	1300.00	3.7500	45.1000	2.0400	3.3000	24.7000	2.5000	0.8400	0.3360	1.6600
• 374:	4.0000	1400.00	3.5000	43.7000	1.9900	3.2400	26.5000	2.2400	0.8300	0.3705	1.4100
• 375:	4.0000	1500.00	3.7500	44.1000	1.9300	3.4800	30.3000	2.1200	0.8200	0.3868	1.3000
• 376:	4.0000	1600.00	4.0000	39.9000	2.0000	3.4800	31.3000	1.8800	0.7000	0.3723	1.1800
• 377:	4.0000	1700.00	4.5000	46.0000	2.1000	4.1600	32.7000	1.6500	0.7000	0.4247	0.9500

	CODE	KPM	P*TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	10
• 360:	4.0000	0.0000	114.200	0.4800	9.4600	0.3300	0.4000	41.0000	30.6000	97.0000	90.0000
• 361:	4.0000	100.000	235.200	1.0700	13.0000	0.5100	0.6400	43.0000	33.8000	97.0000	90.0000
• 362:	4.0000	200.000	270.500	0.8200	16.2000	0.6700	0.8200	44.0000	35.6000	97.0000	96.0000
• 363:	4.0000	300.000	211.100	0.8300	15.9000	0.6800	0.8300	44.0000	37.0000	97.0000	96.0000
• 364:	4.0000	400.000	289.400	1.1800	19.7000	0.8400	1.0100	46.0000	37.0000	96.0000	108.000
• 365:	4.0000	500.000	393.300	1.3300	21.5000	0.9800	1.1300	46.0000	39.5000	96.0000	108.000
• 366:	4.0000	600.000	398.800	1.3000	24.5000	1.1200	1.2400	47.0000	39.8000	96.0000	114.000
• 367:	4.0000	700.000	389.800	1.3000	27.1000	1.2400	1.3400	48.0000	39.8000	96.0000	176.000
• 368:	4.0000	800.000	485.600	1.5000	30.5000	1.4400	1.5500	49.0000	40.5000	97.0000	132.000
• 369:	4.0000	900.000	490.500	1.5000	34.3000	1.6500	1.7100	49.0000	40.0000	96.0000	138.000
• 370:	4.0000	1000.00	486.200	1.6000	38.1000	1.8300	1.8300	50.0000	42.0000	96.0000	142.000
• 371:	4.0000	1100.00	531.200	1.8000	41.1000	2.0100	2.0500	50.0000	42.3000	96.0000	150.000
• 372:	4.0000	1200.00	616.590	1.7000	44.4000	2.2200	2.1900	48.0000	40.0000	96.0000	156.000
• 373:	4.0000	1300.00	642.200	2.0400	50.2000	2.4300	2.3400	50.0000	-42.0000	97.0000	156.000
• 374:	4.0000	1400.00	661.200	1.9000	52.8000	2.6000	2.4000	47.0000	40.0000	95.0000	162.000
• 375:	4.0000	1500.00	772.700	2.0500	58.4000	2.8500	2.6000	48.0000	43.0000	96.0000	168.000
• 376:	4.0000	1600.00	701.100	1.8000	62.7000	3.0900	2.7000	50.0000	43.4000	95.0000	174.000
• 377:	4.0000	1700.00	866.600	2.0200	67.6000	3.4000	2.8000	48.0000	43.0000	94.0000	188.000

Tab 7.3.4.5 Individual data of subject 4, El.

	CODE	KPM	cor Borg	P-MOUTH	Vt	$\dot{V}$I	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
♦ 453:	4.0000	0.0000	4.5000	23.5000	0.4500	0.7000	14.6700	2.2000	0.7000	0.3182	1.5000
♦ 454:	4.0000	100.000	2.7500	26.9000	0.4300	1.1000	26.4100	2.0800	0.6000	0.2885	1.4800
♦ 455:	4.0000	200.000	2.7500	32.0000	0.4600	1.3000	28.1100	2.6000	0.8200	0.3154	1.7800
♦ 456:	4.0000	300.000	3.0000	36.0000	0.5700	1.5000	26.6800	2.5600	0.7800	0.3047	1.7800
♦ 457:	4.0000	400.000	3.2500	40.7000	0.7400	1.5300	24.0500	2.6400	0.9500	0.3598	1.6900
♦ 458:	4.0000	500.000	3.5000	40.0000	0.7900	1.7800	25.5400	2.2500	0.8000	0.3556	1.4500
♦ 459:	4.0000	600.000	3.7500	41.1000	0.8000	1.7600	28.4900	2.2000	0.7900	0.3591	1.4100
♦ 460:	4.0000	700.000	4.5000	47.9000	0.8500	2.1000	29.9700	2.1000	0.7800	0.3714	1.3200
♦ 461:	4.0000	800.000	5.0000	49.4000	0.9500	2.3700	30.0000	2.0000	0.7400	0.3700	1.2600
♦ 462:	4.0000	900.000	6.2500	50.2000	1.0900	2.6000	31.2600	1.8000	0.7000	0.3889	1.1000
♦ 463:	4.0000	1000.00	6.7500	52.2000	1.1200	2.5900	34.1200	1.6000	0.6900	0.4313	0.9100
♦ 464:	4.0000	1100.00	7.7500	54.8000	1.2400	3.0000	34.3400	1.6900	0.6500	0.3846	1.0400
♦ 465:	4.0000	1200.00	8.2500	59.0000	1.3200	3.1900	34.0300	1.6000	0.6900	0.4313	0.9100
♦ 466:	4.0000	1300.00	9.0000	58.1000	1.3200	2.9800	35.0200	1.5000	0.7000	0.4667	0.8000
♦ 467:	4.0000	1400.00	9.5000	49.5000	1.3100	3.4000	35.3000	1.7000	0.7000	0.4118	1.0000
♦ 468:	4.0000	1500.00	10.0000	59.1000	1.3500	3.2000	36.7300	1.6600	0.6700	0.4036	0.9900

	CODE	KPM	P*TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	10
♦ 453:	4.0000	0.0000	279.000	0.4800	6.5400	0.2700	0.3700	40.0000	35.5000	96.0000	96.0000
♦ 454:	4.0000	100.000	325.780	0.6000	11.2300	0.4700	0.6400	42.0000	36.2000	97.0000	102.000
♦ 455:	4.0000	200.000	392.000	0.7000	13.0000	0.5700	0.7900	43.0000	38.3000	95.0000	108.000
♦ 456:	4.0000	300.000	406.200	0.7600	15.0800	0.7200	0.9900	44.0000	40.0000	95.0000	120.000
♦ 457:	4.0000	400.000	592.500	0.8500	17.6800	0.8900	1.1400	46.0000	42.5000	95.0000	120.000
♦ 458:	4.0000	500.000	644.000	0.9700	20.0500	1.0300	1.2600	46.0000	43.0000	96.0000	126.000
♦ 459:	4.0000	600.000	632.000	0.9900	22.6500	1.1800	1.4000	47.0000	43.0000	96.0000	132.000
♦ 460:	4.0000	700.000	83.0800	1.1700	25.3300	1.3300	1.5300	46.0000	42.0000	95.0000	138.000
♦ 461:	4.0000	800.000	982.400	1.1700	28.5800	1.5300	1.7300	49.0000	42.5000	95.0000	150.000
♦ 462:	4.0000	900.000	991.700	1.1900	34.1500	1.8700	2.0100	49.0000	43.0000	94.0000	168.000
♦ 463:	4.0000	1000.00	1047.90	1.2500	38.1300	2.1000	2.1800	50.0000	44.0000	94.0000	168.000
♦ 464:	4.0000	1100.00	1191.80	1.3000	42.4500	2.3300	2.3700	49.0000	44.0000	94.0000	174.000
♦ 465:	4.0000	1200.00	1300.00	1.4800	44.7500	2.4700	2.4700	50.0000	43.4000	94.0000	174.000
♦ 466:	4.0000	1300.00	1296.60	1.2500	46.2300	2.5800	2.5900	55.0000	48.0000	92.0000	174.000
♦ 467:	4.0000	1400.00	1127.00	1.5000	46.4000	2.6400	2.6300	52.0000	48.0000	92.0000	180.000
♦ 468:	4.0000	1500.00	1374.00	1.4300	49.5800	2.8600	2.7600	54.0000	49.6000	92.0000	180.000

Tab 7.3.4.6 Individual data of subject 4, E2.

	CODE	KPM	cor Borg	P-MOUTH	Vt	$\dot{V}$I	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
♦ 535:	4.0000	0.0000	2.7500	20.3500	0.3700	0.4100	19.6300	3.4000	1.2700	0.3735	2.1300
♦ 536:	4.0000	100.000	3.2500	24.0600	0.5200	0.7000	18.3600	4.0500	1.2500	0.3086	2.8000
♦ 537:	4.0000	200.000	3.7500	35.6700	0.6100	0.8500	18.2900	3.6000	1.0000	0.2778	2.6000
♦ 538:	4.0000	300.000	3.7500	33.2900	0.6600	0.9800	21.4100	2.7700	0.9700	0.3502	1.8000
♦ 539:	4.0000	400.000	4.0000	38.7800	0.7200	1.0700	22.6800	2.7300	1.1500	0.4212	1.5800
♦ 540:	4.0000	500.000	4.2500	35.4700	0.6900	1.2800	27.4700	2.9000	1.0000	0.3448	1.9000
♦ 541:	4.0000	600.000	4.5000	45.4100	0.9700	1.3900	22.1500	2.7000	0.9500	0.3519	1.7500
♦ 542:	4.0000	700.000	5.0000	45.1000	1.0300	1.3400	22.7900	2.6300	1.1700	0.4449	1.4600
♦ 543:	4.0000	800.000	6.2500	57.5000	0.9700	1.5600	26.8100	2.6800	1.0500	0.3918	1.6300
♦ 544:	4.0000	900.000	7.7500	56.4300	1.2700	1.6400	23.0000	2.2000	0.8500	0.3864	1.3500
♦ 545:	4.0000	1000.00	9.0000	54.2800	1.1800	1.6400	27.6700	2.0600	0.8800	0.4272	1.1800
♦ 546:	4.0000	1100.00	10.0000	50.4300	1.0400	2.0000	33.8000	1.8000	0.6300	0.3500	1.1700

	CODE	KPM	P*TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	18
♦ 535:	4.0000	0.0000	505.670	0.4400	7.2100	0.2200	0.3200	48.5600	29.0000	96.0000	66.0000
♦ 536:	4.0000	100.000	531.300	0.5200	9.5300	0.3600	0.5500	44.7500	32.6000	95.0000	96.0000
♦ 537:	4.0000	200.000	869.300	0.7700	11.2000	0.4800	0.7400	50.0200	36.8000	93.0000	102.000
♦ 538:	4.0000	300.000	586.200	0.5600	14.0800	0.6200	0.9200	52.9300	38.2000	94.0000	102.000
♦ 539:	4.0000	400.000	955.100	0.6700	16.2800	0.7500	1.0300	52.2500	40.0000	94.0000	108.000
♦ 540:	4.0000	500.000	832.100	0.7900	19.0000	0.9300	1.1900	54.5800	42.5000	94.0000	114.000
♦ 541:	4.0000	600.000	1097.60	0.8400	21.5300	1.1200	1.3300	55.2200	44.6000	95.0000	120.000
♦ 542:	4.0000	700.000	1098.30	0.9300	23.5800	1.2400	1.4200	59.3400	46.0000	94.0000	144.000
♦ 543:	4.0000	800.000	1701.10	1.0900	26.0800	1.4200	1.6000	56.7500	47.4000	94.0000	132.000
♦ 544:	4.0000	900.000	1255.80	1.0400	29.1300	1.6700	1.8000	56.8900	49.6000	93.0000	150.000
♦ 545:	4.0000	1000.00	1188.20	0.9900	32.6500	1.9100	1.9700	58.9100	50.3000	93.0000	140.000
♦ 546:	4.0000	1100.00	1218.10	0.8600	35.2700	2.0800	2.1400	61.3400	51.0000	92.0000	156.000

Tab 7.3.4.7 Individual data of subject 4, E3.

D+lag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 631:	4.0000	0.0000	0.0000	2.0000	0.5600	0.8700	14.3900	3.8700	1.2700	0.3282	2.6000
• 632:	4.0000	100.000	0.0000	3.7500	0.7000	1.0000	16.0000	4.9300	1.2700	0.2576	3.6600
• 633:	4.0000	200.000	0.0000	3.3300	0.9100	1.1000	14.8000	4.3000	1.3700	0.3186	2.9300
• 634:	4.0000	300.000	0.0000	4.0000	1.1700	1.3200	14.1000	4.1200	1.3800	0.3350	2.7400
• 635:	4.0000	400.000	0.5000	4.0000	1.0800	1.5200	18.7000	3.4600	1.3000	0.3757	2.1600
• 636:	4.0000	500.000	0.5000	4.0000	1.4700	1.5600	15.2000	2.9600	1.1000	0.3716	1.8600
• 637:	4.0000	600.000	1.0000	4.0000	1.4100	1.6000	19.2000	3.9000	1.5300	0.3923	2.3700
• 638:	4.0000	700.000	1.2500	4.0000	1.4200	1.8000	21.3000	3.3500	1.1700	0.3493	2.1800
• 639:	4.0000	800.000	1.7500	5.4000	1.6700	2.3700	20.5000	3.0500	1.3000	0.4262	1.7500
• 640:	4.0000	900.000	2.2500	6.0000	1.8300	2.3200	21.5000	3.5600	1.3000	0.3652	2.2600
• 641:	4.0000	1000.00	2.5000	6.0000	1.9700	2.5300	22.5000	3.0000	1.1500	0.3833	1.8500
• 642:	4.0000	1100.00	3.2500	6.8000	2.4300	2.7800	21.2000	3.2100	1.3600	0.4237	1.8500
• 643:	4.0000	1200.00	2.7500	6.6700	2.5900	2.8000	21.1000	2.9300	1.2300	0.4198	1.7000
• 644:	4.0000	1300.00	3.5000	8.0000	2.3900	3.3600	22.8000	2.4800	1.1200	0.4516	1.3600
• 645:	4.0000	1400.00	3.7500	7.5000	2.7000	3.3600	24.7000	2.3600	1.0000	0.4237	1.3600
• 646:	4.0000	1500.00	4.0000	9.1700	2.7600	3.8800	25.8000	2.2600	0.9600	0.4248	1.3000
• 647:	4.0000	1600.00	6.0000	11.2000	2.6100	4.5000	28.6000	1.7800	0.7700	0.4326	1.0100
• 648:	4.0000	1700.00	8.7500	11.8000	2.5400	4.5000	33.8000	1.6400	0.7100	0.4329	0.9300

D+lag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 631:	4.0000	0.0000	29.0000	0.7300	8.0600	0.2900	0.3300	42.0000	31.3000	97.0000	84.0000
• 632:	4.0000	100.000	28.4000	1.0300	11.2000	0.4300	0.5700	41.0000	33.4000	97.0000	90.0000
• 633:	4.0000	200.000	24.4000	1.0300	13.4000	0.5500	0.6700	44.0000	35.6000	96.0000	96.0000
• 634:	4.0000	300.000	37.4300	1.2700	16.4000	0.7000	0.8500	44.0000	36.3000	96.0000	102.000
• 635:	4.0000	400.000	40.0700	1.3000	20.1000	0.8700	1.0300	45.0000	37.7000	97.0000	108.000
• 636:	4.0000	500.000	44.5100	1.2800	22.3000	0.9900	1.1000	47.0000	37.7000	96.0000	114.000
• 637:	4.0000	600.000	43.9300	1.9000	27.0000	1.1900	1.3000	47.0000	39.1000	95.0000	120.000
• 638:	4.0000	700.000	47.7400	1.4200	30.4000	1.4000	1.4600	46.0000	39.1000	95.0000	126.000
• 639:	4.0000	800.000	69.3500	2.0200	34.3000	1.5800	1.6300	47.0000	40.5000	97.0000	138.000
• 640:	4.0000	900.000	61.8100	2.3600	39.3000	1.8500	1.9100	50.0000	41.2000	95.0000	144.000
• 641:	4.0000	1000.00	70.8400	2.1300	44.3000	2.1800	2.1400	49.0000	42.0000	97.0000	144.000
• 642:	4.0000	1100.00	72.8300	2.7000	51.6000	2.4900	2.3400	52.0000	42.7000	95.0000	156.000
• 643:	4.0000	1200.00	85.9300	2.6000	54.4800	2.6200	2.4300	52.0000	42.7000	96.0000	162.000
• 644:	4.0000	1300.00	112.580	2.7000	54.4000	2.6500	2.4800	48.0000	39.8000	95.0000	156.000
• 645:	4.0000	1400.00	112.040	2.8800	66.6000	3.0300	2.6500	48.0000	38.4000	97.0000	174.000
• 646:	4.0000	1500.00	144.470	2.6500	71.2000	3.2100	2.7300	49.0000	38.4000	96.0000	174.000
• 647:	4.0000	1600.00	179.020	2.8000	74.6000	3.3700	2.8400	48.0000	37.7000	95.0000	180.000
• 648:	4.0000	1700.00	174.700	2.5000	85.7000	3.6000	2.9000	46.0000	36.3000	96.0000	180.000

Tab 7.3.4.8 Individual data of subject 4, C2.

	CODE	KPM	cor Borg	P-MOUTH	Vt	$\dot{V}$I	FR	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
♦ 77:	5.0000	0.0000	0.0000	2.0000	0.5500	0.7500	19.8000	3.2000	1.2000	0.3750	2.0000
♦ 78:	5.0000	100.000	0.0000	3.0000	0.8800	0.8000	19.0100	3.8000	1.7000	0.4474	2.1000
♦ 79:	5.0000	200.000	0.5000	3.0000	0.8900	0.7500	16.2900	3.0000	1.4000	0.4667	1.6000
♦ 80:	5.0000	300.000	0.0000	5.0000	1.0000	1.0000	16.3800	2.9800	1.1000	0.3793	1.8000
♦ 81:	5.0000	400.000	0.5000	6.4000	1.2200	1.5000	17.4800	3.4000	1.6000	0.4706	1.8000
♦ 82:	5.0000	500.000	1.2500	6.0000	1.5600	1.6000	14.2200	4.1000	2.8000	0.4878	2.1000
♦ 83:	5.0000	600.000	1.7500	7.0000	1.4300	1.3000	17.2000	3.6000	1.5000	0.4167	2.1000
♦ 84:	5.0000	700.000	1.7500	7.7000	1.6100	1.4000	17.3200	3.8000	1.5000	0.3947	2.3000
♦ 85:	5.0000	800.000	2.2500	7.4000	2.0500	1.5000	15.5000	3.8000	1.9000	0.5000	1.9000
♦ 86:	5.0000	900.000	2.7500	7.5000	2.2300	2.1000	15.4800	3.9000	1.8000	0.4615	2.1000
♦ 87:	5.0000	1000.00	3.2500	7.6000	1.4900	2.5000	29.5500	2.2000	0.9000	0.4091	1.3000
♦ 88:	5.0000	1100.00	3.2500	7.9000	1.5900	2.5000	29.3700	2.0000	0.9500	0.4750	1.0500
♦ 89:	5.0000	1200.00	3.7500	8.9000	1.6100	2.8000	30.8700	1.9500	0.9000	0.4615	1.0500
♦ 90:	5.0000	1300.00	3.7500	9.6000	1.8500	2.9000	30.6900	1.9800	0.9500	0.4798	1.0300
♦ 91:	5.0000	1400.00	3.7500	10.4800	1.9100	3.0000	30.9900	1.9800	0.9200	0.4646	1.0600
♦ 92:	5.0000	1500.00	4.5000	11.3000	2.0900	3.5000	31.1000	1.9300	0.9100	0.4715	1.0200
♦ 93:	5.0000	1600.00	4.5000	12.0000	2.3200	3.7000	30.7200	1.8500	0.8800	0.4757	0.9700
♦ 94:	5.0000	1700.00	5.0000	12.8000	2.4600	3.8000	31.3800	1.9100	0.9200	0.4817	0.9900
♦ 95:	5.0000	1800.00	6.2500	13.1000	2.7200	4.3000	32.4200	1.6500	0.8400	0.5091	0.8100
♦ 96:	5.0000	1900.00	6.7500	15.7000	2.8300	4.7000	35.6500	1.2000	0.6100	0.5083	0.5900

	CODE	KPM	P*TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	12	10
♦ 77:	5.0000	0.0000	10.2000	0.6000	10.8900	0.2800	0.3400	37.0000	27.4000	98.0000	60.0000
♦ 78:	5.0000	100.000	15.4000	0.8500	19.7300	0.5100	0.6500	37.0000	26.2000	98.0000	72.0000
♦ 79:	5.0000	200.000	18.7000	0.9000	14.5000	0.4700	0.6400	38.0000	28.2000	98.0000	84.0000
♦ 80:	5.0000	300.000	34.4000	0.7000	16.3800	0.5600	0.7900	38.0000	29.8000	98.0000	84.0000
♦ 81:	5.0000	400.000	49.6000	1.6000	21.3300	0.7600	1.0100	38.0000	30.5000	98.0000	84.0000
♦ 82:	5.0000	500.000	42.9000	1.6000	22.1800	0.8500	1.0600	39.0000	33.3000	98.0000	90.0000
♦ 83:	5.0000	600.000	55.3000	1.0000	24.6000	0.9400	1.1400	39.0000	33.2000	98.0000	90.0000
♦ 84:	5.0000	700.000	62.1000	1.4000	27.8800	1.1100	1.3400	40.0000	33.0000	98.0000	102.000
♦ 85:	5.0000	800.000	67.4000	1.7500	31.7800	1.3300	1.5200	42.0000	36.5000	98.0000	108.000
♦ 86:	5.0000	900.000	69.9000	1.8000	34.5300	1.4600	1.6600	42.0000	36.9000	98.0000	107.000
♦ 87:	5.0000	1000.00	78.5000	1.5000	44.0300	1.6500	1.8500	41.0000	32.6000	98.0000	120.000
♦ 88:	5.0000	1100.00	93.7000	1.6000	46.7000	1.8000	2.0200	42.0000	33.3000	97.0000	126.000
♦ 89:	5.0000	1200.00	129.400	1.7000	49.7000	2.0000	2.2200	42.0000	35.5000	97.0000	120.000
♦ 90:	5.0000	1300.00	130.000	1.9000	56.7800	2.2600	2.3700	42.0000	34.7000	98.0000	137.000
♦ 91:	5.0000	1400.00	130.000	1.9000	59.2000	2.3600	2.4800	42.0000	34.7000	97.0000	132.000
♦ 92:	5.0000	1500.00	134.000	2.1000	65.0500	2.6300	2.7300	42.0000	35.5000	97.0000	138.000
♦ 93:	5.0000	1600.00	130.000	2.1000	71.7800	2.9400	2.9400	42.0000	35.8000	97.0000	150.000
♦ 94:	5.0000	1700.00	156.600	1.9400	77.2000	3.1300	3.1300	42.0000	35.1000	98.0000	150.000
♦ 95:	5.0000	1800.00	188.000	2.1000	88.1800	3.5000	3.3900	42.0000	34.0000	96.0000	156.000
♦ 96:	5.0000	1900.00	217.000	1.9000	100.900	4.0100	3.7000	44.0000	34.7000	96.0000	162.000

Tab 7.3.5.1 Individual data of subject 5, CI.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
167:	5.0000	0.0000	1.7500	9.4500	1.1200	0.3100	7.9200	9.9500	7.1800	0.7216	2.7700
168:	5.0000	100.000	2.2500	19.1400	1.4100	0.6400	9.7500	6.7500	5.3000	0.7852	1.4500
169:	5.0000	200.000	2.2500	16.9100	1.8200	0.7200	7.0300	8.4000	7.2000	0.8571	1.2000
170:	5.0000	300.000	2.7500	21.1700	1.9600	0.8500	7.2300	5.8000	4.8000	0.8276	1.0000
171:	5.0000	400.000	3.2500	26.3800	2.0900	0.8700	8.2900	6.1000	4.9000	0.8033	1.2000
172:	5.0000	500.000	3.7500	28.4300	2.5000	1.3000	6.5100	6.5000	5.1000	0.7846	1.4000
173:	5.0000	600.000	4.0000	35.5900	2.7500	1.0300	7.7900	7.3000	6.2000	0.8493	1.1000
174:	5.0000	700.000	4.5000	33.6600	2.5900	1.0700	9.0000	5.6500	4.8000	0.8496	0.8500
175:	5.0000	800.000	5.5000	38.7400	2.5200	1.4600	10.0900	5.6500	4.5000	0.7965	1.1500
176:	5.0000	900.000	6.0000	49.6000	2.7800	1.7400	11.1100	5.5000	4.7500	0.8636	0.7500
177:	5.0000	1000.00	6.2500	52.0600	2.6700	1.7900	12.1500	4.8000	3.9300	0.8187	0.8700
178:	5.0000	1100.00	7.7500	65.2800	2.8700	1.5800	12.2100	4.4000	3.8300	0.8705	0.5700
179:	5.0000	1200.00	8.7500	70.7000	2.8400	1.7000	13.7900	3.9300	3.1700	0.8066	0.7600
180:	5.0000	1300.00	9.0000	74.2000	3.0400	1.7700	12.9500	4.6000	4.0000	0.8696	0.6000
181:	5.0000	1400.00	9.5000	80.5700	3.0300	1.6900	14.0700	4.1000	3.7300	0.9098	0.3700
182:	5.0000	1500.00	10.0000	81.3600	2.7000	1.8500	17.9300	3.5300	2.9700	0.8414	0.5600

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
167:	5.0000	0.0000	65.1000	1.2400	8.8400	0.3300	0.3700	42.0000	33.9000	96.0000	60.0000
168:	5.0000	100.000	202.400	1.2600	13.0000	0.5600	0.7000	44.0000	36.8000	95.0000	78.0000
169:	5.0000	200.000	211.600	1.9900	12.7800	0.5800	0.7200	45.0000	38.9000	96.0000	87.0000
170:	5.0000	300.000	336.900	2.0400	14.1300	0.6700	0.8300	47.0000	40.3000	96.0000	84.0000
171:	5.0000	400.000	476.700	2.2800	17.3500	0.8400	1.0400	48.0000	41.7000	95.0000	94.0000
172:	5.0000	500.000	588.500	2.8000	16.3000	0.8500	1.0800	50.0000	42.5000	96.0000	102.000
173:	5.0000	600.000	651.200	2.8000	21.3000	1.0700	1.2600	50.0000	43.8000	96.0000	102.000
174:	5.0000	700.000	789.300	2.6600	23.2800	1.1900	1.3800	50.0000	44.5000	95.0000	108.000
175:	5.0000	800.000	886.900	2.5100	25.4000	1.3300	1.5500	53.0000	45.2000	95.0000	114.000
176:	5.0000	900.000	1227.70	3.2600	30.9000	1.5900	1.8300	52.0000	44.5000	95.0000	120.000
177:	5.0000	1000.00	1281.80	2.9000	32.3800	1.7300	2.0000	54.0000	46.7000	94.0000	126.000
178:	5.0000	1100.00	1577.60	2.7800	35.0000	1.9200	2.1900	55.0000	48.1000	94.0000	132.000
179:	5.0000	1200.00	1679.60	2.5000	39.1000	2.1600	7.3900	57.0000	50.2000	92.0000	138.000
180:	5.0000	1300.00	1850.20	3.1000	39.3500	2.2800	2.5100	58.0000	50.[illegible]000	91.0000	144.000
181:	5.0000	1400.00	2088.90	3.2000	42.6300	2.4800	7.6700	62.0000	51.6000	89.0000	150.000
182:	5.0000	1500.00	2088.00	2.7700	48.4000	2.8800	2.9100	62.0000	51.8000	85.0000	150.000

Tab 7.3.5.2 Individual data of subject 5, R1.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 28	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 237:	5.0000	0.0000	2.7500	13.9000	1.5000	0.2000	5.4500	10.6000	7.4000	0.6981	3.2000
• 238:	5.0000	100.000	2.7500	20.6000	1.5600	0.4000	5.8800	8.1000	7.6000	0.9383	0.5000
• 239:	5.0000	200.000	3.7500	33.4000	1.6200	0.5000	4.7000	13.4000	10.7000	0.7617	3.2000
• 240:	5.0000	300.000	4.0000	35.9000	2.7600	0.4500	5.2200	12.4000	11.0000	0.8871	1.4000
• 241:	5.0000	400.000	4.5000	46.4000	2.9700	0.6000	5.6000	9.1000	8.5000	0.9341	0.6000
• 242:	5.0000	500.000	6.0800	44.5000	3.1000	0.8800	5.5700	9.6000	9.3000	0.9687	0.3000
• 243:	5.0000	600.000	6.2500	52.1000	2.9000	0.7000	5.9300	12.1000	10.8000	0.8926	1.3000
• 244:	5.0000	700.000	8.2500	56.1000	2.7500	0.8500	7.4400	6.4000	5.3000	0.8281	1.1000
• 245:	5.0000	800.000	8.7500	61.8000	3.0300	0.8500	7.2100	8.8000	7.5000	0.8523	1.3000
• 246:	5.0000	900.000	9.5000	51.8000	2.5600	0.9500	8.6800	7.3000	6.4000	0.8767	0.9000
• 247:	5.0000	1000.00	10.0000	66.6000	2.7200	1.2000	12.5100	5.6000	4.6000	0.8214	1.0000
• 248:	5.0000	1100.00	10.0000	66.8000	2.0900	1.0500	13.6900	3.6000	3.1000	0.8611	0.5000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 237:	5.0000	0.0000	579.900	0.9000	8.1900	0.3000	0.3400	41.0000	33.2000	97.0000	84.0000
• 238:	5.0000	100.000	984.900	1.3000	8.8800	0.4000	0.5200	49.0000	38.8000	96.0000	84.0000
• 239:	5.0000	200.000	1071.60	2.0000	12.3000	0.6100	0.8500	52.0000	43.1000	96.0000	84.0000
• 240:	5.0000	300.000	1192.80	1.6000	14.4000	0.7400	0.9700	55.0000	43.8000	96.0000	96.0000
• 241:	5.0000	400.000	1224.70	1.5000	16.3300	0.8500	1.0200	55.0000	44.5000	97.0000	102.000
• 242:	5.0000	500.000	1295.00	2.4000	17.3300	0.9400	1.1300	60.0000	46.6000	96.0000	108.000
• 243:	5.0000	600.000	1331.90	2.4000	17.1800	0.9700	1.1600	60.0000	48.7000	94.0000	108.000
• 244:	5.0000	700.000	1553.50	2.4000	20.4500	1.1700	1.3800	60.0000	49.4000	94.0000	114.000
• 245:	5.0000	800.000	1576.80	2.5000	21.8800	1.2900	1.5000	62.0000	50.8000	93.0000	114.000
• 246:	5.0000	900.000	1914.80	1.9000	22.2300	1.3800	1.6000	64.0000	53.0000	94.0000	120.000
• 247:	5.0000	1000.00	1571.26	1.7500	27.8000	1.7100	1.8800	62.0000	53.7000	93.0000	120.000
• 248:	5.0000	1100.00	1545.60	1.8500	28.5700	1.8100	1.9300	66.0000	54.4000	92.0000	152.000

Tab 7.3.5.3 Individual data of subject 5, R2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FR 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
◆ 292:	5.0000	0.0000	2.7500	22.5000	1.6700	0.7000	4.2600	12.2000	10.5000	0.8607	1.7000
◆ 293:	5.0000	100.000	3.2500	33.1000	2.1200	0.3000	4.3200	15.1000	12.8000	0.8477	2.3000
◆ 294:	5.0000	200.000	3.5000	41.8000	2.3400	0.4000	4.4600	13.8000	11.7000	0.8478	2.1000
◆ 295:	5.0000	300.000	5.5000	50.7000	2.9700	0.5000	4.3000	13.3000	11.2000	0.8421	2.1000
◆ 296:	5.0000	400.000	6.2500	58.8000	2.8300	0.5000	4.8900	12.1000	10.4000	0.8595	1.7000
◆ 297:	5.0000	500.000	7.7500	63.4000	2.9100	0.6000	5.2100	11.1500	9.1000	0.8161	2.0500
◆ 298:	5.0000	600.000	8.2500	66.3000	2.7300	0.8000	6.4800	8.1500	6.9500	0.8528	1.2000
◆ 299:	5.0000	700.000	9.0000	74.4000	2.3000	0.8000	8.4900	6.6000	5.5000	0.8333	1.1000
◆ 300:	5.0000	800.000	10.0000	76.7000	2.0600	0.8000	9.2200	6.5000	5.2000	0.8000	1.3000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
◆ 292:	5.0000	0.0000	928.100	3.1000	7.1200	0.3200	0.4200	46.0000	39.7000	98.0000	60.0000
◆ 293:	5.0000	100.000	930.700	3.0000	9.1500	0.4600	0.5900	46.0000	39.0000	96.0000	78.0000
◆ 294:	5.0000	200.000	1391.50	2.2800	10.5500	0.5400	0.7100	47.0000	42.0000	97.0000	78.0000
◆ 295:	5.0000	300.000	1547.20	2.6000	12.7800	0.6500	0.8700	50.0000	44.0000	96.0000	84.0000
◆ 296:	5.0000	400.000	1666.70	2.6000	13.8500	0.7600	0.9700	52.0000	45.0000	97.0000	90.0000
◆ 297:	5.0000	500.000	1955.40	3.0000	15.1800	0.8500	1.0800	56.0000	47.9000	95.0000	102.000
◆ 298:	5.0000	600.000	2200.00	1.9000	17.7000	1.0300	1.2200	56.0000	48.0000	94.0000	102.000
◆ 299:	5.0000	700.000	2357.30	2.0000	19.5300	1.1400	1.3600	56.0000	48.0000	96.0000	108.000
◆ 300:	5.0000	800.000	2450.80	2.0000	18.9500	1.1300	1.3400	56.0000	48.0000	93.0000	114.000

Tab 7.3.5.4 Individual data of subject 5, R3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 378:	5.0000	0.0000	1.0000	14.1000	0.6500	0.9200	28.1500	2.7300	1.2000	0.4396	1.5300
• 379:	5.0000	100.000	1.0000	14.8000	0.6600	1.1700	23.5700	2.3800	1.0500	0.4412	1.3300
• 380:	5.0000	200.000	1.0000	12.0100	0.6700	1.1700	23.3600	2.3800	1.0000	0.4207	1.3800
• 381:	5.0000	300.000	1.2500	14.0000	0.7500	1.5200	24.2300	2.4500	1.0000	0.4082	1.4500
• 382:	5.0000	400.000	2.2500	18.1000	0.9000	1.6500	23.2700	2.4800	1.1800	0.4758	1.3000
• 383:	5.0000	500.000	2.7500	17.9000	0.9680	1.6300	26.4800	2.2000	1.0000	0.4545	1.2000
• 384:	5.0000	600.000	3.2500	19.7000	0.9600	1.7900	27.4400	2.0800	0.9200	0.4423	1.1600
• 385:	5.0000	700.000	3.7500	17.6000	1.0200	2.0900	30.6100	1.8500	0.7700	0.4162	1.0800
• 386:	5.0000	800.000	4.5000	18.9000	1.0200	2.1600	34.3500	1.7700	0.8000	0.4520	0.9700
• 387:	5.0000	900.000	5.0000	21.4000	1.0400	2.3600	35.0000	1.7300	0.7600	0.4393	0.9700
• 388:	5.0000	1000.00	5.0000	21.9000	1.2000	2.5300	36.1600	1.7300	0.8300	0.4798	0.9000
• 389:	5.0000	1100.00	5.5000	23.1000	1.2700	2.7800	36.7500	1.5500	0.7600	0.4903	0.7900
• 390:	5.0000	1200.00	5.5000	21.7000	1.4200	2.8400	35.9800	1.3800	0.6700	0.4855	0.7100
• 391:	5.0000	1300.00	6.2500	23.1000	1.3500	3.2800	40.6900	1.4700	0.7100	0.4830	0.7600
• 392:	5.0000	1400.00	6.7500	28.5000	1.5800	3.5000	41.3700	1.5000	0.7100	0.4733	0.7900
• 393:	5.0000	1500.00	7.7500	31.6000	1.6100	3.3300	39.0700	1.6000	0.8300	0.5188	0.7700
• 394:	5.0000	1600.00	8.2500	28.6000	1.6500	3.8000	41.3200	1.4800	0.6900	0.4662	0.7900
• 395:	5.0000	1700.00	8.5000	31.0400	1.7200	4.0000	41.5900	1.4600	0.6900	0.4726	0.7700
• 396:	5.0000	1800.00	9.0000	36.9000	1.8000	4.3000	43.0100	1.4700	0.6700	0.4558	0.8000
• 397:	5.0000	1900.00	9.5000	47.6000	1.8000	3.7800	43.0000	1.4700	0.6700	0.4558	0.8000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 378:	5.0000	0.0000	241.800	0.5800	13.1100	0.3700	0.3800	32.0000	22.6000	96.0000	60.0000
• 379:	5.0000	100.000	264.000	0.6500	15.5000	0.4900	0.5500	38.0000	27.5000	96.0000	72.0000
• 380:	5.0000	200.000	237.300	0.6500	16.9300	0.5800	0.7100	40.0000	29.7000	95.0000	84.0000
• 381:	5.0000	300.000	368.300	0.8000	18.0500	0.7000	0.9300	43.0000	33.8000	94.0000	84.0000
• 382:	5.0000	400.000	425.800	0.9800	21.0000	0.8600	1.0500	45.0000	36.0000	95.0000	96.0000
• 383:	5.0000	500.000	431.600	0.9300	[illegible]	1.0300	1.1500	44.0000	35.3000	95.0000	90.0000
• 384:	5.0000	600.000	425.300	0.9100	26.2800	1.0900	1.2700	44.0000	36.5000	95.0000	96.0000
• 385:	5.0000	700.000	391.800	0.9000	31.1500	1.2900	1.4300	45.0000	36.3000	95.0000	107.000
• 386:	5.0000	800.000	556.500	1.0100	35.1300	1.4300	1.5000	46.0000	35.9000	93.0000	108.000
• 387:	5.0000	900.000	497.000	1.0600	36.6800	1.5900	1.8000	47.0000	37.4000	94.0000	120.000
• 388:	5.0000	1000.00	611.100	1.1800	43.4500	1.8900	2.0000	46.0000	38.1000	94.0000	120.000
• 389:	5.0000	1100.00	599.030	1.5600	46.8000	2.0200	2.1000	46.0000	38.1000	94.0000	126.000
• 390:	5.0000	1200.00	484.100	1.1100	49.7300	2.1300	2.2100	48.0000	37.4000	93.0000	132.000
• 391:	5.0000	1300.00	622.600	1.2300	54.7300	2.3900	2.9900	48.0000	38.1000	93.0000	138.000
• 392:	5.0000	1400.00	802.600	1.4700	65.2300	2.8300	2.7200	47.0000	37.4000	93.0000	144.000
• 393:	5.0000	1500.00	1000.20	1.4600	62.8000	2.8100	2.8300	48.0000	38.8000	92.0000	150.000
• 394:	5.0000	1600.00	809.900	1.6100	68.2800	3.0600	3.0900	48.0000	38.8000	92.0000	150.000
• 395:	5.0000	1700.00	811.000	1.6800	71.6000	3.1800	3.1500	47.0000	38.1000	91.0000	167.000
• 396:	5.0000	1800.00	890.300	1.6700	77.5300	3.5900	3.4900	51.0000	40.2000	91.0000	162.000
• 397:	5.0000	1900.00	890.300	1.5300	65.8000	3.5900	3.4500	51.0000	43.1000	89.0000	168.000

Tab 7.3.5.5 Individual data of subject 5, El.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FR 7	TTOT 5	TI 19	TI/Ttot 25	TE 28
♦ 469:	5.0000	0.0000	1.0000	17.5000	0.5200	0.7700	28.0100	2.2200	0.8200	0.3694	1.4000
♦ 470:	5.0000	100.000	1.7500	21.2000	0.4200	0.7000	30.1800	2.3700	0.9700	0.4093	1.4000
♦ 471:	5.0000	200.000	2.2500	23.3000	0.5000	1.1000	34.2700	1.9700	0.6700	0.3401	1.3000
♦ 472:	5.0000	300.000	2.7500	26.8000	0.6200	1.1400	32.3200	2.1600	0.8000	0.3704	1.3600
♦ 473:	5.0000	400.000	3.2500	29.6000	0.6900	1.4000	29.9300	2.1400	0.7400	0.3458	1.4000
♦ 474:	5.0000	500.000	3.7500	32.4000	0.7200	1.5000	31.2500	1.9200	0.6800	0.3542	1.2400
♦ 475:	5.0000	600.000	4.0000	33.8000	0.8300	1.6000	31.4800	2.0000	0.7800	0.3900	1.2200
♦ 476:	5.0000	700.000	4.5000	36.4000	0.9100	1.7400	31.2600	1.9200	0.7400	0.3854	1.1800
♦ 477:	5.0000	800.000	5.5000	43.2000	0.9900	2.1200	34.1600	1.9200	0.7800	0.4063	1.1400
♦ 478:	5.0000	900.000	6.0000	49.2000	1.1000	2.4100	32.7900	1.8900	0.6800	0.3598	1.2100
♦ 479:	5.0000	1000.00	6.2500	53.6400	1.2100	2.4400	33.4400	1.9600	0.7600	0.3878	1.2000
♦ 480:	5.0000	1100.00	6.7500	57.0000	1.2500	2.6800	34.3700	1.9800	0.8000	0.4040	1.1800
♦ 481:	5.0000	1200.00	7.7500	60.8000	1.3700	2.9400	35.1100	1.8800	0.7200	0.3830	1.1600
♦ 482:	5.0000	1300.00	8.7500	59.8000	1.2500	2.9000	40.9800	1.6400	0.6600	0.4024	0.9800
♦ 483:	5.0000	1400.00	9.0000	63.6000	1.4900	3.2800	36.5500	1.7000	0.6500	0.3824	1.0500
♦ 484:	5.0000	1500.00	9.5000	62.4000	1.6500	3.4700	37.1500	1.5800	0.6000	0.3797	0.9800
♦ 485:	5.0000	1600.00	10.0000	65.6000	1.6900	3.5800	39.0900	1.5000	0.6000	0.4000	0.9000
♦ 486:	5.0000	1700.00	10.0000	67.6000	1.7600	3.6000	39.7200	1.5200	0.6200	0.4079	0.9000

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 469:	5.0000	0.0000	380.400	0.4000	14.4800	0.4100	0.3800	32.0000	23.4000	98.0000	60.0000
♦ 470:	5.0000	100.000	609.000	0.5000	12.7500	0.4200	0.5100	37.0000	28.3000	97.0000	72.0000
♦ 471:	5.0000	200.000	509.600	0.4800	17.0500	0.6200	0.8300	40.0000	31.2000	97.0000	90.0000
♦ 472:	5.0000	300.000	627.000	0.5600	19.8800	0.7800	0.8800	40.0000	32.6000	97.0000	78.0000
♦ 473:	5.0000	400.000	650.400	0.6800	20.5800	0.7900	0.9600	40.0000	33.3000	96.0000	90.0000
♦ 474:	5.0000	500.000	606.300	0.7000	22.4300	0.9000	1.0600	42.0000	34.7000	96.0000	90.0000
♦ 475:	5.0000	600.000	720.600	0.7600	26.0500	1.0500	1.1600	42.0000	34.7000	97.0000	96.0000
♦ 476:	5.0000	700.000	764.000	0.8000	28.4500	1.1600	1.2900	41.0000	35.4000	96.0000	102.000
♦ 477:	5.0000	800.000	1007.40	0.9400	33.6500	1.4300	1.5900	44.0000	36.8000	95.0000	114.000
♦ 478:	5.0000	900.000	1043.40	1.1000	36.1500	1.6100	1.7700	46.0000	38.2000	95.0000	120.000
♦ 479:	5.0000	1000.00	1212.20	1.1600	40.3000	1.8000	1.8800	46.0000	38.9000	96.0000	126.000
♦ 480:	5.0000	1100.00	1432.23	1.2000	43.0500	1.9600	2.0400	46.0000	38.9000	96.0000	132.000
♦ 481:	5.0000	1200.00	1384.70	1.3200	47.9300	2.2200	2.3100	47.0000	40.4000	95.0000	138.000
♦ 482:	5.0000	1300.00	1700.70	1.2600	51.0300	2.4300	2.4600	48.0000	41.1000	93.0000	150.000
♦ 483:	5.0000	1400.00	1370.60	1.4200	54.3800	2.6000	2.5600	48.0000	41.4000	92.0000	150.000
♦ 484:	5.0000	1500.00	1354.90	1.4400	61.2000	2.9300	2.8300	50.0000	41.1000	92.0000	156.000
♦ 485:	5.0000	1600.00	1456.10	1.5000	65.8800	3.2500	3.0400	50.0000	42.5000	91.0000	156.000
♦ 486:	5.0000	1700.00	1587.20	1.6000	69.8000	3.5400	3.2300	51.0000	43.9000	89.0000	162.000

Tab 7.3.5.6 Individual data of subject 5, E2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	$\dot{V}$I 8.	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 547:	5.0000	0.0000	1.7500	23.9000	0.5400	0.5300	21.2200	2.6200	1.1000	0.4198	1.5200
• 548:	5.0000	100.000	2.2500	26.0700	0.5300	0.8600	28.2400	1.9800	0.9200	0.4646	1.0600
• 549:	5.0000	200.000	2.7500	28.9800	0.5300	0.8500	28.6700	2.1500	0.8400	0.3907	1.3100
• 550:	5.0000	300.000	3.0000	31.6600	0.5300	1.1200	27.8900	2.0800	0.7200	0.3462	1.3600
• 551:	5.0000	400.000	3.7500	36.4800	0.6800	1.3900	31.8900	1.9200	0.6700	0.3490	1.2500
• 552:	5.0000	500.000	4.0000	42.8700	0.7000	1.3700	30.8700	2.0800	0.8300	0.4150	1.1700
• 553:	5.0000	600.000	4.0000	46.8000	0.8600	1.6000	29.8000	2.0000	0.6800	0.3400	1.3200
• 554:	5.0000	700.000	4.5000	47.5300	0.9000	1.6900	30.6100	1.9200	0.8200	0.4271	1.1000
• 555:	5.0000	800.000	4.7500	47.3400	1.0100	1.8000	30.4500	1.9200	0.8200	0.4271	1.1000
• 556:	5.0000	900.000	6.0000	52.3700	1.0500	1.9900	30.5500	1.9900	0.7000	0.3518	1.2900
• 557:	5.0000	1000.00	6.7500	52.7300	1.0300	2.1500	32.5100	1.8000	0.7000	0.3889	1.1000
• 558:	5.0000	1100.00	7.2500	62.4400	1.1200	2.3000	33.4000	1.7300	0.6300	0.3642	1.1000
• 559:	5.0000	1200.00	8.7500	68.3400	1.1800	2.3000	34.4800	1.7100	0.6200	0.3626	1.0900
• 560:	5.0000	1300.00	9.0000	71.4200	1.2400	2.5700	37.2800	1.6300	0.6400	0.3926	0.9900
• 561:	5.0000	1400.00	9.5000	74.0100	1.3700	2.7800	35.1900	1.7100	0.6400	0.3743	1.0700
• 562:	5.0000	1500.00	10.0000	87.0000	1.4400	3.0100	37.0600	1.6000	0.6800	0.4250	0.9200

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}$E 9	$\dot{V}$CO2 13	$\dot{V}$O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 547:	5.0000	0.0000	462.600	0.3000	11.5400	0.3200	0.3400	34.0000	23.3000	95.0000	60.0000
• 548:	5.0000	100.000	547.900	0.4000	15.2000	0.4600	0.5600	38.0000	26.2000	95.0000	72.0000
• 549:	5.0000	200.000	596.300	0.4000	15.0500	0.4900	0.7100	40.0000	28.3000	94.0000	78.0000
• 550:	5.0000	300.000	630.300	0.5000	14.8500	0.5400	0.8200	43.0000	31.8000	94.0000	84.0000
• 551:	5.0000	400.000	835.500	0.6000	21.5300	0.8300	1.1000	43.0000	33.2000	95.0000	90.0000
• 552:	5.0000	500.000	1049.40	0.6200	21.1300	0.8700	1.1300	44.0000	36.1000	93.0000	102.000
• 553:	5.0000	600.000	1010.20	0.8000	25.7000	1.0900	1.2900	44.0000	36.8000	94.0000	102.000
• 554:	5.0000	700.000	1215.20	0.7000	27.6300	1.2200	1.4000	46.0000	38.2000	94.0000	114.000
• 555:	5.0000	800.000	1291.10	0.8000	30.7500	1.3900	1.5800	47.0000	38.9800	93.0000	120.000
• 556:	5.0000	900.000	1332.00	0.8400	32.0800	1.5100	1.7000	48.0000	40.7000	94.0000	120.000
• 557:	5.0000	1000.00	1284.20	0.9000	33.3300	1.6000	1.8200	49.0000	41.7000	92.0000	132.000
• 558:	5.0000	1100.00	1389.40	1.0000	37.5300	1.8500	2.0700	49.0000	42.8000	91.0000	138.000
• 559:	5.0000	1200.00	1527.50	1.0300	40.7800	2.0600	2.2300	52.0000	43.5000	91.0000	144.000
• 560:	5.0000	1300.00	1804.40	1.0500	46.3300	2.3100	2.4300	52.0000	43.1000	90.0000	144.000
• 561:	5.0000	1400.00	1703.20	1.3000	48.3000	2.4600	2.5300	51.0000	44.2000	90.0000	150.000
• 562:	5.0000	1500.00	1930.80	1.3900	53.3300	2.7100	2.7500	52.0000	43.8000	89.0000	150.000

Tab 7.3.5.7 Individual data of subject 5, E3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 649:	5.0000	0.0000	0.0000	2.0500	0.5400	0.8300	22.5600	2.8900	1.0100	0.3495	1.8800
♦ 650:	5.0000	100.000	0.0000	2.8000	0.7000	0.9500	24.1900	2.8000	1.1200	0.4000	1.6800
♦ 651:	5.0000	200.000	0.0000	3.2000	0.8500	1.2800	22.5700	2.8000	1.1000	0.3929	1.7000
♦ 652:	5.0000	300.000	0.5000	2.7000	0.9900	1.3500	21.3900	2.6600	1.0400	0.3910	1.6200
♦ 653:	5.0000	400.000	0.5000	3.3000	1.0600	1.5500	21.5300	3.1000	1.1300	0.3645	1.9700
♦ 654:	5.0000	500.000	0.5000	3.9000	1.1100	1.5600	23.2300	2.8000	1.1700	0.4179	1.6300
♦ 655:	5.0000	600.000	0.5000	3.6000	1.2900	1.5000	22.8000	3.0500	1.2500	0.4098	1.8000
♦ 656:	5.0000	700.000	1.0000	3.0500	1.4800	1.6400	19.6800	3.1000	1.2300	0.3968	1.8700
♦ 657:	5.0000	800.000	1.0000	4.3000	1.7000	1.9600	20.1800	3.0000	1.2300	0.4100	1.7700
♦ 658:	5.0000	900.000	1.2500	4.3000	1.8700	2.2700	20.5300	2.8000	1.2000	0.4286	1.6000
♦ 659:	5.0000	1000.00	1.2500	5.2000	1.9700	1.9800	20.5600	2.6000	1.1800	0.4538	1.4200
♦ 660:	5.0000	1100.00	1.7500	5.0000	1.8700	2.3400	22.0100	2.5500	1.0700	0.4196	1.4800
♦ 661:	5.0000	1200.00	1.7500	6.0000	2.0300	2.2100	22.1200	2.5000	1.1300	0.4520	1.3700
♦ 662:	5.0000	1300.00	2.2500	6.1000	2.0300	2.4200	24.2300	2.4000	1.0600	0.4417	1.3400
♦ 663:	5.0000	1400.00	2.2500	6.0000	2.0600	2.6000	26.7600	2.2000	1.0400	0.4727	1.1600
♦ 664:	5.0000	1500.00	2.7500	7.3000	2.2000	2.8300	24.7900	2.3700	1.0600	0.4473	1.3100
♦ 665:	5.0000	1600.00	3.2500	8.8000	[illegible].3100	2.9900	25.6400	2.3000	1.0600	0.4609	1.2400
♦ 666:	5.0000	1700.00	3.2500	8.8000	2.4700	3.1000	25.3900	2.3200	1.0200	0.4397	1.3000
♦ 667:	5.0000	1800.00	4.0000	9.9000	2.4600	3.6000	32.0000	1.7400	0.8400	0.4828	0.9000
♦ 668:	5.0000	1900.00	4.5000	12.5000	2.7700	3.8400	35.8300	1.6600	0.8000	0.4819	0.8600
♦ 669:	5.0000	2000.00	4.5000	14.3000	2.8600	4.2700	38.2000	1.5000	0.7200	0.4800	0.7800

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}E$ 9	$\dot{V}CO2$ 13	$\dot{V}O2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 649:	5.0000	0.0000	26.8000	0.5300	12.0800	0.3400	0.4000	34.0000	24.0000	96.0000	66.0000
♦ 650:	5.0000	100.000	27.2000	0.6500	16.8800	0.5100	0.5800	39.0000	26.8000	97.0000	78.0000
♦ 651:	5.0000	200.000	32.0200	0.8800	19.0800	0.6300	0.7700	40.0000	30.4000	96.0000	90.0000
♦ 652:	5.0000	300.000	32.8900	0.9300	21.1800	0.7200	0.9000	40.0000	29.7000	96.0000	90.0000
♦ 653:	5.0000	400.000	42.8700	1.1100	22.8300	0.8500	1.0100	41.0000	31.8000	96.0000	90.0000
♦ 654:	5.0000	500.000	39.7900	1.2500	25.7300	0.9800	1.1100	40.0000	33.2000	96.0000	96.0000
♦ 655:	5.0000	600.000	38.9000	1.0800	29.4000	1.1200	1.2200	42.0000	33.7000	97.0000	96.0000
♦ 656:	5.0000	700.000	49.4000	1.3400	29.1800	1.1900	[illegible].3300	42.0000	34.6000	96.0000	102.000
♦ 657:	5.0000	800.000	54.8000	1.6200	34.2500	1.4000	1.5400	44.0000	35.3000	97.0000	114.000
♦ 658:	5.0000	900.000	66.3000	1.7000	38.4000	1.6100	1.7900	44.0000	36.0000	96.0000	120.000
♦ 659:	5.0000	1000.00	186.860	1.6000	40.4500	1.6900	1.8300	44.0000	36.0000	97.0000	114.000
♦ 660:	5.0000	1100.00	94.2200	1.7000	41.0800	1.7200	1.8600	44.0000	34.7000	98.0000	120.000
♦ 661:	5.0000	1200.00	94.9600	1.7300	44.9500	1.8800	2.0700	46.0000	35.3000	97.0000	120.000
♦ 662:	5.0000	1300.00	99.4600	1.8200	49.1300	2.0300	2.1500	46.0000	35.3000	97.0000	126.000
♦ 663:	5.0000	1400.00	110.900	1.9300	53.8800	2.2200	2.3500	45.0000	35.3000	97.0000	132.000
♦ 664:	5.0000	1500.00	104.870	1.8900	54.5300	2.3200	2.4500	46.0000	37.4000	98.0000	138.000
♦ 665:	5.0000	1600.00	102.640	2.1700	59.7300	2.5400	2.6100	47.0000	37.4000	97.0000	138.000
♦ 666:	5.0000	1700.00	126.950	2.1200	62.7800	2.7000	2.7100	44.0000	37.4000	97.0000	150.000
♦ 667:	5.0000	1800.00	205.570	2.2600	78.6500	3.2000	3.1000	46.0000	36.0000	96.0000	168.000
♦ 668:	5.0000	1900.00	188.240	7.2100	99.0800	4.1000	3.5700	46.0000	36.0000	97.0000	168.000
♦ 669:	5.0000	2000.00	279.170	2.3000	189.480	4.1000	3.7000	45.0000	34.6000	96.0000	174.000

Tab 7.3.5.8 Individual data of subject 5, C2.

Oflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
97:	6.0000	0.0000	0.0000	1.8000	0.5600	0.9000	14.0000	3.5900	0.9700	0.2700	2.6200
98:	6.0000	100.000	0.0000	2.2000	0.6300	1.4000	15.0000	4.6900	1.5000	0.3200	3.1900
99:	6.0000	200.000	0.0000	2.6000	1.3700	1.6000	15.4000	3.3000	1.1000	0.3333	2.2000
100:	6.0000	300.000	0.0000	2.6800	1.1200	1.3000	18.7000	2.9000	1.2000	0.4138	1.7000
101:	6.0000	400.000	0.0000	3.2000	1.7600	1.4600	16.7600	3.6000	1.5000	0.4167	2.1000
102:	6.0000	500.000	0.0000	3.4000	1.8500	1.5000	13.7400	3.9800	1.8000	0.4523	2.1800
103:	6.0000	600.000	0.0000	3.7000	1.5500	1.7000	17.7000	3.5000	1.4600	0.4171	2.0400
104:	6.0000	700.000	0.0000	5.0000	1.7200	1.8000	18.5400	3.4500	1.5500	0,4493	1.9000
105:	6.0000	800.000	0.0000	6.1000	1.8800	1.9800	19.9200	3.1000	1.5100	0.4871	1.5900
106:	6.0000	900.000	0.5000	6.1000	1.9100	2.3000	22.6900	2.9100	1.4900	0.5120	1.4200
107:	6.0000	1000.00	0.5000	7.8000	2.5000	2.3000	18.2000	3.8500	1.9000	0.4935	1.9500
108:	6.0000	1100.00	1.0000	8.0000	2.3400	2.6000	22.3500	2.5800	1.2700	0.4922	1.3100
109:	6.0000	1200.00	1.7500	11.8000	3.0400	3.0000	20.7600	3.2000	1.7700	0.5531	1.4300
110:	6.0000	1300.00	3.7500	13.3000	3.4400	3.2000	20.7200	3.4000	2.0000	0.5882	1.4000
111:	6.0000	1400.00	5.5000	19.3000	3.3700	3.1000	23.6500	2.5000	1.6900	0.6760	0.8100

Oflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 18
97:	6.0000	0.0000	15.0000	0.5600	7.8400	0.2700	0.3300	28.0000	23.0000	97,0000	78.0000
98:	6.0000	100.000	78.1000	0.6100	9.4500	0.5100	0.6200	29.0000	24.0000	97.0000	85.0000
99:	6.0000	200.000	44.4000	1.4400	21.1800	0.5900	0.7000	20.0000	18.5000	96.0000	90.0000
100:	6.0000	300.000	29.9000	1.2000	20.9700	0.6400	0.8400	24.0000	20.0000	96.0000	94.0000
101:	6.0000	400.000	26.9000	1.5000	21.1500	0.7000	0.9700	28.0000	23.0000	95.0000	98.0000
102:	6.0000	500.000	28.3000	1.8900	25.4300	0.8600	1.0700	26.0000	21.0000	95.0000	100.000
103:	6.0000	600.000	39.6000	1.6700	27.5000	0.9500	1.1400	26.0000	22.0000	96.0000	105.000
104:	6.0000	700.000	46.3000	1.6000	31.4600	1.0900	1.2700	26.0000	22.0000	96.0000	113.000
105:	6.0000	800.000	55.7000	2.1000	37.3800	1.3000	1.4900	26.0000	22.0000	96.0000	117.000
106:	6.0000	900.000	78.0000	2.1000	43.4300	1.4900	1.6200	26.0000	21.0000	96.0000	120.000
107:	6.0000	1000.00	80.0000	2.8000	45.7000	1.6200	1.7600	26.0000	23.0000	96.0000	125.000
108:	6.0000	1100.00	90.0000	2.1000	52.2300	1.8200	1.9400	24.0000	20.0000	96.0000	130.000
109:	6.0000	1200.00	114.470	3.4000	63.0600	2.1800	2.2100	25.0000	20.0000	96.0000	135.000
110:	6.0000	1300.00	136.800	3.8000	71.3500	2.4400	2.4200	24.0000	20.0000	96.0000	140.000
111:	6.0000	1400.00	155.800	2.8000	79.7500	2.5900	2.5500	26.0000	22.0000	97.0000	145.000

Tab 7.3.6.1 Individual data of subject 6, Cl.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 183:	6.0000	0.0000	0.5000	6.5000	1.6500	0.4530	6.8400	5.5600	2.9000	0.5216	7.6600
• 184:	6.0000	100.000	0.5000	9.0000	1.4800	0.6000	8.3000	6.2000	3.6500	0.5887	7.5500
• 185:	6.0000	200.000	0.7500	10.2000	2.6300	0.8000	6.1800	13.0000	9.0000	0.6923	4.0000
• 186:	6.0000	300.000	1.0000	17.1000	2.7500	1.0000	7.0900	6.5500	4.3500	0.6641	2.2000
• 187:	6.0000	400.000	1.0000	19.8000	2.4400	1.1300	10.0500	5.5000	3.7300	0.6782	1.7700
• 188:	6.0000	500.000	1.2500	23.1000	2.8700	1.1000	9.5400	6.1500	4.3000	0.6992	1.8500
• 189:	6.0000	600.000	1.7500	20.1000	2.5900	1.1300	12.1300	5.6500	4.0500	0.7168	1.6000
• 190:	6.0000	700.000	2.7500	22.5000	3.1200	1.2000	11.3000	5.2300	3.6700	0.7017	1.5600
• 191:	6.0000	800.000	3.7500	27.6000	3.1100	1.4000	12.5000	4.0000	2.9500	0.7375	1.0500
• 192:	6.0000	900.000	8.7500	33.8000	3.2900	1.6000	13.4200	3.6300	2.6700	0.7355	0.9600
• 193:	6.0000	1000.00	10.0000	58.7000	2.7200	1.8300	19.0200	3.1500	2.3000	0.7302	0.8500

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 17	HR 10
• 183:	6.0000	0.0000	145.500	1.0000	11.2700	0.3400	0.4000	35.0000	28.1000	95.0000	78.0000
• 184:	6.0000	100.000	225.900	1.7000	12.3000	0.4400	0.5800	39.0000	31.6000	97.0000	90.0000
• 185:	6.0000	200.000	311.500	2.8000	16.2500	0.6200	0.8400	43.0000	33.0000	96.0000	96.0000
• 186:	6.0000	300.000	514.400	2.9000	19.4800	0.8000	1.0600	41.0000	35.2000	97.0000	96.0000
• 187:	6.0000	400.000	598.000	2.8000	24.4800	1.0000	1.7300	41.0000	35.2000	97.0000	108.000
• 188:	6.0000	500.000	596.400	3.2000	27.3500	1.1500	1.3400	40.0000	33.0000	97.0000	108.000
• 189:	6.0000	600.000	717.500	3.5000	31.4300	1.2900	1.4800	41.0000	33.5000	96.0000	114.000
• 190:	6.0000	700.000	886.700	3.8000	35.2500	1.4400	1.5900	41.0000	33.0000	96.0000	120.000
• 191:	6.0000	800.000	1011.80	3.1000	38.8300	1.6000	1.7600	42.0000	35.2000	97.0000	132.000
• 192:	6.0000	900.000	1295.20	3.6000	44.1300	1.8300	1.9900	43.0000	35.9000	97.0000	138.000
• 193:	6.0000	1000.00	1685.50	2.9500	51.7000	2.1500	2.2300	43.0000	35.9000	95.0000	150.000

Tab 7.3.6.2 Individual data of subject 6, R1.

Dflag	CODE 1	KPM 4	cor Rorg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 249:	6.0000	0.0000	0.5000	0.0000	1.2700	0.3000	7.2900	10.7300	6.4300	0.5993	4.3000
• 250:	6.0000	100.000	0.5000	23.6000	1.5400	0.4200	8.6700	5.1300	3.1000	0.6199	1.9500
• 251:	6.0000	200.000	1.0000	24.0000	1.5400	0.4800	10.5500	7.5000	5.0700	0.6760	2.4300
• 252:	6.0000	300.000	1.2500	36.5000	1.6600	0.6400	10.9000	3.5200	2.4200	0.6875	1.1000
• 253:	6.0000	400.000	2.2500	41.1000	2.0600	0.6900	10.9300	3.3000	2.3700	0.7030	0.9800
• 254:	6.0000	500.000	3.7500	50.3000	1.9500	0.8000	13.0300	4.2500	3.7600	0.8847	0.4900
• 255:	6.0000	600.000	6.2500	50.4000	2.4900	0.9200	11.9900	4.3400	3.6000	0.8295	0.7400
• 256:	6.0000	700.000	8.2500	57.4000	2.7500	1.0000	14.8100	5.2600	4.4000	0.8365	0.8600
• 257:	6.0000	800.000	10.0000	67.2000	2.5600	1.0000	18.6000	4.0600	3.3800	0.8325	0.6800

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}E$ 9	$\dot{V}CO2$ 13	$\dot{V}O2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 249:	6.0000	0.0000	234.400	1.3000	8.7300	0.3900	0.5300	38.0000	29.1000	95.0000	78.0000
• 250:	6.0000	100.000	673.700	1.0500	13.3800	0.5000	0.6700	37.0000	31.9000	97.0000	102.000
• 251:	6.0000	200.000	593.300	1.6500	16.2000	0.6200	0.8500	38.0000	33.4000	95.0000	102.000
• 252:	6.0000	300.000	944.600	1.2300	18.1000	0.6900	0.9500	38.0000	33.4000	95.0000	105.000
• 253:	6.0000	400.000	973.800	1.2800	22.5500	0.8600	1.1500	40.0900	33.4000	96.0000	108.000
• 254:	6.0000	500.000	1274.40	1.8300	25.3800	0.9900	1.2600	40.0000	34.1000	95.0000	108.000
• 255:	6.0000	600.000	1418.40	2.0200	29.8300	1.1800	1.4300	40.0000	34.1000	95.0000	120.000
• 256:	6.0000	700.000	1784.60	2.7000	33.0000	1.3300	1.5800	40.0000	34.8000	96.0000	126.000
• 257:	6.0000	800.000	1761.30	2.0400	37.9700	1.5100	1.7400	42.0000	34.9000	95.0000	132.000

Tab 7.3.6.3 Individual data of subject 6, R2.

	CODE	KPM	cor Borg	P-MOUTH	Vt	$\dot{V}$I	FB	TTOT	TI	Ti/Ttot	TE
Dflag	1	4	29	20	21	8	7	5	19	25	28
301:	6.0000	0.0000	2.7500	24.0800	1.8600	0.3300	5.1000	9.2000	6.7000	0.7283	2.5000
302:	6.0000	100.000	3.2500	37.1500	1.9300	0.5300	7.0600	9.7000	6.8000	0.7000	2.9000
303:	6.0000	200.000	4.0000	36.1000	2.3100	0.4500	6.9700	10.9000	8.6000	0.7890	2.3000
304:	6.0000	300.000	4.5800	38.4600	2.5100	0.5000	6.6800	6.8700	5.6000	0.8151	1.2700
305:	6.0000	400.000	6.2500	55.3800	2.7300	0.5800	7.8800	7.3000	5.9000	0.8082	1.4000
306:	6.0000	500.000	9.0000	56.7300	1.8900	0.5300	12.2800	6.5000	5.1000	0.7846	1.4000
307:	6.0000	600.000	10.0000	76.6700	1.8400	0.6300	15.1200	4.1000	3.3000	0.8049	0.8000

	CODE	KPM	P*TIME	Vt	$\dot{V}$E	$\dot{V}$CO2	$\dot{V}$O2	PETCO2	PECO2	SAO2	HR
Dflag	1	4	22	6	9	13	14	11	36	17	18
301:	6.0000	0.0000	431.000	1.9500	9.6100	0.3700	0.4500	38.0000	34.0000	94.0000	84.0000
302:	6.0000	100.000	946.100	1.9000	13.6000	0.5500	0.7000	42.0000	34.7000	95.0000	102.000
303:	6.0000	200.000	1202.40	1.9500	15.9700	0.6500	0.8500	41.0000	35.0000	93.0000	96.0000
304:	6.0000	300.000	1393.40	1.7700	16.7800	0.7300	0.9500	40.0000	36.0000	93.0000	96.0000
305:	6.0000	400.000	1750.20	2.2000	21.2500	0.9300	1.1900	42.0000	36.0000	94.0000	108.000
306:	6.0000	500.000	1782.40	1.6500	23.2000	1.0500	1.2800	38.0000	34.0000	95.0000	120.000
307:	6.0000	600.000	2420.40	1.7800	27.8700	1.2500	1.5000	43.0000	38.0000	94.0000	126.000

Tab 7.3.6.4 Individual data of subject 6, R3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 398:	6.0000	0.0000	0.0000	13.8000	0.9800	0.8000	14.1000	4.2000	1.6000	0.3810	2.6000
• 399:	6.0000	100.000	0.0000	13.4000	1.4500	0.5500	11.3000	4.6000	1.2000	0.2609	3.4000
• 400:	6.0000	200.000	0.0000	33.4000	1.5200	2.7000	10.1000	6.7000	0.9000	0.1343	5.8000
• 401:	6.0000	300.000	0.0000	28.5000	1.3200	1.8000	12.5000	4.9500	1.1000	0.2222	3.8500
• 402:	6.0000	400.000	0.0000	24.2000	1.4200	1.8300	16.2000	4.0700	1.0500	0.2580	3.0200
• 403:	6.0000	500.000	0.5000	30.9000	1.4400	1.8000	17.0000	2.9600	1.0800	0.3649	1.8800
• 404:	6.0000	600.000	1.0000	36.5000	1.8100	2.2000	15.2000	3.3700	1.0700	0.3175	2.3000
• 405:	6.0000	700.000	1.2500	35.2000	1.6000	2.1500	19.9000	3.3700	1.2700	0.3769	2.1000
• 406:	6.0000	800.000	1.7500	43.8000	2.0600	3.0000	29.4000	2.8000	0.9300	0.3321	1.8700
• 407:	6.0000	900.000	2.2500	39.8000	2.2000	2.7300	20.8000	2.6500	0.9000	0.3396	1.7500
• 408:	6.0000	1000.00	3.2500	46.8000	2.3200	3.2000	20.6000	2.7800	1.0200	0.3669	1.7600
• 409:	6.0000	1100.00	3.7500	52.0000	2.5500	3.7000	23.3000	2.3000	0.9000	0.3913	1.4000
• 410:	6.0000	1200.00	4.5000	50.1000	2.5800	3.9000	25.8000	2.1000	0.8500	0.4048	1.2500
• 411:	6.0000	1300.00	6.2500	56.6000	2.6200	4.1000	28.9000	1.8400	0.7100	0.3859	1.1300
• 412:	6.0000	1400.00	8.2500	53.7000	2.4900	4.2000	36.5000	1.6900	0.7300	0.4320	0.9600

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
• 398:	6.0000	0.0000	210.100	0.6300	12.6200	0.3600	0.4300	31.0000	24.9000	95.0000	98.0000
• 399:	6.0000	100.000	161.600	0.4500	16.3000	0.5000	0.5900	33.0000	26.3000	96.0000	90.0000
• 400:	6.0000	200.000	201.000	1.5000	15.4000	0.5100	0.7000	36.0000	29.2000	95.0000	84.0000
• 401:	6.0000	300.000	291.300	1.5000	16.5000	0.5900	0.8300	38.0000	31.3000	96.0000	96.0000
• 402:	6.0000	400.000	320.800	1.3000	23.0000	0.8300	1.0900	38.0000	31.6000	94.0000	96.0000
• 403:	6.0000	500.000	360.400	1.4000	24.4000	0.9100	1.1900	38.0000	32.4000	95.0000	102.000
• 404:	6.0000	600.000	314.600	1.4700	27.4000	1.0700	1.2300	39.0000	32.0000	95.0000	102.000
• 405:	6.0000	700.000	559.200	1.5500	31.8000	1.1800	1.4000	38.0000	32.0000	95.0000	108.000
• 406:	6.0000	800.000	483.500	1.8800	42.0000	1.5100	1.6000	38.0000	31.7000	96.0000	114.000
• 407:	6.0000	900.000	538.700	1.8200	45.6000	1.6600	1.7000	38.0000	31.3000	96.0000	120.000
• 408:	6.0000	1000.00	648.900	2.3000	48.4000	1.7500	1.8500	38.0000	31.3000	96.0000	132.000
• 409:	6.0000	1100.00	706.000	2.4000	59.3000	2.1200	2.1600	37.0000	30.6000	96.0000	138.000
• 410:	6.0000	1200.00	709.500	2.3000	66.3000	2.3000	2.3000	35.0000	29.9000	96.0000	150.000
• 411:	6.0000	1300.00	786.100	2.2700	75.9000	2.5300	2.5000	34.0000	29.2000	97.0000	156.000
• 412:	6.0000	1400.00	865.100	2.3000	90.9000	2.8600	2.8000	34.0000	27.7000	97.0000	168.000

Tab 7.3.6.5 Individual data of subject 6, El.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	V̇I 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 487:	6.0000	0.0000	1.0000	-14.7000	1.1900	0.6500	8.1300	7.7000	4.5000	0.5844	3.2000
♦ 488:	6.0000	100.000	1.2500	29.2300	1.4800	0.7700	8.6300	6.0000	3.5000	0.5800	2.5000
♦ 489:	6.0000	200.000	1.7500	40.5000	1.8300	0.8500	8.8200	4.3000	2.5000	0.5814	1.8000
♦ 490:	6.0000	300.000	3.2500	34.6800	1.7800	1.4000	10.8400	4.3000	2.4000	0.5581	1.9000
♦ 491:	6.0000	400.000	4.5000	47.8400	1.8000	1.6000	11.7600	3.3000	1.8000	0.5455	1.5000
♦ 492:	6.0000	500.000	6.2500	48.3900	1.5100	1.5000	17.5800	3.1000	1.4000	0.4516	1.7000
♦ 493:	6.0000	600.000	10.0000	50.4100	1.3100	2.1000	25.8900	2.2000	1.1000	0.5000	1.1000
♦ 494:	6.0000	700.000	10.0000	47.4400	1.4100	2.0000	27.3600	2.3000	1.3000	0.5652	1.0000
♦ 495:	6.0000	800.000	10.0000	45.4800	1.2300	1.9500	32.5900	1.7000	0.9500	0.5588	0.7500
♦ 496:	6.0000	900.000	10.0000	53.7000	1.4200	2.9000	34.2000	1.7000	0.8500	0.5000	0.8500
♦ 497:	6.0000	1000.00	10.0000	55.8600	1.5900	3.3000	33.7500	1.6700	0.7600	0.4551	0.9100

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 18
♦ 487:	6.0000	0.0000	586.000	0.5000	9.7100	0.3500	0.4300	31.0000	24.5000	97.0000	78.0000
♦ 488:	6.0000	100.000	1029.60	0.8500	12.7300	0.5200	0.6800	38.0000	35.1000	95.0000	90.0000
♦ 489:	6.0000	200.000	1703.30	0.6400	16.1000	0.6600	0.8800	38.0000	34.0000	95.0000	90.0000
♦ 490:	6.0000	300.000	1224.60	0.8400	19.2800	0.8000	1.0800	40.0000	36.7000	95.0000	108.000
♦ 491:	6.0000	400.000	1556.70	1.1000	21.1800	0.9000	1.1600	39.0000	35.0000	94.0000	108.000
♦ 492:	6.0000	500.000	2271.20	1.0300	26.5500	1.1100	1.3500	44.0000	36.2000	95.0000	108.000
♦ 493:	6.0000	600.000	1640.20	1.0100	33.8500	1.3700	1.5300	38.0000	32.7000	96.0000	120.000
♦ 494:	6.0000	700.000	1521.40	1.2700	38.4800	1.5300	1.6400	40.0000	34.0000	96.0000	120.000
♦ 495:	6.0000	800.000	1449.40	1.2000	39.9300	1.5700	1.7300	40.0000	34.7000	96.0000	132.000
♦ 496:	6.0000	900.000	1552.70	1.5000	48.4000	1.9200	2.0100	39.0000	34.0000	96.0000	138.000
♦ 497:	6.0000	1000.00	1714.10	1.4000	53.7500	2.1100	2.0200	40.0000	35.0000	96.0000	144.000

Tab 7.3.6.6 Individual data of subject 6, E2.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 28	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
• 563:	6.0000	0.0000	0.5000	37.7000	0.5100	1.9700	22.1500	2.8000	0.4000	0.1429	2.4000
• 564:	6.0000	100.000	0.5000	26.7000	0.5500	1.5500	30.6000	1.1000	0.3000	0.2727	0.8000
• 565:	6.0000	200.000	1.2500	37.3000	0.6900	2.0700	32.7000	1.7000	0.4000	0.2353	1.3000
• 566:	6.0000	300.000	2.2500	55.0000	0.7700	2.6000	32.6000	1.9000	0.3700	0.1947	1.5300
• 567:	6.0000	400.000	3.2500	55.3000	0.9200	2.7000	31.0000	1.8300	0.4300	0.2350	1.4000
• 568:	6.0000	500.000	3.7500	52.7000	0.9100	2.7000	33.4000	1.9000	0.4000	0.2105	1.5000
• 569:	6.0000	600.000	4.5000	53.6000	0.9700	2.5000	32.9000	1.9600	0.5000	0.2551	1.4600
• 570:	6.0000	700.000	5.5000	63.4000	1.0400	2.9800	35.2000	1.8000	0.4700	0.2611	1.3300
• 571:	6.0000	800,000	6.2500	63.8000	1.1500	2.8000	36.2000	1.5000	0.4600	0.3067	1.0400
• 572:	6.0000	900.000	8.2500	64.4000	1.0800	3.1600	44.9000	1.2800	0.4500	0.3516	0.8300
• 573:	6.0000	1000.00	8.2500	63.2000	1.2900	3.2000	44.9000	1.2000	0.4000	0.3330	0.8000
• 574:	6.0000	1100.00	10.0000	78.6000	1.3600	3.7000	46.9000	1.1000	0.3800	0.3455	0.7200

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	$\dot{V}E$ 9	$\dot{V}CO2$ 13	$\dot{V}O2$ 14	PETCO2 11	PECO2 36	SAO2 12	HR 18
• 563:	6.0000	0.0000	281.300	0.5000	11.5400	0.3400	0.4300	34.0000	26.3000	96.0000	78.0000
• 564:	6.0000	100.000	284.600	0.4000	16.9000	0.5100	0.6900	36.0000	26.3000	96.0000	96.0000
• 565:	6.0000	200.000	434.900	0.6000	22.6000	0.7300	0.9500	36.0000	28.1000	95.0000	102.000
• 566:	6.0000	300.000	638.400	0.8000	26.0000	0.8400	1.1100	40.0000	28.4000	95.0000	102.000
• 567:	6.0000	400.000	660.300	0.9000	28.4000	0.9700	1.2400	38.0000	29.2000	95.0000	114.000
• 568:	6.0000	500.000	668.000	0.8000	30.4000	1.0500	1.3600	40.0000	31.3000	95.0000	114.000
• 569:	6.0000	600.000	875.100	0.9000	31.8000	1.1400	1.4100	40.0000	31.3000	95.0000	120.000
• 570:	6.0000	700.000	929.300	1.0000	36.7000	1.3100	1.5900	40.0000	30.9000	95.0000	126.000
• 571:	6.0000	800.000	1042.60	0.9800	41.4000	1.5400	1.8100	40.0000	32.4000	96.0000	132.000
• 572:	6.0000	900.000	1203.30	1.0200	48.6000	1.7600	1.8100	38.0000	31.3000	96.0000	138.000
• 573:	6.0000	1000.00	1167.40	1.1400	57.7000	2.0400	2.1800	39.0000	30.9000	97.0000	144.000
• 574:	6.0000	1100.00	1528.90	1.3000	63.8000	2.2400	2.3400	38.0000	30.9000	97.0000	150.000

Tab 7.3.6.7 Individual data of subject 6, E3.

Dflag	CODE 1	KPM 4	cor Borg 29	P-MOUTH 20	Vt 21	VI 8	FB 7	TTOT 5	TI 19	Ti/Ttot 25	TE 28
♦ 670:	6.0000	0.0000	0.0000	1.8000	0.5600	0.9300	15.3000	3.5700	0.9700	0.2717	2.6000
♦ 671:	6.0000	100.000	0.0000	2.2000	0.6300	1.4000	25.3000	4.8000	1.5500	0.3229	3.2500
♦ 672:	6.0000	200.000	0.0000	3.0000	0.9100	1.6900	22.8000	2.2600	0.9000	0.3982	1.3600
♦ 673:	6.0000	300.000	0.0000	3.4000	1.0800	1.8000	25.2000	2.2200	0.9600	0.4324	1.2600
♦ 674:	6.0000	400.000	0.5000	3.6000	1.2400	1.8800	19.2000	3.1500	1.1400	0.3619	2.0100
♦ 675:	6.0000	500.000	0.5800	3.9000	1.2400	1.8800	19.6000	3.7200	1.4600	0.3925	2.2600
♦ 676:	6.0000	600.000	1.0000	3.6000	1.2500	2.0200	17.7000	3.8500	1.4800	0.3844	2.3700
♦ 677:	6.0000	700.000	1.0000	4.1000	1.4000	2.1200	21.6000	2.9600	1.2600	0.4257	1.7000
♦ 678:	6.0000	800.000	1.7500	4.5000	1.4500	2.2700	20.7000	2.9900	1.3500	0.4515	1.6400
♦ 679:	6.0000	900.000	2.2500	4.4000	1.7100	2.2200	23.6000	2.7000	1.2700	0.4704	1.4300
♦ 680:	6.0000	1000.00	3.2500	4.6000	1.7100	2.3800	22.9000	3.4300	1.7000	0.4956	1.7300
♦ 681:	6.0000	1100.00	3.7500	8.3000	2.0500	2.9800	24.3000	2.6100	1.2400	0.4751	1.3700
♦ 682:	6.0000	1200.00	4.5000	7.0000	2.2200	2.2900	21.6000	2.4600	1.2500	0.5081	1.2100
♦ 683:	6.0000	1300.00	6.2500	9.0100	2.8100	3.9600	24.1000	2.5300	1.2700	0.5020	1.2600
♦ 684:	6.0008	1400.00	7.2500	10.1300	2.8700	3.4200	27.8000	1.9000	0.9600	0.5053	0.9400

Dflag	CODE 1	KPM 4	P*TIME 22	Vt 6	V̇E 9	V̇CO2 13	V̇O2 14	PETCO2 11	PECO2 36	SAO2 12	HR 10
♦ 670:	6.0000	0.0000	25.4900	0.6600	8.5800	0.2700	0.3500	34.0000	26.3000	95.0000	78.0000
♦ 671:	6.0000	100.000	47.7900	1.8800	15.9000	0.5100	0.6400	39.0000	29.1000	0.9500	90.0000
♦ 672:	6.0000	200.000	52.9700	1.0800	20.8000	0.7100	0.9600	40.0000	29.1000	95.0000	102.000
♦ 673:	6.0000	300.000	70.8000	1.5100	27.1000	0.9000	1.1600	33.0000	29.1000	95.0000	102.000
♦ 674:	6.0000	400.000	60.3400	1.7000	23.7000	0.8500	1.1000	39.0000	39.1000	95.0000	102.000
♦ 675:	6.0000	500.000	58.2800	2.1200	24.5000	0.9100	1.1800	40.0000	32.0000	95.0000	102.000
♦ 676:	6.0000	600.000	69.2600	2.2400	24.8000	0.9300	1.1700	46.0000	32.0000	95.0000	102.000
♦ 677:	6.0000	700.000	73.7500	2.2000	31.3000	1.1300	1.3700	40.0000	32.0000	95.0000	108.000
♦ 678:	6.0000	800.000	94.8200	2.5000	35.5000	[illegible].3000	1.5300	40.0000	31.2000	94.0000	108.000
♦ 679:	6.0000	900.000	123.270	2.2400	40.3000	[illegible].4700	1.6700	40.0000	31.2000	95.0000	120.000
♦ 680:	6.0000	1000.00	112.780	3.0300	46.8000	1.6900	1.8500	40.0000	31.2000	95.0000	132.000
♦ 681:	6.0000	1100.00	146.870	3.0000	53.9000	1.9200	2.0700	40.0000	30.5000	95.0000	132.000
♦ 682:	6.0000	1200.00	178.570	3.2900	60.7000	2.1400	2.2400	39.0000	29.8000	95.0000	144.000
♦ 683:	6.0000	1300.00	208.020	3.5700	69.3000	2.3600	2.4600	37.0000	29.1000	96.0000	150.000
♦ 684:	6.0000	1400.00	221.740	4.4300	83.3000	2.6700	2.7500	37.0000	28.4000	96.0000	162.000

Tab 7.3.6.8 Individual data of subject 6, C2.

7.4 Added Inspiratory Mechanical Loads

External mechanical loads were used in this study (resistive and ealstic circuits) to simulate the resistive and elastic characteristics of the respiratory system. The structure of these two circuits are described in chapter 2. This section aims to expland the rationale of using these load.

7.4.1 Forces Generated by the Respiratory Muscles

The forces generated by the respiratory muscles are required to overcome the elastance of the system, the resistance opposing the airflow and the movement of lung tissues and chest wall, and the inertance of the system . The equation of motion that describes the generated forces to produce displacement and the opposing forces may be expressed as follows (Mead and Milic-Emili, 1964):

$$\mathrm{Pmus} = (\mathrm{Vt} * \mathrm{E}) + (\dot{\mathrm{V}} * \mathrm{R}) + (\ddot{\mathrm{V}} * \mathrm{I}) \quad \text{or}$$

$$\mathrm{Pmus} = \mathrm{P}_{\mathrm{E}} + \mathrm{P}_{\mathrm{R}} + \mathrm{P}_{\mathrm{I}}$$

where Pmus is the total pressure developed by the respiratory muscles, $\mathrm{P}_{\mathrm{E}} = \mathrm{Vt} * \mathrm{E}$ is the pressure generated to overcome the elastance to generate volume, $\mathrm{P}_{\mathrm{R}} = \dot{\mathrm{V}} * \mathrm{R}$ is pressure generated to overcome the resistance to generate flow, and $\mathrm{P}_{\mathrm{I}} = \ddot{\mathrm{V}} * \mathrm{I}$ is the pressure to overcome the inertance to produce acceleration. The inertance is very small in the respiratory system and can be ignored. When external loads are added the equation of motion of the respiratory system can be rewritted as follows:

$$Pmus = (VT * (E + \Delta E)) + (\dot{V} * (R + \Delta R))$$

where E is the externaly added elastance and R is the externally added resistance.

In the present study added elastic loads were used to alter the tidal volume, and added resistive loads were used to alter the inspiratory flow. Thus changes in tidal volume , inspiratory flow, and inspiratory pressure are independent of each other.

7.4.2 Mechanics of Added Elastic Loads

Elasticity is a property of a material that returns it to an original shape on cessation of a distorting force. As mentioned above the forces required to overcome the elastance of the respiratory system can be expressed as follows:

$$P_E = VT * E \quad \text{or} \quad E = P_E / Vt$$

The idea of breathing from an airtight rigid drum (D) is to increase the elastance of the system by changing the relationship between the pressure and volume. This change can be illustrated from the following examples. Suppose we have 3 airtight drums the capacity of each is 10 l (D1), 100 l (D2), and 1000 l (D3). If the drum is open to air the pressure in each drum will be 988 cmH20 (atmosphric pressure). The relationship between the pressure and the volume of the gas (air) in each drum is described by universal gas law: $P * V = NRT$

where P is the atmosphric pressure (988 cmH2), V is the volume occupied by the gas (= the volume of the drum), N is the number of the mole of the gas, R is a universal constant ,and T is the temperature. Thus the relation between the pressure and the volume of the gas in each drum is as follows:

For D1: 988 * 10 = N1 * R * T
for D2: 988 * 100 = N2 * R * T
for D3: 988 * 1000 = N3 * R * T

Suppose each drum is connected to a standard 2 liter syrnge by similar large diameter connecting tubes (Fig 7.4.1) and 1 l is extracted by each syringe from the corresponding drum without any change in the temperature. According to Boyle's law the new changes in pressure and volume (P2 * V2) equal the product of the initial pressure and volume in each drum (P1 * V1):

In D1 988 * 10 = P2 * 11 P2 = 898 cmH20
In D2 988 * 100 = P2 * 101 P2 = 978 cmH20
In D3 988 * 1000 = P2 * 1001 P2 = 987.01 cmH20

According to the third law of motion the applied force to extract one liter from any of these drums is the pressure difference between P1 and P2 which is -89.8 cmH20 in the first case, -9.8 cmH20 in the second case, and -0.99 cmH20 in the third case. If two liter is extracteded under the same conditions the required pressures will be - 164.7, - 19.4, -1.97 cmH20 and so forth if more volume is extracted. The flow will not affect the change in pressure as lon as the resistance is low.

Extrapolating this example to the respiratory system, the lungs represent the syringe and the inspiratory muscles represent the pump driving the syringe. Thus breathing from an airtight drum will add to the elastance of the respiratory system by affecting the relation of the tidal volume and the required pressure to achieve this volume. The smaller the airtight drum the higher is the pressure required to extract a given volume.

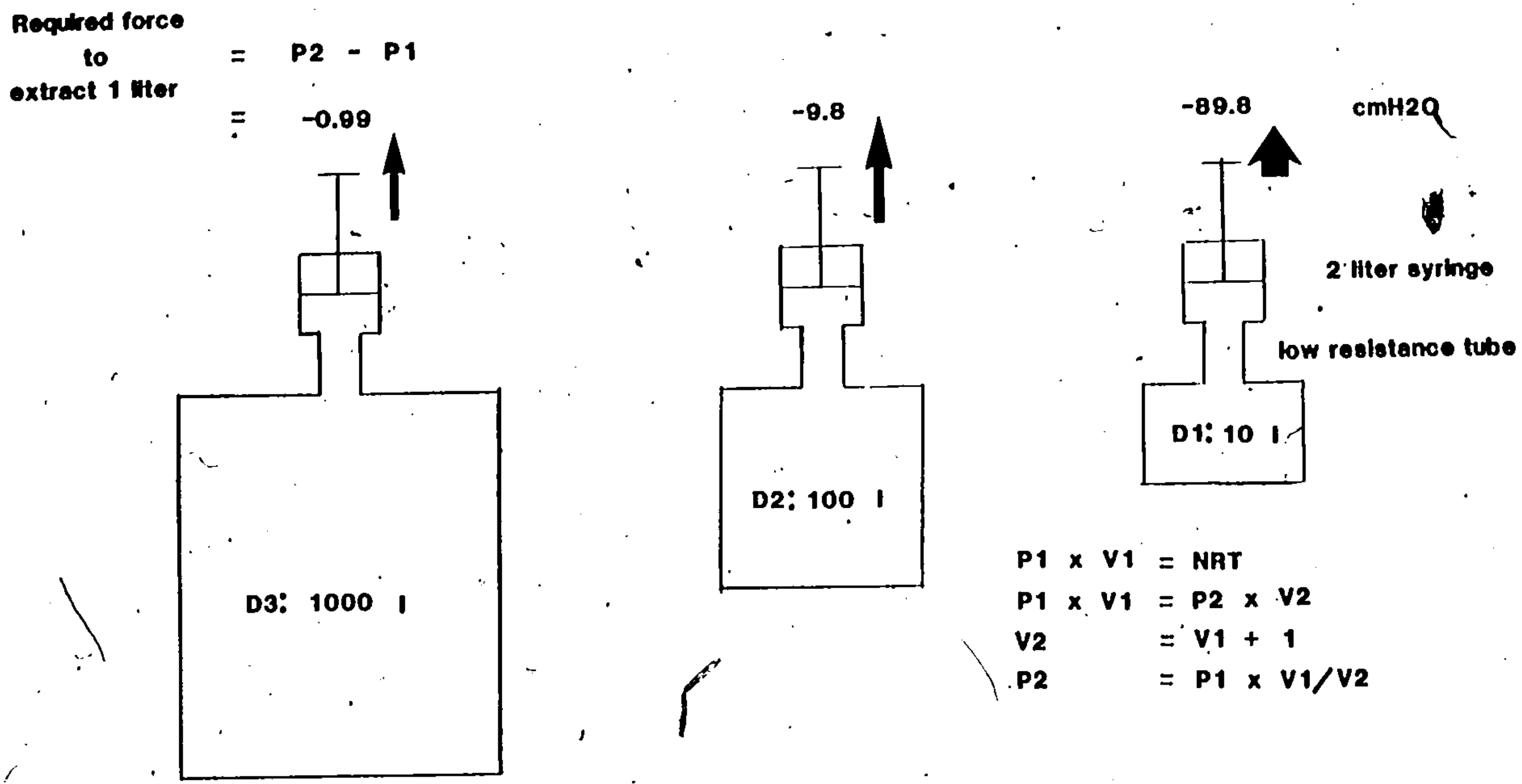
7.4.3 Mechanics of Added Resistive loads

Resistance means opposistion to motion which is caused by the forces of friction. As mentioned above, the required forces (pressure difference generated by the respiratory muscles) to move the air in and out the respiratory system is directly proportional to both the total resistance of the system (frictional forces) and the required airflow; $P = R * \dot{V}i$. To change the relationship between the flow and the required pressure to generate this flow the resistance can be changed. One way of changing the resistance is by having the subjects to breath from a brass tube from which segments of the wall were removed leaving longitudinal and circumfrential ribs. The tube itself is covered with filter paper and secured at the ribs by clamps. Resistances can be selected by moving a plunger with airtight seal from rib to rib. The resistance to airflow (breathing) in this tube will be proportional to property of the filter paper, the diameter and the length of the tube. To breath from this tube the air has to flow through the filter paper and then through the tube lumen. Thus the smaller the area of the wall through which the subjects are allowed to breath through, the higher is the resistance. The pressure difference required to move air from atmospher to the lungs through this tube will be proportional to the magnitude of the added resistance. This magnitude can be calculated by measuring the flow rate at orifice of the tube as well as the differential pressure between the mouth pressure (generated by te respiratory muscles to overcome the external resisance) and the atmospheric pressure from the equation $R = P / \dot{V}i$. Linearity of this resistance can be examined by having the subjects to target several airflows and measuring th pressure gradiant at each flow.

Conclusion

$$Pmus = Vt * (E + \Delta E) + \dot{V} * (R + \Delta R)$$

from a mechanical point of view increasing E is similar to increasing stiffness of the lung or chest wall where as increasing R is similar to narrowing airways.



Required force to extract 1 liter = P2 - P1 = -0.99

$P1 \times V1 = NRT$
$P1 \times V1 = P2 \times V2$
$V2 = V1 + 1$
$P2 = P1 \times V1/V2$

Fig 7.4.1 Illustrate the mechanics of the elastic loads. The required force to extract 1 liter progressively increases as the volume of the drum decreases.

7.5. Multiple Regression Analysis

Mutiple regression analysis is a general statistical technique used to analyse the relationship between a dependent variable and a set of independent contributers. This technique may be viewed as a descriptive tool or as inferenial tool. Using the technique as a descriptive tool, the linear dependance of one variable on others is summarized and decomposed. While using the technique as an inferential tool, the relationships in the population are evaluated from the examination of the sample data.

The basic principles of the multiple regression analysis is the same as that of the bivariate case. The general form of the regresiion is

$$Y' = A + B1 * X1 + B2 * X2 + B3 * X3 + \dots + Bk * Xk$$

where Y' represents the estimate value for Y (dependent variable), A is the Y intercept, the Bi are regression coefficients. The A and Bi coefficients are selected in such a way that the sum of squared residuals (Y - Y') is minimized. This least-squares criterion implies that any other values for A and Bi would yield a larger (Y - Y'). This also implies that the correlation between the actual Y values and the Y' estimated values is maximized, while the correlation between the independent variables and the residuals (Y - Y') is reduced to zero. A partial regression coefficient (Bi), represents the expected change in Y with a change of one unit in X1 when X2 through Xk are held constant. It can also be viewed as a simple B for the regression of Y on the residuals of X1 from which the effects of X2 through Xk are taken out.

As in bivariate case the total variation in the dependent variable (sums of squares in Y, SSy) can be partioned into two independent components, one that is explained by the regression (SSreg) and the other that is unexplained (SSres):

SSy = SSreg + SSres

The proportion of variance of the dependent variable explained (the goodness of fit of the regression equation) is evaluated by examining the square of multiple correlation which is the variation in the dependent variable explained by the combined linear influence of the independent variables (SSreg) divided by the total variation in the dependent variable (SSy). The contribution of a particular independent variable can also be evaluated by measuring the partial and part correlation of this variable. Part correlationis a simple correlation between the original dependent variable Y and the residual of independent variable X1 from which the effects of other independent variable X2 are taken out. It also means the absolute increment in R2 due to the addition of X1 to equation already containing X2. Partial correlation is simple correlation between two residuals, the residual of the dependent variable and the residual of the independent variable X1 from both of which the effects of X2 have taken out. It also means the proportional increment in explained variation due to X1 expressed as a proportion of the variation unexplained by X2.

Overall F test is used to determine the significant contribution of all the K independent variables taken together to the prediction of the dependent variable :

$$F = (SSreg/k) / (SSres/(N-K-1))$$

Where SSreg is the sum of squares explained by the entire regression equation, SSres is the residual unexplained sum of squares, K is the number of independent variables in the equation, and N is the sample size. Partial F test is used to assess whether or not the addition of any specific independent variable to the equation improves the prediction of the dependent variables and reduces the residuals:

$$\text{Partial } F = (\text{Incremental reg due to } X2/1) / (SSres/ (N - K - 1))$$

where the incrementa SSreg of a specific variable = (SSreg of all independent variable - SSreg of all the independent variable except the one examined).

In the present study the multiple regression analysis was used as a descriptive tool. Thus the relationship of the perceived magnitude of breathlessness (the dependent variable) and the pressure, inspiratory flow, tidal volume , frequency and duty cycle (the independent variables) were evaluated and their contribution to breathlessness was quantified.