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THE PHYSIOLOGICAL COST OF USING RESPIRATORY PROTECTIVE DEVICES AND ITS RELATIONSHIP TO AIR FLOW RESISTANCE

By

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B.S.E. Northeast Missouri State Teachers College, 1964

Presented in partial fulfillment of the requirements

for the degree of

Master of Science

UNIVERSITY OF MONTANA

1965

Approved by:

Chairman, Board of Examiners

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SHT

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CHAPTER I

THE PROBLEM AND ITS SCOPE[1]

Introduction. Research has been conducted by both private and governmental agencies on many aspects of respiratory protective equipment. However, the physiological work involved in the use of these devices and its relationship to the resistance of these devices to air flow is not fully understood at this time.

Investigators (11,9,4) have clearly found increased muscular activity associated with forced breathing. Various other studies (14,10,7,13) have produced evidence of reduced oxygen consumption, carbon dioxide elimination, and ventilation with the addition of a resistance to air flow. From this evidence it would appear that increased muscular work is being accomplished with no additional physiological cost to the individual.

Brouha, as reported in Johnson (3), explains that when oxygen delivery is inadequate to meet demands, anaerobic processes can substitute in part for aerobic processes, and energy may still be released. When exercise involving the anaerobic process stops, the consumption of oxygen remains

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[1]This study was completed under a cooperative agreement between the University of Montana Department of Health, Physical Education, and Athletics and the United States Department of Agriculture, United States Forest Service, the Missoula Equipment Development Center.

at an elevated level during the recovery period. The amount of oxygen consumed above the resting level indicates the size of the oxygen debt incurred as a result of the anaerobic work.

It was the hypothesis of this study that an increased physiological cost in the form of an oxygen debt results from the use of a respiratory protective device, and this cost is directly related to the amount of resistance to air flow produced in the device.

I. THE PROBLEM

Statement of the Problem. It was the purpose of this study (1) to compare, at three levels of work, the changes in oxygen consumption during the recovery that were due to the testing conditions, and (2) to relate these changes to the resistance of each mask to air flow.

Significance of the Study. Personnel of the United States Forest Service are often required to work in areas where the atmosphere is contaminated by fumes from burning organic matter. To insure their safety it is often necessary that they use respiratory protective equipment. Frequently, this equipment must be used for extended periods of time under working conditions. Consequently, it is important that methods be found through which the physiological work imposed by the use of this equipment may be indicated or measured, and the factors contributing to this work located.

This study also holds importance for the personnel working in exercise physiology. The collection of exhaled gas for analysis to determine energy expenditure is a common practice in this field. In many instances this requires the subject to wear a face mask of the type used in respiratory protective equipment. While these are relatively easy to breath through, there is a resistance similar to that found in the protective equipment. It is important that the researcher know if the use of this equipment is placing an additional work load on his subjects, so that it may be considered in the analysis.

In this study the oxygen consumption during recovery after the use of one of three masks was compared to that of the other two, and to a control condition to determine if a significant difference existed, showing increased oxygen debts and physiological work.

II. DEFINITIONS OF TERMS USED

The following terms are defined as they were used in this study.

Physiological Work. The metabolic rate as indicated by the rate of oxygen consumption.

Anaerobic Work. That work done without an adequate supply of oxygen to the functioning muscles.

Aerobic Work. Work in which the supply of oxygen meets the demands of the functioning muscles.

Oxygen Debt. The extent to which anaerobic processes were utilized to achieve performance as reflected by the rate of oxygen consumption during recovery.

Respiratory Protective Devices. Any device worn by an individual for the specific purpose of protecting the respiratory system, and not to include supplied air respirators which are essentially closed circuit systems.

Steady State. A steady state of physiological adjustment in which all the factors regulating a given function are in balance and maintaining the function at a constant level.

III. BASIC ASSUMPTIONS

The following assumptions were made for this study.

1. It was assumed that additional oxygen consumption during recovery, above that of the control conditions, was used for the repayment of increased oxygen debt.

2. It was assumed that there were no interacting effects on the subjects physiological state due to the experimental situation.

IV. LIMITATIONS

The following limitations were made in regard to this study.

1. Each of the subjects were observed only once under each of the test conditions, and the day to day variance of

the subject's metabolic rate was not determined.

2. The subjects used were limited to volunteers from the required physical education program at the University of Montana.

3. Temperature and humidity of the test area could be controlled only to a limited degree.

4. Only limited control could be maintained over the activities, meals, and rest of the subjects.

CHAPTER II

REVIEW OF THE LITERATURE

A survey of the literature revealed significant information and research findings on the effect of resistance to breathing as would be encountered in the use of respiratory protective devices. A brief summary of the literature reviewed is here presented.

Zechman, Hall, and Hull (15) conducted experiments in 1957 on eleven male subjects to determine the effects of air flow resistance when added independently or simultaneously to inspiration and expiration. Resistance values ranged from 0.10 to 0.43 mm. of water per cubic centimeter of air per second. The effects were observed during exercise and at rest. The addition of the resistance produced: (1) a reduction of air flow velocity and an increase in the duration of the impeded phase, (2) reduction in respiratory frequency, and an increase in tidal volume with an increase in expiratory reserve, (3) reduced pulmonary ventilation with a rise in alveolar carbon dioxide and a decrease in oxygen tension. The effects on the breathing cycle were associated mainly with impedance of expiratory flow. Changes in alveolar gas composition changed dramatically when ventilatory demands were increased by moderate exercise, with very little change noted when the subjects remained at rest.

Cooper (10) reviewed studies carried on by Silverman who recorded the effects of air flow restriction on groups of eighteen and fifty-five men. The subjects were tested at various work loads on the treadmill. The effect of the resistance was to reduce oxygen consumption, carbon dioxide elimination, and minute volume during high rates of exertion. Oxygen uptake was also found to be reduced when resistance to expiration exceeded that of inspiration. It was the feeling of Cooper that these results were limited because of the short periods used in the testing.

Fink, Ngai, and Holaday, (11), in view of reports indicating reduced pulmonary ventilation and an alveolar carbon dioxide increase when resistance was added to respiration, conducted a study on eighteen decerebrated cats to study the effect of air flow resistance upon the diaphragm. A resistance was provided through the use of a vacuum fan attached to a breathing apparatus on the cat. Results were recorded through the use of an eight channel oscillograph. Action potentials were obtained from the diaphragm by the insertion of two monopolar electrodes at the ninth intercostal opening. In the unanesthetized cats an increase in resistance to eight cm. of water, or above, produced an increased voltage output in the diaphragm that was in a linear relation to the resistance. There was an accompanying decrease in volume and flow rate of respiration. In the anesthetzed cats the results were more pronounced in respect to respiration rate and volume, while diaphramic contractions were prolonged over a longer period with no increase in intensity. Recovery of volume was noted at low resistance levels, but never to pre-obstruction levels.

Campbell (9) had conducted a similar study in which electromyographic recordings were made of the action potential of the anterior-lateral abdominal muscles using surface electrodes. Intragastric pressure was also measured with an air-filled balloon in the stomach connected to an inductance manometer. Five subjects were used for the study and all observations were made with the subjects in a supine position. Threshold resistance to expiration was developed by the collapsing of a latex tubing in the breathing apparatus with a known outside pressure. A known pressure was than required for respiration regardless of the rate or volume of flow. Observations were recorded under two conditions: (1) a sudden application of resistance during quiet breathing, and (2) increased pulmonary ventilation (produced by rebreathing expired air with no carbon dioxide absorber) while breathing against a constant threshold. In the first condition values of resistance up to 10.0 cm. of water produced no action in the abdominals, or rise in pressure. Above 17.5 cm. of water the abdominals were active in all subjects with an increase in intragastric pressure. This action was felt to be volumtary in nature when later tests with unconscience subjects under the same conditions produced an increase in the inspiration volume with the added recoil of the chest walls used to overcome the expiratory resistance. The subjects were found to be able to maintain a rate of forty liters per minute against a resistance value of 10.0 cm. of water with no action from the abdominals.

Martin (4) in speaking on deep breathing or forced expiration, stated that movements that were passive in nature became active muscular acts, and a great many more muscles took part in the respiratory movement. He included in these the abdominals, the internal intercostals, and the scalenes. There was also an increase in intrathoracic pressure which may occlude the large veins in the chest and seriously impair the inflow of blood to the heart.

More recent studies have tended to support earlier findings on the effect of added resistance to breathing. In 1960 Tabakin, and Hanson (14) studied five male subjects between the ages of twenty-seven and thirty-seven for their responses to ventilatory obstruction during steady-state exercise. Two twenty minute exercise periods were used. The first was to establish steady-state function levels, and the second was to determine changes when a five millimeter-diameter-tube was added to the gas collection apparatus as a resistance to expiration. The resistance reduced carbon dioxide elimination, for the complete period of observation. Oxygen consumption fell during the first minute, but gradually increased during the next two minutes. However, at no time did oxygen consumption exceed pre-obstruction levels, and an "oxygen debt" was established when calculated at the sum of differences in oxygen level minute by minute below the steady state level. It was felt at this time that the reduction in oxygen tension found by others was not solely responsible for the reduction in oxygen consumption.

In 1961 Levy (12) in cooperation with Tabakin and Hanson conducted another study on ventilatory obstruction to determine if the reduced oxygen consumption was due to a reduction of cardiac output. The procedure used was the same as the study just mentioned with the exception that cardiac output was measured during the first twenty minute period, and then again at the instant the resistance was inserted, three minutes after the insertion, and immediately after removal. All exercise was continuous and uninterupted. The "t" test for small samples was applied to differences of cardiac output for any one obstruction period and the preceeding steady state period. In all cases the change in cardiac output was significant, but unpredictable as to direction, magnitude and point in time at which it occurred. It was felt that reduced cardiac output was the general trend, but that true increases may have been the result of blood being forced into the left ventricle of the heart from the lungs by increased intrathoracic pressure. It was therefore concluded that decreased cardiac output was not the cause of the reduced oxygen consumption.

The American Industrial Hygiene Association (7) presented data in 1963 collected on eleven subjects. Work loads varied from sedentary to 1,066 Kilogram-meters per minute. Comparisons were made between the effects produced using an inspiratory resistance of six millimeters and an expiratory resistance of three millimeters for an air flow of eighty-five liters per minute to the effects produced by substituting sixty-four mm. and forty-one mm. for the resistance values to inspiration and expiration respectively. It was noted that the first resistance values are less than the difference between mouth and nasal breathing. The following results were obtained: (1) negligible change in pulse rate, (2) reduced minute volume and maximum inspiration and expiration flow, (3) reduced respiratory rate, and (4) reduced oxygen consumption with a greater per cent of oxygen removal from each cycle.

Data collected by Silverman in 1951 was also presented. This data had been collected on twelve subjects exercising at a work rate of 830 Kilogram-meters per minute. Resistance levels were paired in many combinations and ranged from 6 and 3 mm. for inspiration and 76 mm. for expiration. There was little or no change observed in oxygen consumption or pulse rate. Inspiratory flow decreased with a rise in resistance to inspiration alone or to both phases. It increased with resistance to expiration alone. A decrease resulted when resistance to expiration exceeded an increased resistance to inhalation.

Spioch, Kobza, and Rump (13) investigated the effects of respirators on physiological reactions to physical effort. The examinations were carried out on ten male subjects. They were required to perform light or intensive work while wearing respirators, and without respirators. The intensive work consisted of the Harvard step-up test at thirty cycles per minute for five minutes. The light work consisted of using a Zimmermann ergometer until exhaustion. Before and after the intensive work tests, the following measurements were made: pulse rate during thirty seconds, arterial blood pressure in the humeral artery, blood oxygenation degree by the bloodless method on the ear lobe. Measurement of lung ventilation, inspiratory and expiratory gas composition, respiration frequency were also made. This required modification of the respirator masks. A Cardiovar IV-Alvar apparatus was used to determine oxygen consumption, and carbon dioxide exhalation. The intensive work tests were carried out only while the subjects were wearing respirators. In this phase the same measurements were made as before, and the following additional measurements were made: body temperature was taken in the rectum and on the skin, the hematocrit index was determined by the Hedima-Cartner method and alkaline blood reserve by conductometric method. In order to determine the influence of respirators on some functions of the central nervous system, especially the degree of concentration and fatigue, psychotechnical examination was performed by means of the Bourdon test. The tests were performed in rest, with and without respirators, and after exercise with and without respirators. The following conclusions were drawn from the results: (1) performance of physical effort with respirators, as compared to the same work without respirators, resulted in a significant extension of minute volume and systolic output, (2) the use of respirators did not increase oxygen consumption, lung ventilation, or influence the degree of blood oxygenation, (3) respirators produced an increase of physiological dead space, (4) the use of a respirator did not essentially influence the ECG curve, and (5) phychotechnical examination showed that the use of respirators prolongs the time of taks performance and increases the numbers of errors. A drop of the alkaline reserve level after the effort as a result of lactic acid formation was noted, but not thought large enough to change the homeostasis and impair the functions of tissues and organs.

In summary, it may be said that resistance produces: an increase in the duration of the impeded phase, an increase in muscular activity, a reduction in respiratory frequency, a reduction in pulmonary ventilation, a reduction in carbon dioxide elimination, a reduction in oxygen consumption and tension, no change in pulse rate, and no predictable change in cardiac output.

However, the presence of increased muscular work along with a decreased oxygen consumption present a paradox requiring further study. Also, ther is a need for more specific information related to the relationship of resistance to physiological cost.

CHAPTER III

PROCEDURE OF THE STUDY

I. SUBJECTS

Five volunteers from a physical conditioning section of the required physical education program at the University of Montana served as the subjects for this study. The characteristics of the subjects are presented in Table I.

TABLE I

CHARACTERISTICS OF TEST SUBJECTS

Subjects	Height-inches	Weight-lbs.	Age
G. Sw.	73	152	20
R. Re.	72	140	18
S. Da.	71	184	20
G. Pe.	67	165	19
N. Ha.	70	151	18

II. PILOT STUDY AND PRE-TRAINING PERIOD

A short pilot study was conducted to determine which angles and speeds on the treadmill would best produce pulse rates corresponding approximately to those of light, moderate, and heavy work loads as described in Johnson (3).

As a result of this study grades of zero, five, and ten percent were selected. Speed was held constant at 3.5 miles per hour, which is approximately average walking speed.

This phase also served as pre-training for the subjects. While acting as subjects for this phase of the study they became familiar with the equipment, purpose and procedure of the entire study. This time was used by the investigator and assistants to establish and practice the entire testing routine. The pilot study covered the two weeks just prior to the time of the actual testing for the major study.

III. SELECTION OF OBSERVATION PERIODS

Johnson (3) presents data which shows that during moderate exercise pulse rate and oxygen consumption reach a steady state in three to five minutes, and that ninety-eight percent of the first phase of the oxygen debt is recovered during the first three minutes of rest after exercise.

On the basis of this data, a five minute exercise period was selected in order that the subjects reached a steady state. The exhaled gas from the first three minutes of recovery was collected and analyzed.

IV. EQUIPMENT AND APPARATUS

Respiratory Protective Devices

The primary purpose of all respiratory protective equipment is to prevent the inhalation of harmful or objectionable atmospheres.

The protective device may be one of two basic types. The first of these is the contaminant removal. This type removes particulate matter by means of filtration, gaseous contaminants by chemical reaction or absorbtion, or is a combination to the two processes. The second major class is the atmospheric supply respirator, which is essentially a closed system with its own atmosphere supply. The devices used in this study were all of the contaminant removal class.

American Optical Mask. Mask I (Figure 1) was a half mask equipped with two removable absorbent-filteration cartridges designed for protection against dust, mists, fumes, organic vapors, and acid gases. The dual inhalation ports were 1-1/16 inches in diameter, and regulated by a rubber flutter valve. The single exhalation port was 1-1/8 inches in diameter, and regulated by a rubber flutter valve. The mask was held to the face by four rubber straps leading from the sides of the mask and hooking behind the head.

Acme Mask. Mask II (Figure 2) was a common full face type. It had been tested and approved by the United States Bureau of Mines. It was equipped with a single filter-absorbent canister designed to filter organic vapor, acid vapor, and particulates. The dual inhalation ducts were each 7/16 by 1/2 inch rectangles leading from a single central duct was an open ring around the central inhalation duct. It had an outside diameter of 1-9/16 inches and an inside diameter of 1-1/16 inches. It was regulated by means of a rubber flutter valve. The mask was held to the face by a

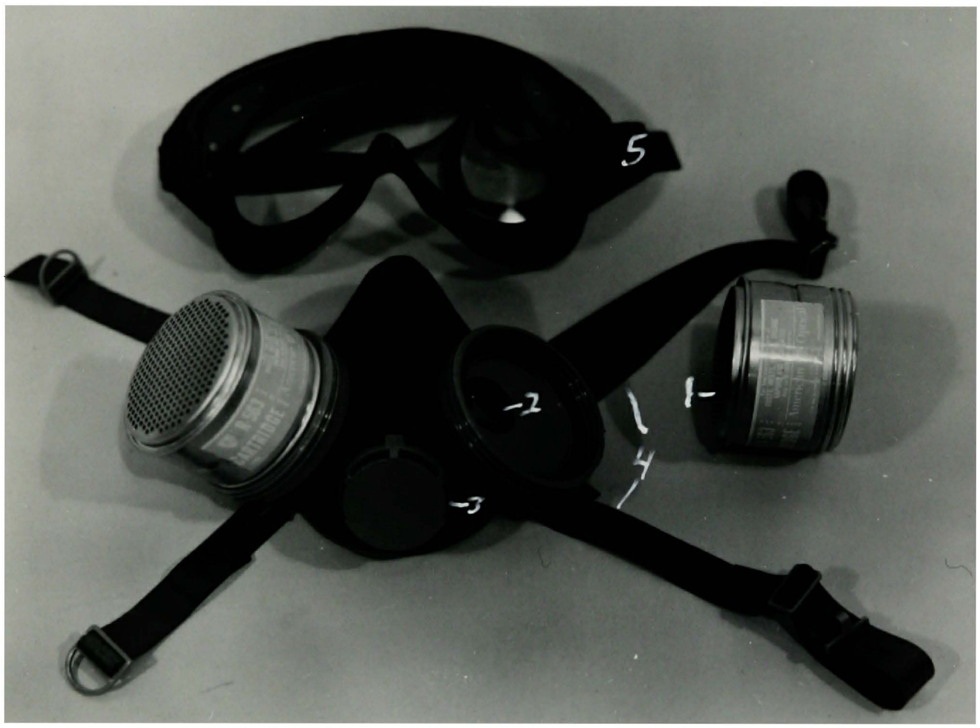

FIGURE I

AMERICAN OPTICAL MASK

1. filter-absorbent cartridge
2. inhalation duct
3. exhalation duct
4. head straps
5. goggles-not used in study

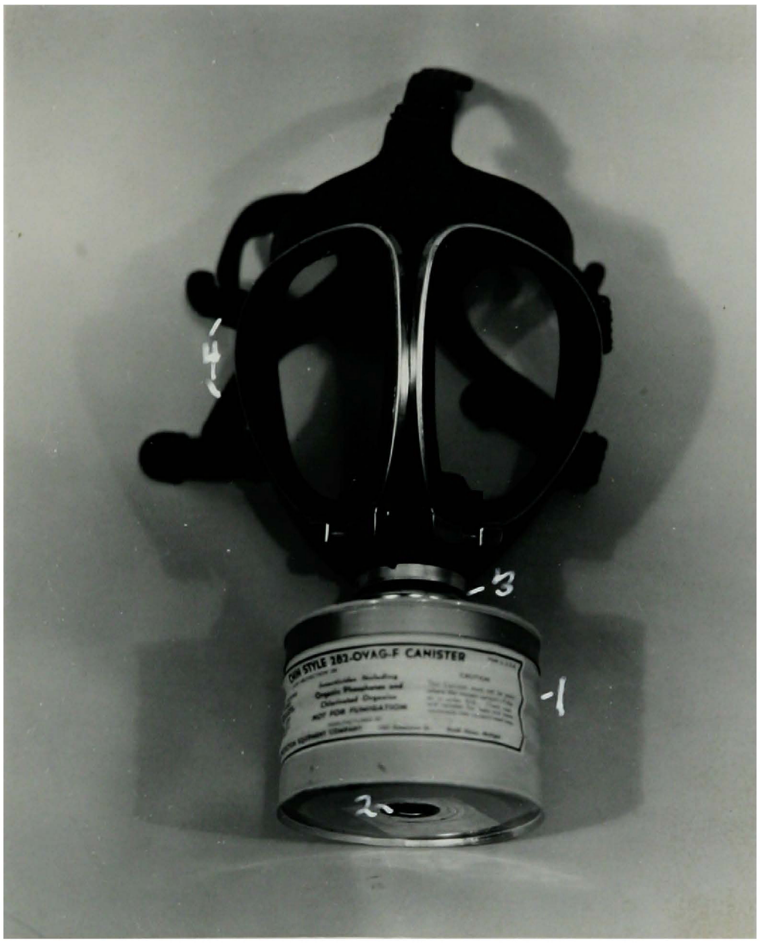

FIGURE 2

ACME MASK

1. filter-absorbent cartridge
2. inhalation duct
3. exhalation duct
4. head webbing

five strap webbing from the sides and top of the mask and passing behind the head.

<u>MSA Mask</u>. Mask III (Figure 3) was a half face device. It was also approved by the United States Bureau of Mines. It was equipped with two absorbant cartridges. An auxiliary static web filter was added for protection against particulate matter. The inhalation ducts were 7/8 of an inch in diameter and regulated by rubber flutter valves. The single exhalation duct was 1-1/16 inches in diameter, and also regulated by a rubber flutter valve. The mask was held to the face by means of four elastic straps attached to a metal yoke in the front of the mask, and hooked behind the head.

<u>Resistance Values</u>.[2] The resistance of each mask to air flow during inhalation was determined by placing the mask on a manikin head attached to a vacuum fan. Resistance was recorded as a pressure drip measured in inches of water by a manometer. To measure exhalation resistance the inhalation ducts were plugged, and a hood placed over the manikin head and sealed at the throat. The vacuum fan was than attached to this hood. Resistance was again recorded as a pressure drop measured in inches of water by a manometer.

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[2]This phase of the study was carried out by C. G. Blake, A. J. Mattila, H. K. Harris, H. H. Fowler, and D. B. Gordon of the Department of Agriculture, United States Forest Service, the Missoula Equipment Development Center.

FIGURE 3

MSA MASK

a. absorbant cartiridge
b. static web filter
c. clamp for filter
d. inhalation duct
e. exhalation duct
f. head straps
g. goggles-not used in test

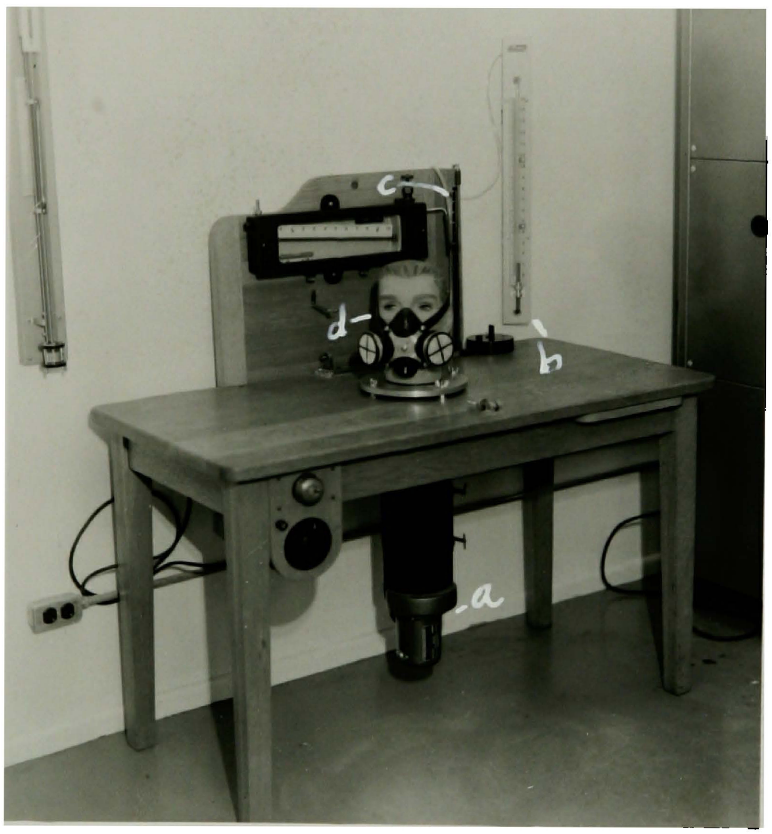

FIGURE 4

INHALATION RESISTANCE TEST

a. vacuum fan
b. manometer to measure pressure drop
c. manometer to measure air flow
d. manikin head

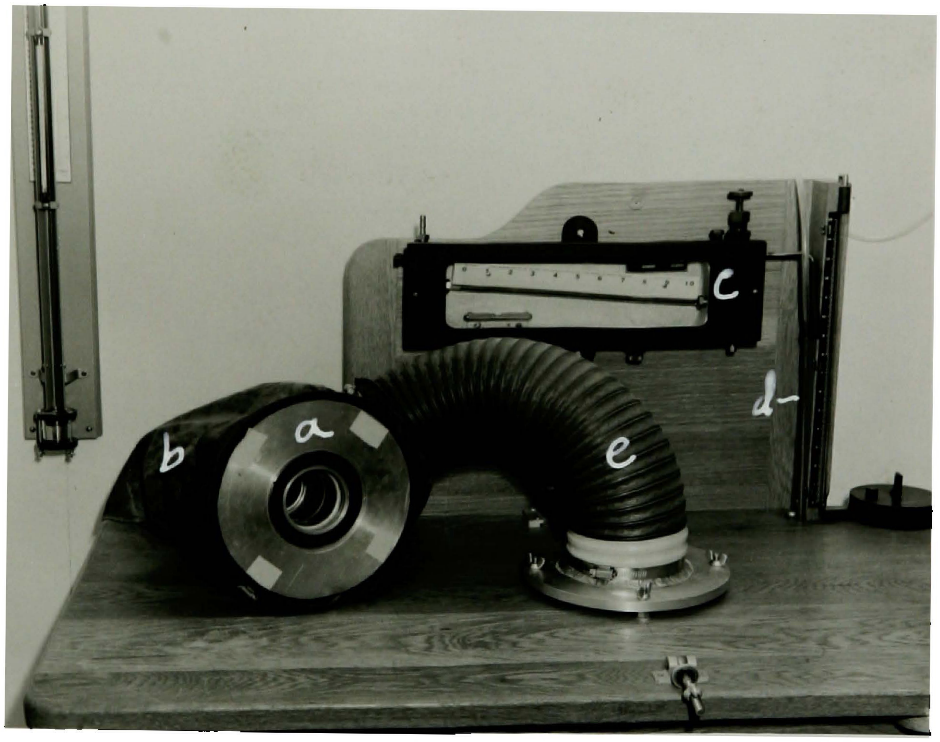

FIGURE 5

EXHALATION RESISTANCE TEST

a. manikin base
b. hood
c. incline manometer to measure pressure drop
d. manometer to measure air flow
e. connection to vacuum fan

Figures IV and V show this phase of the study. Air flow was manually regulated, and measured by the rise of pressure in a water manometer through the use of a barometric conversion table for a Sherman W. Frazier fabric permeability instrument. Temperature was held constant at seventy degrees, and relative humidity at forty percent. The barometric pressure of the environment was approximately 27. inches of water. The flow rates used for the testing were 85 and 170 liters per minute. The resistance values as determined for the masks by this method are presented in Table XIV, Chapter IV.

Cardiotachometer

A Waters C-225B cardiotachometer (Figure 7) was used to measure pulse rate. Beats per minute were indicated directly on a dual scale meter with a rate range from 40 to 360. Individual beats were indicated by a flashing neon light. Three circular electrodes were placed on the subject, and a nine foot cable completed the connection to the instrument. An integral circuit provided calibrated pulses at rates of 40, 120, and 360 beats, enabling fast, accurate calibration of the pulse rate meter. The calibration was checked and adjusted prior to each test. The electrode placement used in this study is shown in Figures 6 and 7 by the letters f, a, and b. The "NEUTRAL" electrode was placed on the back of the neck. The "RIGHT" electrode on the right

FIGURE 6

CHEST ELECTRODE PLACEMENT

a. right electrode
b. left electrode

chest, and the "LEFT" electrode on the left chest. The pulse rate of the subject was recorded three times during the rest period before the test, and every thirty seconds during exercise and recovery.

Timer

A Grey Laboratory Universal Timer (Figure 7) was used to time the length of all test periods. A manual switch was used to start and stop the timer. An automatic buzzer indicated the end of the time period for which the timer had been set. In this study the timer was always set for eight minute periods, and the investigator was responsible for indicating the end of the five minute exercise period and the start of the recovery period.

Treadmill

The walking surface of the treadmill was a continuous belt eight feet long and three feet wide. It was made of Goodyear wedge grip rubber and revolved on two 8.5 inch end rollers with forty-two 1.9 inch bed rollers between them. The smaller rollers furnished support for the walking surface. The speed and elevation of the treadmill were manually controlled. Speed was pre-set before each test by means of a hand crank located near the end of the treadmill. The angle of inclination, if any, was also pre-set by a hand winch near the front of the treadmill. A dial on the side of the walking bed indicated the percent of grade.

Gas Collection and Metering

The basic equipment used in this phase is shown in Figures 7 and 8. During the recovery the subjects inhaled and exhaled through a plastic breathing valve (a). Rubber tubing connected the exhale port of this valve to a manually controlled three-way valve (b). This valve could be turned to communicate the breathing valve with the gasometer, the breathing valve with the Douglas bag, or the Douglas bag with the gasometer. The exhaled gas was initially collected in the Douglas bag (a of Figure 8). The sample to be used for analysis was then collected over mercury through a small side hose on the neck of the Douglas bag. The manual valve was turned and the circuit leading to the gasometer opened. The gas was transferred to the gasometer for volume measurement.

The gasometer used in this study was a 600 liter chain compensated model, and served as the standard metering device in the laboratory. Change in the gas volume of the gasometer bell was measured by the fall of a meter stick on the side of the tank as the gas entered the bell. The net change in centimeters was multiplyed by a conversion factor of 5.158 to express the volume change in liters. Prior to taking the final measurement the gas was mixed by an electric fan in the gasometer bell. The temperature of the gas was obtained from a thermometer which was sealed in the top of the gasometer bell. The temperature reading was taken at the same time as

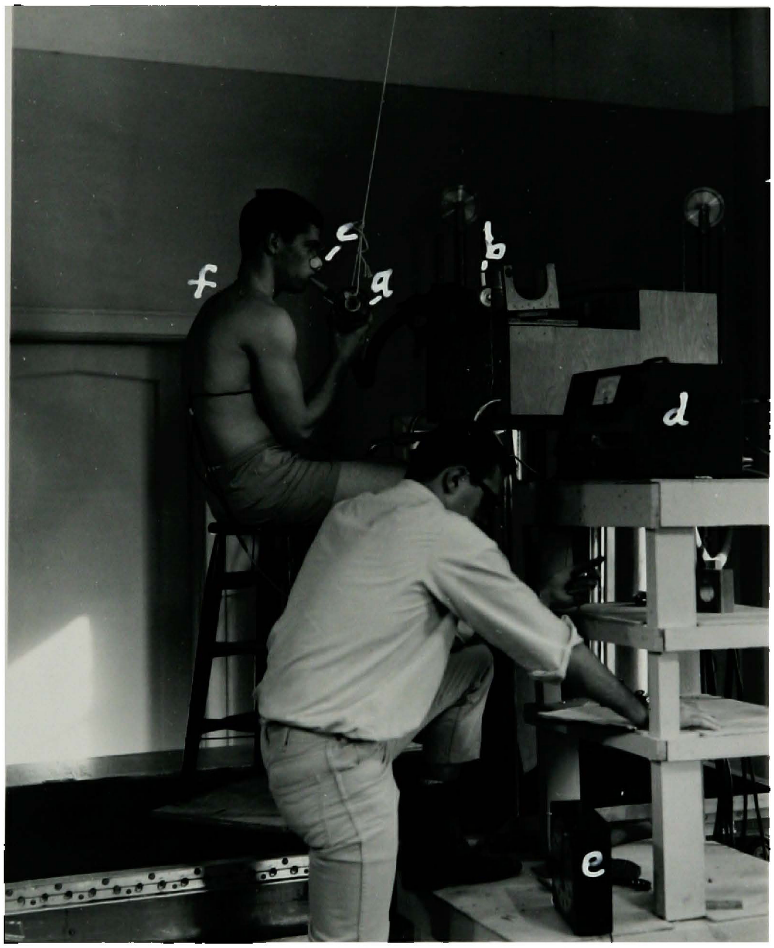

FIGURE 7

TEST AND GAS COLLECTION EQUIPMENT

a. plastic breathing valve
b. three way manual valve
c. nose clamp
d. cardiotachometer
e. timer
f. neutral electrode placement

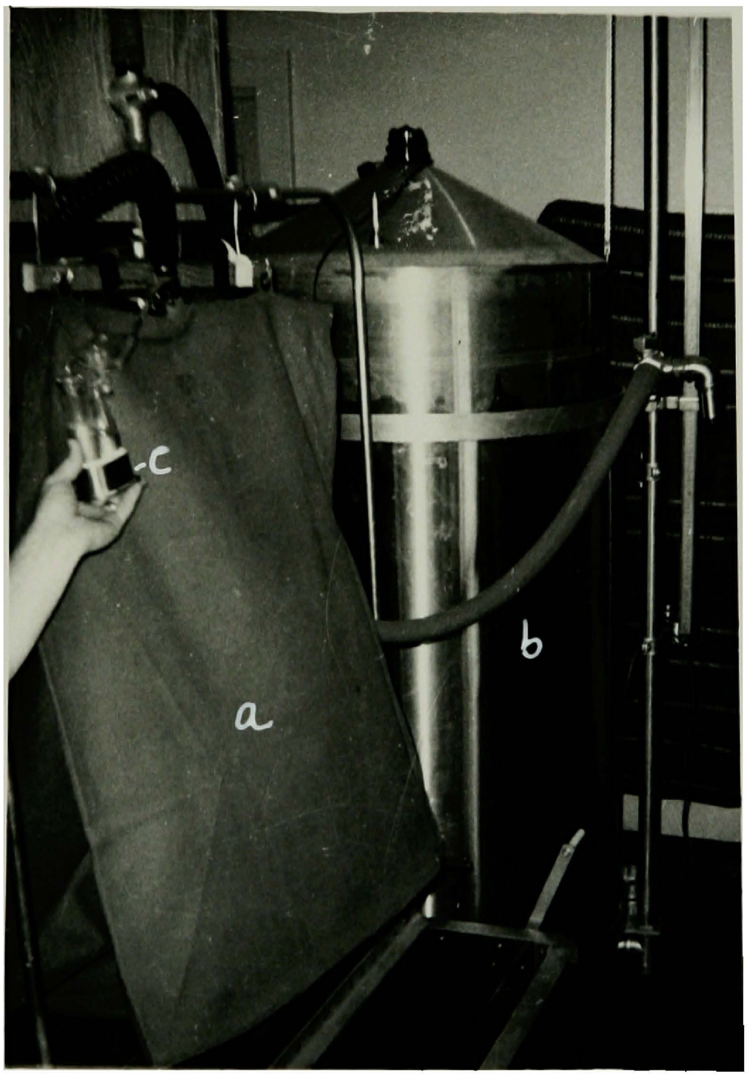

FIGURE 8

GAS COLLECTION EQUIPMENT

a. Douglas bag
b. gasometer
c. Bailey bottle

the final volume reading. The gas volume was corrected to dry volume at standard temperature and pressure throught the use of Darling's line chart, as described in Consolazio, Johnson, and Pecora (1).

Gas Analysis

The Scholander method of gas analysis, as described by Consolazio, Johnson, and Pecora (1), was used to determine the percentages of oxygen and carbon dioxide in the gas samples. The determined percentages were referred to Dill's line chart, as described in Consolazio, Johnson, and Pecora (1), and the percentage of oxygen consumed determined. For an analyses had to be within plus or minus 0.05 percent of each other, and the two oxygen percentages in the same sample had to be within plus or minus 0.10 percent of each other.

V. TESTING

Testing Schedule. All testing was done between the hours of 12:00 p.m. and 6:00 p.m. Monday through Saturday in the Research Laboratory of the Physical Education Department at the University of Montana. The grade, condition and order of testing were determined for each subject by the use of a table of random numbers from Walker and Lev (6). Appendix A shows the order of grades and conditions for each subject.

Testing Procedure. The subjects were tested four times at each of the three grades; once with each of the three masks, and once with no mask as a control condition. On the day of the test the subject took part in his normal daily routine with the following exceptions: (1) the subject was to take part in no strenuous activity of any type, (2) the subject was not to eat for three hours prior to the time of the test.

The daily testing procedure was as follows:

1. The subject reported to the laboratory in gym shorts and tennis shoes. He filled out the personnel checklist on the data sheet (Appendix C), and the electrodes were taped to him.
2. The subject was seated on a stool on the teadmill, and the electrodes were connected to the cardio-tachometer. During the next eight to ten minutes the resting pulse was recorded.
3. At the end of the rest period, which was a minimum of fifteen minutes, the subject was told to stand on the treadmill, and the mask was fitted to his face, or in the case of the control no mask was used. When the subject indicated he was ready the treadmill was started. The exercise portion of the test is shown in Figure 9.
4. At the end of the five minute exercise period

the treadmill was stopped, the mask removed, and the mouth piece of the breathing valve placed in his mouth. It was necessary for the subject to hold his breath during the short period from the time the mask was removed until the mouth piece was in place. A nose clamp was used to prevent nasal breathing. The exhaled gas was collected for the first three minutes, sampled, measured, and analyzed.

5. At the end of the test the subject was excused, and told the time of his next test.

VI. METHOD OF DATA COLLECTION

The data from each test period was collected on an individual data sheet during each test. A copy of the data sheets used has been included in Appendix C.

FIGURE 9

SUBJECT DURING EXERCISE

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

I. ANALYSIS OF RESULTS

The data which was collected from the subjects during the test is shown in Appendix B. Exercise pulse rates represent an average of the six readings taken during the last three minutes of exercise, the resting pulse rate an average of the three readings taken while the subject was at rest prior to the test. The data was grouped in relation to work load for analysis.

II. METHOD OF ANALYSIS

Since the same subjects were tested under each condition, the analysis of variance for experiments with two criteria of classification was used as described in Garrett (2) and Snedecor (5). The Hartely test, as described in Snedecor (5), was used to locate significant differences when it became evident that these differences existed.

The hypotheses tested were:

1. There were no differences in oxygen consumption during recovery resulting from a particular test condition.
2. There were no differences in the net increase in

pulse rate during exercise due to a particular test condition.

The .05 level of significance was chosen as the point at which the null hypothesis was to be rejected.

Because of the small number of conditions the relationship between resistance and oxygen consumption was presented in graphic form.

III. COMPARISON OF CONDITIONS

Walking on Level. The mean oxygen consumption of the subjects during recovery, and the mean net increases in pulse rate during exercise are shown in Table II. Oxygen consumption is expressed in cubic centimeters per minute, and pulse rate is expressed in beats per minute.

TABLE II

MEAN OXYGEN CONSUMPTION DURING RECOVERY AND MEAN NET PULSE INCREASE WHILE WALKING ON LEVEL

	No Mask	Mask I	Mask II	Mask III
OC	521.3	685.7	600.7	553.4
PR	28.8	29	35	29.8

A significant "F" ratio was found to exist for the differences between the oxygen consumption means (Table III). The Hartley test (Table IV) revealed that a significant difference existed beteen the mean oxygen consumption of the subjects while using Mask I, and all other conditions. No other significant differences were found to exist.

TABLE III

ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION AFTER WALKING ON THE LEVEL

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F ratio
Means	3	76,691.40	25,563.80	8.42**
Among Sub.	4	96,595.59	19,914.89	
Interaction	12	36,423.61	3,035.30	
Total	19	209,710.61		

*Significant at the .05 level.
**Significant at the .01 level.

TABLE IV

HARTLEY TEST FOR LOCATION OF SIGNIFICANT DIFFERENCES IN OXYGEN CONSUMPTION ON THE LEVEL

Condition	$\bar{x}$	$\bar{x}$-521.3	$\bar{x}$-553.4	$\bar{x}$-600.7
Mask I	685.7	164.4 (103.5)*	132.3 (92.9)*	85.0 (75.9)*
Mask II	600.7	79.4 (92.9)	57.3 (75.9)	
Mask III	553.4	32.1 (75.9)		
Control	521.3			

*Indicates a significant difference from the eliminated condition in each column at the .05 level of confidence.

No significant differences were found to exist between mean net increases in pulse rate due to any of the test conditions (Table V).

TABLE V

ANALYSIS OF VARIANCE FOR NET PULSE RATE INCREASE WHILE WALKING ON THE LEVEL

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Means	3	180.95	60.32	3.30 N.S.
Among Sub.	4	186.80	46.70	
Interaction	12	218.80	18.23	
Total	19	586.55		

<u>Walking on 5 Percent Grade.</u> The mean oxygen consumptions of the subjects during recovery, and the mean net increased in pulse rate during exercise are shown in Table VI. Oxygen consumption is expressed in cubic centimeters per minute, and pulse rate is expressed in beats per minute.

TABLE VI

MEAN OXYGEN CONSUMPTION DURING RECOVERY AND MEAN NET PULSE INCREASE WHILE WALKING ON 5 PERCENT GRADE

	No Mask	Mask I	Mask II	Mask III
CC	685.7	870.8	902.1	766.9
PR	58.6	58.0	65.4	62.6

A significant "F" ration was found to exist for the differences between the oxygen consumption means (Table VII). The Hartley test revealed that a significant difference existed between the mean oxygen consumption of the subjects while using Mask II, and mean oxygen consumption under the control condition with no mask. There were no other significant differences (Table VIII).

TABLE VII

ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION AFTER WALKING ON 5 PERCENT GRADE

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Means	3	147,165.91	49,055.30	4.01*
Among Sub.	4	395,339.32	98,834.83	
Interaction	12	146,587.01	12,215.58	
Total	19	689,092.28		

*Significant at the .05 level
**Significant at the .01 level

TABLE VIII

HARTLEY TEST FOR LOCATION OF SIGNIFICANT DIFFERENCES IN OXYGEN CONSUMPTION AT 5 PERCENT GRADE

Condition	$\bar{x}$	$\bar{x}$-685.7	$\bar{x}$-766.9	$\bar{x}$-870.8
Mask II	902.1	216.4 (207.6)*	135.2 (186.4)	131.2 (149.2)
Mask I	870.8	185.1 (186.4)	103.9 (149.5)	
Mask III	766.9	81.2 (149.6)		
Control	685.7			

*Indicates a significant difference from the eliminated condition in each column at the .05 level of confidence.

No significant differences were found to exist between the net pulse rate increase means (Table IX).

TABLE IX

ANALYSIS OF VARIANCE FOR NET PULSE RATE INCREASE WHILE WALKING ON 5 PERCENT GRADE

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Means	3	112.95	37.6	.365 N.S.
Among Sub.	4	2,931.30	732.8	
Interaction	12	1,283.30	103.1	
Total	19	4,282.55		

Walking on 10 Percent Grade. The mean oxygen consumptions of the subjects during recovery, and the mean net increases in pulse rate during exercise are shown in Table X. Oxygen consumption is again expressed in cubic centimeters per minute, and pulse rate is expressed in beats per minute.

TABLE X

MEAN OXYGEN CONSUMPTION DURING RECOVERY AND MEAN NET PULSE INCREASE WHILE WALKING ON 10 PERCENT GRADE

	No Mask	Mask I	Mask II	Mask III
OC	823.5	1,061.5	1,077.1	986.1
PR	82.2	87.4	88.2	85.0

A significant "F" ratio was found to exist for the differences between the oxygen consumption means (Table XI). The Hartley test revealed that a significant difference existed between the mean oxygen consumption of the subjects while using Mask I, II, or III and the mean oxygen consumption of the subjects under the control condition with no mask. There were no other significant differences (Table XII).

TABLE XI
ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION AFTER WALKING ON 10 PERCENT GRADE

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Means	3	189,528.24	63,176.08	9.20**
Among Sub.	4	866,507.54	216,626.88	
Interaction	12	82,379.92	6,864.99	
Total	19	1,138,413.70		

*Significant at the .05 level
**Significant at the .01 level

TABLE XII

HARTLEY TEST FOR LOCATION OF SIGNIFICANT DIFFERENCES IN OXYGEN CONSUMPTION AT 10 PERCENT GRADE

Condition	$\bar{x}$	$\bar{x}$-823.5	$\bar{x}$-986.1	$\bar{x}$-1,061.5
Mask II	1,077.1	253.6 (155.61)*	91.0 (139.67)	15.6 (114.11)
Mask I	1,060.5	238.0 (139.67)*	75.4 (114.11)	
Mask III	986.1	152.6 (114.11)*		
Control	823.5			

*Indicates a significant difference from the eliminated condition in each column at the .05 level of confidence.

No significant differences were found to exist between the pulse rate means (Table XIII).

TABLE XIII

ANALYSIS OF VARIANCE FOR NET PULSE RATE INCREASE WHILE WALKING ON 10 PERCENT GRADE

	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Means	3	109.4	36.4	.452 N.S.
Among Sub.	4	3,037.7		
Interaction	12	965.7	80.4	
Total	19	4,112.2		

<u>Oxygen Consumption Compared to Resistance</u>

Oxygen consumption, during recovery, was higher in cases following the use of a mask as compared to the control at a given work load. As the work load increased the oxygen consumption also increased during recovery. At the heavy and moderate work levels the degree of increase corresponds to the ranking of the masks with regard to inhalation resistance valuses, e.g., the highest rate of oxygen consumption resulted from the condition where the mask with the greatest resistance to inhalation was used, and the lowest rate to the mask with the least resistance to inhalation (Figure 10). It should be noted that this relationship did not hold true at the light work load. The same results were found when oxygen consumption was compared directly to the resistance values for each mask (Figure 12). As the resistance increases with the moderate and heavy work loads, the rate of oxygen consumption during recovery also increases. Table XIV presents the resistance data for each of the masks used in this study.

TABLE XIV

RESISTANCE VALUES OF MASKS TO INHALATION AND EXHALATION AIR FLOW AT RATES OF 85 AND 170 LITERS PER MINUTE

	85 Liters		170 Liters	
Mask	Inhalation	Exhalation	Inhalation	Exhalation
I	2.3	0.72	5.2	1.9
II	3.0	0.65	6.9	1.3
III	1.5	0.93	3.7	2.3

As may be seen in Figure 11 there was no clear pattern or relationship between test conditions and net pulse increase. Increases would seem to be related primarily to work load increase.

IV. SUBJECTIVE EVALUATION

All subjects were asked to give an opinion of the masks after each test.

The subjects were unanimous in their selection of Mask III as the easiest to wear and most confortable to work in. Both Mask I and II were disliked and considered difficult to breath in, with Mask II generally considered the worst of the three. There was a definite difficulty with getting Mask I to fit, and the subjects complained of difficulty with exhalation as well as inhalation at the high work levels. Mask II drew severe complaints at the high work level. The subjects were unable to get sufficient air flow causing a short winded sensation.

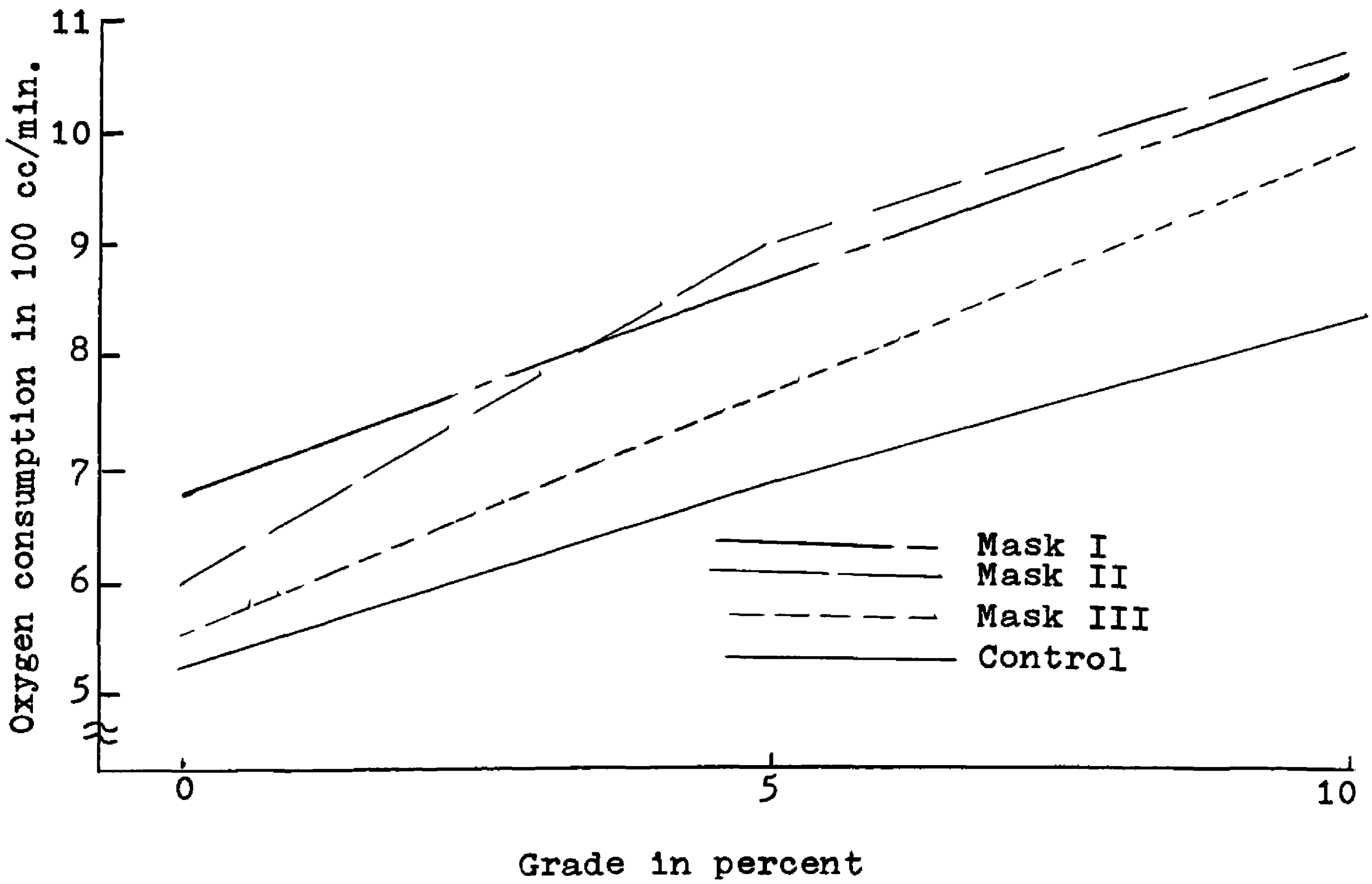

FIGURE 10

THE RELATIONSHIP OF OXYGEN CONSUMPTION AFTER EXERCISE TO PERCENT GRADE USING THREE PROTECTIVE DEVICES

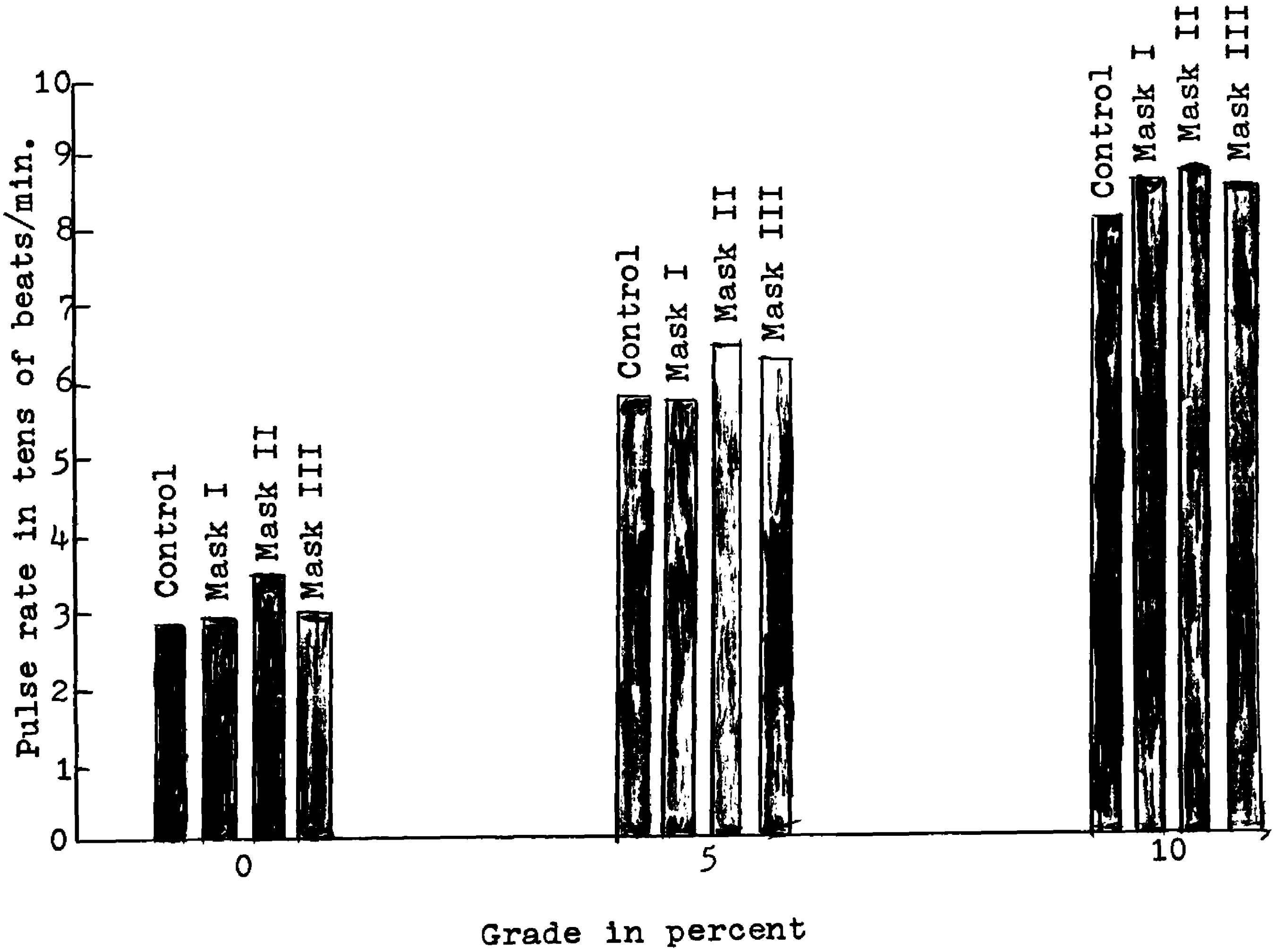

FIGURE 11

THE RELATIONSHIP OF NET PULSE RATE INCREASE TO THE PERCENT OF GRADE USING THREE PROTECTIVE DEVICES

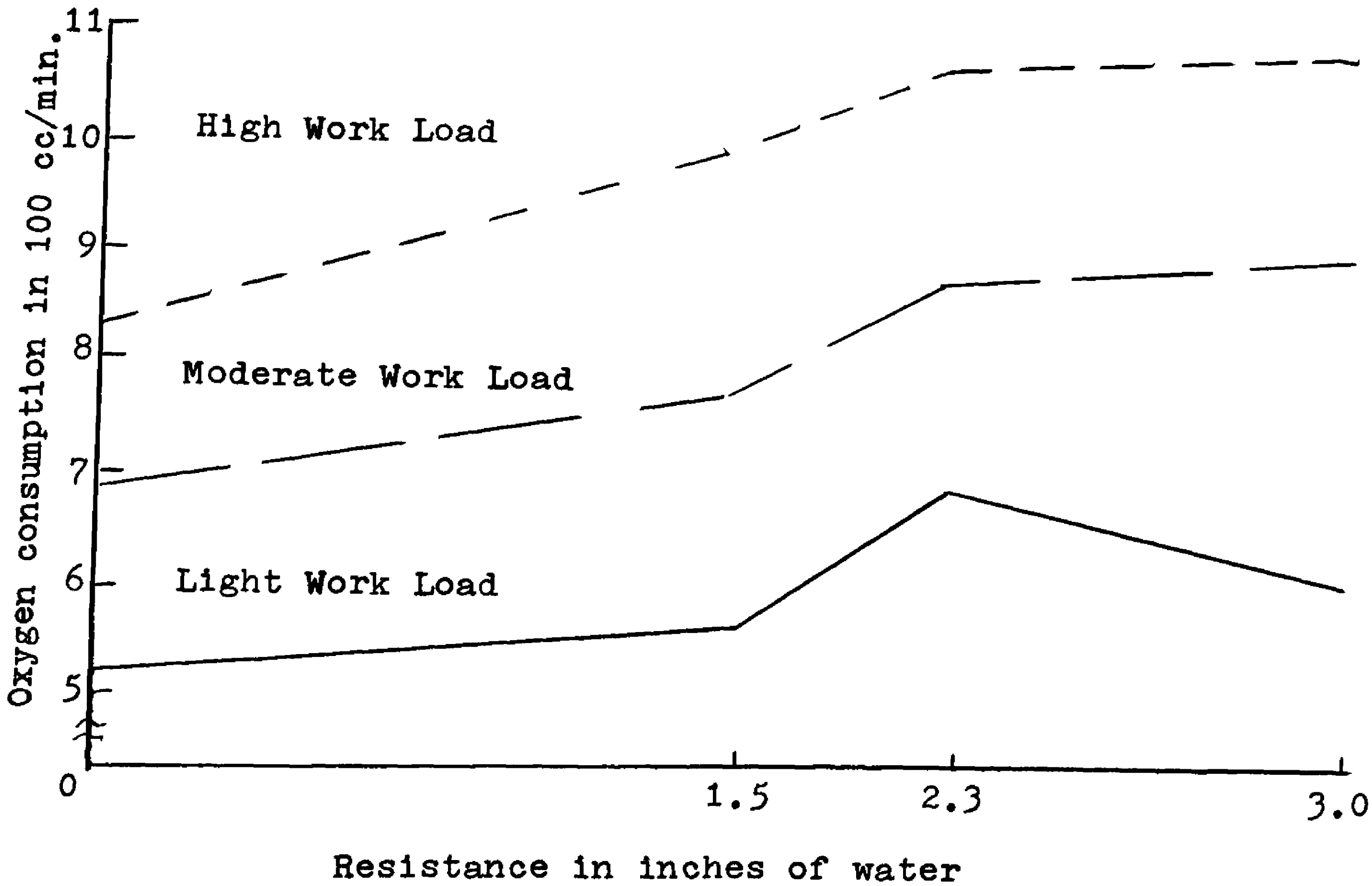

FIGURE 12

THE RELATIONSHIP OF OXYGEN CONSUMPTION AFTER EXERCISE TO RESISTANCE TO AIR FLOW AT EIGHTY-FIVE LITERS PER MINUTE

V. DISCUSSION OF RESULTS

At all work levels the use of a respiratory protective device produced a higher oxygen consumption rate during recovery than was produced by the control trial. In at least one case at each work level the difference was significant at the .05 level of confidence. At the high work level the increase due to the use of any of the masks was significantly greater that the control.

This supports the hypothesis that the use of a respiratory protective device imposes an additional physiological work load on the individual in the form of an increased oxygen debt, and that this would be indicated by an increase in oxygen consumption during recovery. While the increase was not always statistically significant at the lower levels, there was always an increase, thus, establishing a definite trend even at the lower levels of work.

At the moderate and high work levels there appears to be a definite relationship between resistance to inhalation air flow and the physiological work imposed as indicated by the increase in oxygen consumption after exercise above that of the control. At the low work level it may have been that there was not a large enough variance in resistance to produce accurate results. At the higher work levels where the air flow must be increased, there differences would become more pronounced. Exhalation resistance has not been considered as it is well below the 2:1 ratio of inhalation-exhalation resistance values recommended by Cooper (10).

No significant net increase was found in the pulse rate during exercise. This was expected, and agrees with the studies mentioned earlier by The American Hygiene Association (7), and Silverman (7).

It is, therefore, the conclusion of this study that the use of a respiratory protective device does impose a greater physiological work load on the individual. This increased work load is compensated for by an increased oxygen debt as indicated by increased oxygen consumption during recovery after exercise, and there is a direct relationship between the resistance to inhalation and the amount of additional work imposed at moderate and heavy work loads.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

The purpose of this study was to (1) compare at three work levels the changes in oxygen consumption during recovery, as caused by the use of a particular respiratory protective device, to all other devices tested and the control condition, and (2) to relate these changes to the resistance of each device to air flow.

Five male students served as subjects for this study. Each subject was tested on the level, on a 5 percent grade, and on a 10 percent grade with each of the three test masks, and with no mask. The exercise period was 5 minutes in length. Expired gas was collected during the first three minutes of recovery, sampled, measured, and analyzed. Pulse rate was recorded for the entire test period.

The two null hypotheses tested statistically were: (1) there were no differences in oxygen consumption during recovery resulting from a particular test condition, and (2) there were no differences in the net increase of pulse rate during exercise due to any of the test conditions.

The analysis of variance for experiments with two criteria of classification was used to determine if a significant difference in oxygen consumption or pulse rate resulted from any of the test conditions.

II. CONCLUSIONS AND RECOMMENDATIONS

Within the limits of the method used there would seem to be a significant physiological cost resulting from the use of a respiratory protective device. This is readily evident by the high recovery compensation. There would also seem to be a relationship between the resistance to inhalation air flow afforded by the mask and the physiological work of using it.

It is evident that the increased cost associated with wearing a respiratory protective device, coupled with a possible restriction in oxygen consumption during the effort, would result in an increased need for anaerobic metabolism and, therefore, hasten the onset of fatigue.

It is recommended that future studies relate resistance values to maximal work capacity and the rate of contraction of the oxygen debt.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

1. Consolazio, C. Frank, Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Functions in Man. New York: Blakiston Division, McGraw-Hill Book Company, Inc., 1963, pp. 505.

2. Garrett, Henry E. Statistics in Psychology and Education. New York: David McKay Company, Inc., 1958, pp. 478.

3. Johnson, Warren R. Science and Medicine of Exercise and Sports. New York: Harper and Brothers Publishers, 1960, pp. 740.

4. Martin, H. Newell. The Human Body. New York: Henry Holt and Company, 1937, pp. 701.

5. Snedacor, George W. Statistical Methods. The Iowa State University Press, Ames Iowa: 1956, pp. 534.

6. Walker, Helen Mary, and Joseph Lev. Elementary Statistical Methods. New York: Henry Holt and Company, 1950, pp. 302.

B. PUBLICATIONS OF THE GOVERNMENT AND OTHER ORGANIZATIONS

7. American Industrial Hygiene Association. Respiratory Protective Devices Manual. Ann Arbor: Broun and Brumfield, Inc., 1963.

8. Schrenk, H. H. Testing and Design of Respiratory Protective Devices. United States Bureau of Mines, Information Circular 7086. Washington: Government Printing Office, 1939.

C. PERIODICALS

9. Campbell, E. J. M. "The Effects of Increased Resistance to Expiration on the Behavior of the Abdominal Muscles and Intra-Abdominal Pressure," Journal of Physiology, 136(2):556-562, 1957.

10. Cooper, E. A. "Suggested Methods of Testing and Standards of Resistance for Respiratory Protective Devices," _Journal of Applied Physiology_, 15(6):1053-1061, 1960.

11. Fink, B. Raymond, Shik-Hsun Nghi, and Duncan A. Holaday. "Effect of Air Flow Resistance on Ventilation and Respiratory Muscle Activity," _American Medical Association Journal_, 168:2245-2252, 1958.

12. Levy, A. M., J. S. Hanson and B. S. Tobakin. "Circulatory Response to Ventilatory Obstruction During Steady State Exercise," _Journal of Applied Physiology_, 16(2):309-312, 1961.

13. Spioch, Franciszek M., Romuald Kobza, and Slawomir Rump. "The Effects of Respirators on Some Physiological Reactions to Physical Effort," _Acta Physiologica Polonica_, XIII(4-5):542-553, 1962.

14. Tabakin, B. S., and J. S. Hanson. "Response to Ventilatory Obstruction During Steady State Exercise," _Journal of Applied Physiology_, 15(4):579-582, 1960.

15. Zechman, Fred, J. G. Hall, and W. E. Hull. "Effects of Graded Resistance to Tracheal Air Flow in Man," _Journal of Applied Physiology_, 10(3):356-362, 1957.

APPENDIX

APPENDIX A

CONTROL DATA

Subject	Average Room Temp. ° C	Average Rel. Humidity Percent	Average Pressure mm. Hg	Test Order*
G. Sw.	23	21%	685	6-8-9-7-5-4-10-3-1-11-12-1
R. Re.	24	24%	680	2-9-5-8-11-7-12-6-1-4-10-3
S. Da.	23	20%	680	6-10-8-11-9-7-5-12-3-1-2-4
G. Pe.	23	21%	680	5-9-4-6-2-8-11-12-3-10-7-2
N. He.	23	23%	680	5-2-4-9-12-1-3-7-6-10-11-8

*Test conditions are numbered as follows: 1-Control at level, 2-Mask I at level, 3-Mask II at level, 4-Mask III at level, 5-Control at 5 percent, 6-Mask I at 5 percent, 7-Mask II at 5 percent, 8-Mask III at 5 percent, 9-Control at 10 percent, 10-Mask I at 10 percent, 11-Mask II at 10 percent, 12-Mask III at 10 percent.

APPENDIX B

TEST DATA

Subject: G. Sw.

Test	Oral Temp.	Rest* Pulse	Exercise** Pulse	Recovery*** Pulse	Oxygen' Consumption
1	97.0 °F	79	109	84	447.4cc/min.
2	97.4	80	108	80	582.7
3	98.0	77	111	86	555.2
4	97.4	83	112	84	499.6
5	98.0	77	143	92	626.2
6	98.6	96	158	114	1,036.6
7	97.6	73	148	95	706.3
8	98.3	63	147	88	666.3
9	96.2	76	175	120	729.0
10	97.3	79	173	116	907.7
11	96.8	64	178	117	956.6
12	96.0	66	160	99	908.6

Subject: R. Re.

Test	Oral Temp.	Rest* Pulse	Exercise** Pulse	Recovery*** Pulse	Oxygen' Consumption
1	98.4 °F	82	108	83	458.5cc/min.
2	98.3	84	106	77	723.1
3	97.6	84	124	87	562.5
4	97.6	74	105	79	529.8
5	98.8	80	130	90	516.1
6	99.2	66	133	89	664.2
7	98.8	77	121	81	779.9
8	98.2	81	126	84	637.4
9	96.8	70	147	87	609.9
10	98.6	84	157	96	916.5
11	97.8	67	151	93	994.3
12	98.0	68	146	89	735.9

APPENDIX B (continued)

Subject: S. Da.					
Test	Oral Temp.	Rest* Pulse	Exercise** Pulse	Recovery*** Pulse	Oxygen' Consumption
1	98.3 °F	72	102	82	668.7
2	97.2	75	113	79	763.9
3	98.6	72	105	81	781.6
4	97.0	64	98	74	672.4
5	95.8	79	154	101	891.9
6	97.8	79	145	105	1,068.6
7	98.0	72	148	109	1,231.4
8	96.1	71	144	100	1,091.8
9	98.2	65	163	112	1,225.4
10	97.0	72	164	116	1,359.2
11	97.4	76	176	132	1,536.8
12	96.0	71	176	123	1,446.3

Subject: G. Pe.					
Test	Oral Temp.	Rest* Pulse	Exercise** Pulse	Recovery*** Pulse	Oxygen' Consumption
1	98.6 °F	84	107	87	496.9
2	98.2	86	120	104	787.5
3	97.8	72	112	83	553.4
4	99.0	76	108	83	524.1
5	96.8	71	127	85	715.5
6	98.2	91	140	100	857.1
7	97.5	75	141	95	760.6
8	97.6	72	134	91	738.1
9	99.0	90	165	128	770.3
10	97.0	74	164	115	1,153.6
11	97.0	83	166	117	954.7
12	97.8	79	165	108	994.8

APPENDIX B (continued)

Subject: N. He.					
Test	Oral Temp.	Rest* Pulse	Exercise** Pulse	Recovery*** Pulse	Oxygen' Consumption
1	98.0 °F	82	107	86	535.2
2	98.6	81	104	89	571.6
3	96.6	68	96	74	550.9
4	98.6	82	109	88	541.1
5	97.5	80	112	89	678.6
6	97.2	72	118	83	727.7
7	98.6	84	140	107	1,032.0
8	97.4	71	116	90	701.2
9	97.6	80	142	102	783.0
10	97.4	69	147	108	977.0
11	98.0	72	132	93	943.0
12	97.4	74	136	100	845.1

*Resting pulse was the average of the three readings taken during rest.

**Exercise pulse was the average of the readings taken during the last three minutes of exercise.

***Recovery pulse was the average of the readings taken for the three minutes of recovery.

'All oxygen consumption values have been rounded to the first decimal place.

APPENDIX C

SAMPLE DATA SHEET

Subject____________ Date ________Treatment________

Control Data: Rm Temp_____Bar Pr___ Rel Hum___ Oral Temp__

Bdy Wt_____ Ht_____Resting Pulse ________Bl Pr ________

Last food ________ Drink(not H_2O)________Hrs. Slp____Last ex__

Other ______________________________________

Experimental Data:

____

____

____

____

Ventilation: Gasometer factor (GF)_____Meter factor________
Conversion factor (derived from bar pr and temp of gas) - CF

post pre dif

_____ - _____ = _____x GF=_____x CF_____/min.=______VR (L/min)

_____ _____ _____ _____ _____ ______

Gas Analysis:

CO_2____ ____ ____ ____ _____ x ____ = ____x 1,000=ccO_2/min

O_2____ ____ ____ ____ _____ ____ ____ ______

____ ____ ____ ____ _____ ____ ____ ______

____ ____ ____ ____ _____ ____ ____ ______

Comments: