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MEASURE OF WORK PERFORMANCE DECREMENT

DUE TO RESPIRATORS

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16. Abstract (Limit: 200 words) The effects of respirator wear were determined in 12 subjects using a battery of physical, cognitive and psychomotor tasks. Three types of respirators were studied: a disposable dust mask, an air purifying half mask, and a full face airline respirator. Physical work, studied as the task of bicycle riding, indicated a 10% increase in oxygen consumption with the half and full face masks over the oxygen consumption in the control state, wearing no respirator. Respirator wear did not significantly affect the performance of cognitive tasks. The best indicators of respiratory effects on work performance decrement were the psychomotor task test methods. A steadiness task demonstrated a 31% decrement for the full face respirator condition. The One Hole Test indicated an average movement time decrement of 16%. The authors conclude that, generally, respirators produce an increase in oxygen consumption during physical tasks, and cause decrements in psychomotor performance with regard to hand movement speed and steadiness.

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LIST OF ABBREVIATIONS

ANOVA - analysis of variance

ECG - electrocardiogram

G - Group

GRE - Graduate Record Examination

GXT - graded exercise test

HEPA - High Efficiency Particulate Air

HR - heart rate

Kcal/min - kilocalories per minute

Kg - kilogram

Km/hr - kilometer per hour

mmHg - millimeters mercury

O - Order

OSHA - Occupational Safety and Health Administration

P - Pattern of respirator order

S - Session

T - Type of Task

VO_2 - oxygen consumption

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ABSTRACT

Possible work decrements caused by respirator usage were examined. A
battery of physical, cognitive and psychomotor tasks were used to
investigate the effects of respirator wear on twelve subjects. A repeated
measures experimental design was used to study the effects of three types
of respirators: a disposable dust mask, an air purifying half-mask and a
full-face airline. Performance while wearing a mask was compared to the
control condition without a respirator. The results from the physical work
task of bicycle riding indicated approximately a 10% increase in oxygen
consumption with the half and full face masks, supporting previous
physiological findings. The results indicate that the respirators did not
significantly affect the performance of cognitive tasks. The psychomotor
task test methods appear to be the best indicators of respiratory effects
on work performance decrement. A steadiness task showed a 31% decrement
for the full-face respirator. The One-Hole Test, which includes a number
of measurement variables indicated an average movement time decrement of
16%. The other One-Hole Test indicators also showed decrements, but were
lower and not statistically significant. In general, respirators can be
shown to produce an increase in oxygen consumption for physical tasks and
decrements in psychomotor performance with regard to hand movement speed
and steadiness.

1. INTRODUCTION

The exposure of workers to hazardous amounts of toxic chemicals has been a concern to labor, management and governmental agencies. The preferred approach to reducing these hazards is a program of engineering and administrative controls to protect workers. When the work environment cannot be controlled adequately or during emergencies, respiratory protection equipment must be relied on to protect the worker.

Although respirator usage is acknowledged to be the last choice for assuring worker safety and health, it is accepted that respirators are used or recommended for use in a variety of industrial situations because other control methodologies do not provide sufficient hazard reduction. Three factors should be used in selecting respirator masks. First, the ability to protect the worker from toxic agents should be evaluated. Second, the cost of using the particular respirator must be considered. Third, the effects on operator performance while wearing the respirator must be determined. Although the first factor is the most crucial in respirator wear, this study evaluates only the third factor of effects of the respirator on the wearer. Although many evaluative tools have been used to determine the effectiveness of a respirator's operation or its physiological effects on the wearer, little attention has been paid to the quantitave assessment of respirator effects on the performance of a worker's task. Such an assessment would be useful not only for evaluating the respirator in terms of worker acceptance, but also in terms of worker productivity. This latter evaluation has major economic implications with regard to determining the true overall cost of different types of respirators or of respirator usage versus engineering control. In other words, if a certain type of respirator caused a 20% decrement in the

performance of a certain type of work, the economic losses (due to less product and less effective use of salary) must be included as costs due to respirator use along with the capital cost of the respirator equipment and the operating costs to maintain the respirator program when determining the real overall cost of a respirator program.

In the past, evaluations of respirator effects have concentrated only on the physiological work decrement. Raven, Dodson and Davis (1979) reviewed past literature on physiological effects of respirators. Work decrements as large as 20% resulting from respirator wear were reported. These findings, however, were attributed mainly to the weight of large, bulky respirators, such as self-contained breathing apparatus. A number of studies do not differentiate between the combined effects of respirator usage and heat stress (Goldman, 1970, James, Dukes-Dobos and Smith, 1984, Johnson & Cummings, 1975). Other studies examined the combined effects of respirator usage and protective clothing (Goldman, 1963, Atterbom and Mossman, 1978, Martin & Goldman, 1972). Where some studies, such as by Louhevaara, Smolander, Tuomi et al (1985), show increased workload requirements with respirator usage, and thus, reduced productivity, others, such as Dahlback and Balldin (1984), did not observe any effect, perhaps because their experimental design did not allow for a true control condition with no respiratory interference to the subject during his exercise.

While research does exist on the physiological effects of respirators, little is known concerning cognitive decrements and psychomotor decrements. Withey (1981) stressed the need for a systematic study of respirator effects using a battery of tasks. Goldman (1985) believes that performance decrements are task dependent as well as dependent on motivation of the worker. Since performance effects of respirators may be task dependent, a

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battery of tasks should be selected to properly describe respirator effects. Hence, there is a demand for a thorough exploration, conducted in a systematic fashion, of the physical, cognitive and psychomotor effects of respirators.

A comprehensive study was conducted to investigate test procedures which could be used to quantitatively determine any decrement in work performance due to the use of a respirator. The subjects' responses were monitored while they successively wore three popular types of respirators currently in use and successively performed three tasks intended to simulate the majority of activities in a typical industrial workplace setting. The three types of respirators were selected to represent the more commonly used types of respirators in industry and included a disposable dust mask, a half-mask with HEPA cartridges, and a full-face mask with pressure-demand air-line supplied air.

The three types of work tasks, physical, psychomotor and cognitive, were selected to represent the broadest spectrum of simulated work tasks. A physical task was included even though it is the area that has been most extensively examined in the past since this allows for confirmation of existing data by means of the techniques used in this study for estimating work performance effects. However, what distinguishes this study is the inclusion of the psychomotor and cognitive task performance analyses, since not all aspects of tasks performed while wearing a respirator are strictly related to physical exertion.

Physical performance was tested with subjects pedaling a bicycle ergometer at a constant rate and with a constant load. The bicycle load was designed to simulate a moderate work load for an average healthy subject, of approximately four to five kcal/min (Astrand & Rodahl, 1970).

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Work decrement was estimated indirectly by the increase in oxygen consumption (VO_2), which was correlated to measured heart rate (HR).

Psychomotor performance involves motor behavior, typically combining manual manipulation and decision making, and forms the basis of much repetitive industrial work. Fleishman (1975) has identified eleven psychomotor factors which describe a spectrum of psychomotor abilities. The range of factors implies that different performance abilities are needed for each factor, therefore performance in one task associated with a particular factor may not predict performance on another task related to a different factor. Due to the factor specific nature of tasks, a battery of tasks were selected to reflect performance abilities of the following four of Fleishman's eleven factors, which were considered to be critical and representative for the types of performance required while wearing respirators: arm-hand steadiness, control precision, finger dexterity, and reaction time.

The steadiness task tests the first factor of arm-hand steadiness. The pursuit rotor task measures both arm-hand steadiness and the second factor of control precision. The one hole test evaluates the third factor of finger dexterity. The fourth factor of reaction time is measured by a four choice reaction time task. The hand dynamometer which measures grip strength served as an additional diagnostic aid in evaluating respirator effects on psychomotor skills. The battery of psychomotor tasks selected for the study enables the evaluation of factor specific respirator effects. Due to the physiological studies on mask usage (Raven et al, 1979), one might expect to see patterns of work decrement on the psychomotor tasks tested in this experiment.

The third category of tasks was cognitive. Due to the repeated measures design of the study, the selection of the cognitive tasks was

limited to those which would show no obvious effects of practice. Tests were also selected based on the availability of material to occupy subjects for the total time of experimentation. These constraints led to the selection of standardized Miller Analogy, GRE logical and GRE analytical tests as well as a hypothesis test (Levine, 1966).

2. METHODS

2.1. SUBJECTS

Twelve male Purdue University students with an average age of 20.5 years (range: 18 to 24 years), average height of 6' 1" (range: 5' 7" to 6' 7") and average weight of 170 pounds (range: 135 to 205 pounds) participated in this experiment. To control for as many subject related variables as possible, a careful pre-screening of the potential subjects was performed. Non-smoking college students with no chronic illnesses, allergies or asthma were accepted. In addition, a subject was only accepted if he did not need to wear glasses during the tests, had no excess facial hair and had no abnormal facial characteristics, three important factors in fitting respirators. Finally, subjects of average physical fitness status (determined by their indication of participation in 3-4 weekly exercise sessions) were considered optimal.

All subjects underwent a medical evaluation which included a questionnaire (see Appendix A) similar to the questionnaire in the OSHA Asbestos Standard (U.S. Code, 1989), a physical examination and a pulmonary function test. The questionnaire included questions pertaining to physical characteristics, past medical conditions, respiratory ailments, family medical histories, presence of a persistent cough or wheezing, personal habits such as smoking, and level of exercise. Only two potential

candidates had to be rejected, one due to subnormal spirometry and one due to obesity. All twelve accepted subjects were normal by examination and spirometry.

Subjects were fit-tested for the half-mask respirator to ensure adequate fit. Subjects were trained in donning and wearing the full-face airline respirator. They attended a two-hour respirator wearers' training and orientation program before beginning the actual experimental sessions to simulate the same experience that a typical worker would receive. During the experiment, subjects used their preferred dominant hand, which, for this sample was the right hand.

2.2. RESPIRATORS

The three respirators chosen for the study were: a disposable dust mask (3M Model 8710); a rubber half-mask with HEPA cartridges (North Series 7700-30); and a full-facepiece airline respirator in pressure-demand mode (Drager Nova Model) with grade D breathing air supplied from compressed air cylinders. Small, medium and large face pieces were available for the half-mask in the fitting sessions, with one subject requiring a small, seven subjects wearing medium and four subjects needing a large. The disposable and full-face masks were of one standard size.

2.3. EXPERIMENTAL DESIGN

The purpose of the experiment was to compare the performance of subjects on various tasks under four conditions involving respirators. These were control (no mask), dust mask, half-face mask and full-face mask. To maximize the power for these comparisons, a repeated measures design was used. Each subject performed the physical, cognitive and psychomotor tasks

under each of the respirator conditions of interest.

There is no standard time interval for typical industrial usage of respirators. The time interval can range from a few minutes to 8-hours. The experimental session length was set at two hours, which was judged to be of sufficient duration to allow the effects to be observable. A longer session would have been less practical and acceptable for the prospective subject. Each two-hour session was broken down into three 40-minute sub-sessions, or trials, in which the subject worked for the first 30 minutes, followed by a ten minute rest period.

In any given session, only one of the three tasks types was performed with only one respirator condition. This constraint is incorporated into the design of the experiment. Learning and practice effects are potential confounding factors and were taken into account in the design. The resulting design is considerably more complicated that the typical repeated measures design.

The twelve subjects were randomly assigned to two groups of six subjects each. Because part of the design is to compare results obtained with subjects wearing masks to results without masks, the order in which the control or no-mask condition occurs could introduce bias due to a possible practice affect. One design to cancel out this practice affect would have been to randomize the order of all four mask conditions - the no-mask and the three mask types. However, it was felt that by positioning the control first for half the subjects and last for the other half, not only would the final results cancel out the practice effect, but this effect, if any, could be identified by examining the F and p values for the analysis of variance term of mask or of mask by group for the group effect. Thus, for the first group, (G_1, which included orders 1-3), the control was the first condition used in each task series, while in the second group,

(G_2, which included orders 4-6), the control was the last condition used.
Within each group, two subjects were randomly assigned to each of three
orders for performance of the tasks. The orders were not the same for the
two groups. There were six orders with three nested within each of the two
groups. The order specifies which type of task - psychomotor, cognitive,
or physical - was to be performed first, second, or third as well as the
order of the masks to be used in each series of sessions. Within each
group, a Graeco-Latin square was used to determine the combinations of the
order of the tasks and the order of the masks. Since control (no
respirator) tests were pre-established as occurring either first or last in
the design, the core of the design for the respirators consisted of the
following four factors: 1) Session (S_1, S_2, S_3); 2) Order (O_1, O_2, O_3,
O_4, O_5, O_6); 3) Type of task (psychomotor, cognitive, physical: T_1, T_2,
T_3); and 4) Pattern of respirator order (P_1, P_2, P_3, P_4, P_5, P_6). The
pattern specifies the order in which each of the mask types is to be used.
For group 1 orders, the patterns are: P_1 - 1,2,3; P_2 - 2,3,1; and P_3 -
3,1,2. For group 2 orders, the patterns are: P_4 - 1,3,2; P_5 - 3,2,1,; and
P_6 - 2,1,3. In these pattern specifications, 1=dust mask, 2=half-facemask
and 3=full-facemask. Note that considering just the experimental design by
mask order combination, a different Latin square is formed for each group.
Figure 1 illustrates the total experimental design used for the
comprehensive study.

The experimental null hypothesis that the performance would be the
same for the four experimental conditions was examined by an analysis of
variance model. The model for the analysis is summarized in Table 1 which
gives sources and degrees of freedom for the various terms of the model.
Parentheses designate factors which are nested and interactions are

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specified by an asterisk. The terms G and O(G) are tested by s(O) and all other terms are tested by error. Note that the factor M, corresponding to masks, has three degrees of freedom because there are four mask conditions to be compared. This term is decomposed to give a contrast for comparing the no mask condition to the average of the three mask conditions.

The analysis of the various tasks is as follows. The physical experiment had one task, the ergometer, with three measurement variables, VO_2, systolic and diastolic blood pressure. Three one-factor analysis of variance tests were conducted. The psychomotor study had five tasks with a total of ten measurement variables. The one hole test had five dependent variables, the pursuit rotor had two, while the hand dynamometer, reaction time, and steadiness test had one measurement variable each. Ten one-factor repeated measures analysis of variance tests evaluating psychomotor effects of respirators were conducted. The cognitive section had four tasks with the Miller, GRE logical, GRE analytical and the hypothesis test all having one measurement variable each. Four one-factor repeated measures analysis of variance tests evaluating effects of respirators were conducted. Since there were no main effects of session or subsession, discussion of the results will be confined to the main effects of the mask type (factor M) and the planned comparison of the control condition versus the mask conditions. Because this comparison was planned before the data were collected, it was tested using a 0.05 alpha level. If the original null hypothesis was rejected or the contrast showed a significant difference between the control and the average of the three masks, additional tests of statistical significance for the intercomparisons (between each respirator and the control, and between each type of respirator) were conducted. These comparisons used the Bonferroni multiple comparison procedure to examine which pairs of mask conditions differed

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significantly.   Since there are (4x3)/2 = 6 paired comparisons, the normally accepted level of significance of $p \leq 0.05$ (the Type 1 error) must be divided among these six pairwise comparisons.   Thus, for this statistical analysis, a t-test for each comparison of group means must meet the criteria of $p \leq 0.0083$ to be judged statistically significantly different.   Conversely, the p values obtained by the Bonferroni tests must be multiplied by a factor of 6 before using the $p \leq 0.05$ criteria.

3.   EXPERIMENT 1 - EVALUATION OF PHYSICAL EFFECTS

3.1. TASK

Exercise was performed on a standard, single-wheel bicycle ergometer (Model 868, Monarch).   The ergometer was equipped with a tachometer and weights for adjusting the workload.   A Metabolic Measurement Cart (MMC Horizon System, SensorMedics) was used to collect oxygen consumption data (VO_2) and heart rate (HR) data, in conjunction with a six-lead electrocardiogram (ECG) monitor (EK-8, Burdick).   Blood pressure was collected manually with an arm-cuff sphygmomanometer.

3.2. PROCEDURE

At the beginning of each physical task session after measurement of a resting HR and BP, a submaximal graded exercise test (GXT) was performed with the subject on the bicycle.   After attaching six chest leads to the subject and connecting these leads to the ECG monitor, the subject donned the mouthpiece headgear (with the nose clipped shut) so that his exhaled breath would be collected and his oxygen consumption analyzed with the metabolic cart.   The subject then pedaled through successively increasing loads.   The purpose of this procedure was to generate a subject-and

session-specific calibration curve correlating VO_2 with HR. The rationale for this correlation was to allow the measurement of the HR variable during the subsequent respirator sessions to represent the values of VO_2 needed for the results since VO_2 could not be measured while the respirator was worn. By establishing the HR: VO_2 correlation before each session, slight day to day variabilities were minimized.

One would expect that for different conditions such as wearing a respirator, a person's work output and physiological parameters would vary from values measured without the condition. In order to understand the relationship between work output and physiological parameters, either the work output or the physiological parameter should be held constant. Since it is difficult to maintain a constant ventilation rate or HR status, the parameter selected to judge work performance was the change in VO_2 while maintaining a constant external workload. The ergometer load was set at 1 Kg of wheel resistance and the subject was asked to pedal at a rate so the tachometer reading would remain at 20 Km/hr. This combination of resistance and pedal rpm is equivalent to a workload of 5 kcal/min and resulted in a moderate worklevel of approximately 25-30% of VO_2 maximum. This level of work load was specifically selected to simulate the moderate work levels seen frequently in industry rather than higher work loads which are more physiologically taxing, but which would not occur as frequently or for as many workers. Both the subjects' pedal speeds and wheel loads were periodically monitored during each session by the experimenter and were found to be stable. An increase in VO_2 necessary to maintain the predetermined constant workload while wearing a respirator compared to the VO_2 level when not wearing a respirator would be indicative of increased work expenditure. This increase in required work effort can be considered

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a detriment to efficient work productivity and can be used as an estimate of work performance decrement. Since VO_2 cannot be directly measured while wearing a respirator, the measurement of HR was used to estimate VO_2 by the previously mentioned correlation curve method. The only alternative for measurement of VO_2 would have been to alter the respirator or incorporate it into the exhaled air hose circuit, as has been done in other studies. Such an approach, however, would not allow the subjects to wear the respirator in the same manner as that worn in actual use. Given that the correlation coefficient between VO_2 and HR ranged from 0.95 to 0.99, and that a new GXT curve was generated for each session, it was felt that this indirect method of VO_2 measurement while wearing the respirator with no modifications offered the best method of assessing work performance output that would represent actual usage.

After the subject had recovered from the GXT, the three 30 minute ergometer sessions, separated by the 10 minute rest sessions, were begun. Blood pressure measurements were collected every ten minutes, with a resting HR and BP collected at the conclusion of the last rest period. Heart rate measurements were collected automatically by the ECG monitor every 15 seconds. This data was later reduced to average values per trial and converted to average VO_2 per trial from the calibration curve for that session.

3.3 RESULTS

The means and standard deviations for each of the three dependent variables for the four experimental conditions are presented in Table 2. Table 3 contains a summary of the p-values for the mask main effect and the control vs. mask contrast. Table 4 contains the possible pairwise comparisons between the four conditions using the Bonferroni p-values.

The results of the physical task performance tests indicate that blood pressure changes only slightly when a full-face mask is worn. However, while the F ratio and the Bonferroni tests indicate a statistically significant increase in both systolic and diastolic pressures for full-face respirator when compared to the no respirator condition, this 5% increase (approximately 5 mm Hg) is not considered biologically significant. The increase in VO_2 with respirators compared to no respirators is statistically significant, $F(1 ,44) = 15.37$, $p<.0002$. An examination of the different respirator means indicates the source of difference to be from the half-mask and full-face mask respirators, which required approximately 9% and 11%, respectively, more VO_2 (see Table 5), and thus, conversely can be taken to represent a statistically significant decrease in work performance capability. This assumes a relatively constant energy available for the worker to perform his task. Although trial effects were not seen for the other tasks, VO_2 requirements did increase with trial. For example, the overall VO_2 increase for the half and full masks averaged 10% when compared to the control but increased from 7% for the first trial to 15% for the third trial. These trends suggest that the longer the respirator is worn, the more taxing it becomes.

3.4. DISCUSSION

The resulting average increase in VO_2 of approximately 10% (see Table 5) for the half and full mask respirators replicates previous reports of significant performance changes due to respirators, either as increased HR or increased VO_2 required. It is true that the body has the capacity to increase its oxygen consumption to match an increased work load, due to the redistribution of blood flow to sketetal muscles when they are actively contracting, and due to the shift of the oxygen dissociation curve, making

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it easier for the cells to obtain the O_2 from the hemoglobin (resulting from increases in carbon dioxide concentration and associated decreases in blood pH). Therefore, one might be tempted to conclude that simply measuring an increased VO_2 requirement due to respirators would not necessarily have any detrimental affect on work performance. However, this increased exertion could also lead to a decrease in the length of time that the worker can perform. Also, when the increased oxygen requirements attributable to wearing the respirator under controlled conditions are added to other stresses often associated with the use of respirators, such as the weight, restrictiveness or heat buildup of other personal protective gear or environmental conditions such as heat or confined work quarters, the overall impact may be sufficient to cause a decrement in performance and productivity.

4. EXPERIMENT 2 - EVALUATION OF PSYCHOMOTOR EFFECTS

4.1 TASKS

4.1.1 Hand Dynamometer

A hand dynomometer, (Model 78010, Lafayette Instruments) was used to measure basic hand strength in kilograms during the course of an experimental session. Before beginning a session, the dynamometer's grip size was adjusted to fit the hand of the individual subjects so that the moveable grasp bar reached the first joint of the middle digit. Then, subjects were instructed to hold the dynamometer at a right angle from their torso at shoulder height. At the request of the experimenter, the subjects squeezed the hand dynamometer. The experimenter recorded the reading and gave the subject a 10 second rest break between trials. Ten trials were performed following this procedure.

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4.1.2. Pursuit Rotor

A photoelectric pursuit rotor (Model 32534, Lafayette Instruments), was utilized with a triangular template. Light sensitivity reading for the tracking wand was set at 1.5. The tracking task was a clockwise motion at 30 rpm. Time on target and the number of times the stylus left the track of the triangle were recorded by an IBM/PC AT computer. Each subject performed ten trials of 20 seconds durations with a 15 second rest period between each trial. Subjects prepared to begin a trial by placing the tracking sytlus in the center of the triangle. They were told that the trial would start in five seconds by the experimenter who had a visual prompt from the computer terminal. When the subject heard the bell they started the tracking task until the next bell signalled them to return to the center of the template.

4.1.3 Steadiness

The instrumentation was a special modification of the steadiness tester (Model 32011, Lafayette Instruments). In this task, subjects held a stylus in a 1/4 inch round hole in a metal plate with only one hole and attempted not to touch the edges of the circumference. The stylus was 4 1/2 inches in length and had a 1/16 inch diameter. The only feedback was the tactile sensation of the stylus hitting the edge and the slight sound of that movement. The IBM computer mentioned above recorded the number of contacts in a 20 second trial period. There were ten trials with 15 second rest periods between each of them. Five seconds before each trial started, the experimenter said, "five seconds" and the subjects then placed the stylus inside the hole and waited for the trial onset bell to ring. A bell also denoted the end of a trial period. Subjects sat in front of the apparatus with their arm forming a right angle at the elbow. The stylus

was held like a fencing foil. Subjects were not allowed to brace thier hands, fingers or arms against their bodies or the table surface. They were also told to breath normally since holding one's breath facilitates steadiness.

4.1.4. Reaction Time

A four choice reaction time task was used with a four light and a five button response panel, (Model 63035, Lafayette Instruments). The middle response button was not used and does not correspond spatially with any light. Subjects were instructed to use the forefinger of their dominant hand to make the responses. Between responses they returned their hand to the table surface rather than resting it on the response box. There were twenty trials in a block with a 40 second rest break between each block. Data was collected from sixteen successive block of trials. A new trial was initiated immediately following a response. The sequence of lights was determined by a random number generator but there was a check to make sure no light was turned on twice in a row. Response times were measured in milliseconds.

4.1.5 One Hole Test

The one hole test (Model 32036, Lafayette Instruments) developed by Salvendy (1975) measured both large arm movements and finger dexterity. The apparatus consists of a box with a small tray at the base and a hole at the top mounted on a base. A metal plate on the base allows an electrical circuit to be created whenever the subject touches the apparatus while picking up and positioning pins. This allows the measurement by an IBM computer of the amount of time taken to complete each part of the tasks. These component times are called elemental times and are measured in milliseconds.

The task involves picking up a pre-positioned 0.1250" x 1.0" pin from

a small tray at the base of the apparatus and moving it up to the top of the apparatus. It is placed into a small hole .1275" wide and released. The apparatus delivers another pin into the tray and the subject repeats the procedure. Several measurements were recorded including the number of pins inserted, and the elemental times needed to do the task. Elemental times consist of reach time, position time, movement time and grasp time. The subject inserted pins for a one minute cycle and seven cycles were completed in succession without a break.

4.2 METHODS

Except for the hand dynamometer, all data was recorded by the IBM PC. Each subject had his own unique random sequence of tasks which was used each time he came into the lab. The entire experimental session was driven by the computer and the researcher just announced the beginning and end of tasks to the subjects. Each session, which lasted two hours, was divided into three subsessions or trials. During each subsession, the subject went through each of the five tasks. Ten minute rest breaks divided the session into three subsessions.

4.3. RESULTS

The means and standard deviations for the ten dependent variables from the five tasks for the four respirator conditions are presented in Table 6. The repeated measures analysis described in the previous section was used to analyze each of these variables. Tables 7 and 8 contain summaries of the results.

The ANOVA comparing masks worn during the steadiness test revealed a difference between respirators, $F(3,44)=4.85$ p $<.004$. An examination of

the respirator condition means indicated the source of differences to be from the full face respirator which had a mean number of touches of 2.79 versus a mean of 2.13 touches for the no mask condition. This is a 31% performance decrement.

While the difference between experimental conditions for pursuit rotor measurements of time on target was significant at $p < .02$ with an $F(3,44)=3.29$ a comparison of the average of the three respirators versus the no mask condition was not significant. An examination of the means from Table 6 as well as the Bonferroni comparisons in Table 8 demonstrates the lack of any changes of real or statistical significance when comparing the scores with any of the respirators to the score without a respirator. The F ratio for the number of slips off the target also was not significant.

The differences between the results with different respirator conditions for the reaction time task were not significant, although a comparison of the average of all three respirators versus the no mask, control condition was significant with $F(1,44)=4.28$, $p<0.04$. However, as with the pursuit rotor task, an examination of the means, with an actual average decrement of less than 2%, and of the Bonferroni comparisons of means, shows no real or statistically significant changes. The differences between respirator conditions for hand dynamometer reading of hand strength were also not significant.

The one hole test has several measurements: number of pins inserted, grasp time, position time, movement time and reach time. Some dependent variables for this task were significant, while others were not. The number of pins inserted during a particular mask condition was significant, $F(3,44)$ 2.85, $p < .045$ and a comparison of the control mean to the average of the combined respirators was significant at $F(1,44)=6.91$, $p < .01$.

Neither the grasp time nor the position time was significant. The movement time results for comparison of masks were significant at $F(3,44)=6.9$, $p<.0005$, with a comparison of control to the average of the three respirators also significant at $F(1,44)=19.87$, $p<.0001$. Although the reach time comparison of mask results was not significant, the comparison of no mask to masks was significant, $F(1,44)=6.12$, $p<.016$. The relative differences between each respirator and the control condition (expressed as percent of change from the control condition) are presented in Table 5.

4.4 DISCUSSION

The results would indicate that the general diagnostic tasks of hand dynamometer and reaction time were not able to detect any differences in performance caused by respirators. Since other tasks modeling the Fleishman factors - steadiness, and one hole - did show some differences to exist, it is reasonable to assume that any task chosen must be very sensitive and very specific with regard to the attributes measured.

Tests such as the reaction time task, which did not demonstrate any significant affect, are still useful however, as the results, which were times in the 400 millisecond range, were representative of the data usually seen for a four choice reaction time study. This would tend to support the contention that the tests were performed properly and that respirators do not appear to affect reaction time.

From a summary of the task decrements (Table 5) it can be seen that only the elemental measurement of movement time showed a statistically significant decrement in performance due to respirators (as demonstrated by a statistically significant increase in movement time, since the longer the movement time, the less efficient is the subject's performance). It is

equally important, however, to note the trends of the three other elemental time measures and the accuracy measure of number of pins inserted into the hole. The results indicate an average drop of 5% total pins, and increases in times ranging from 3% to 12%. While these four additional measures don't show sufficient differences in means to be statistically significant, the fact that all five measures do show performance decrements, and for all three respirator types, is felt to be significant.

The decrements of movement and reach times indicate that respirator wear affects the speed of movement more than the accuracy and, specifically, the speed of large motor movements more than precise movements of grasping and positioning the pins. What is not demonstrated by these results is any significant differences among the respirators. It can be concluded that either the test wasn't sensitive enough to detect differences, or, that there is no significant difference in effects of different types of respirators on work performance, at least for this type of psychomotor task.

The results of the steadiness task indicate a rather significant decrement of more than 30%, but only with the full-facemask airline respirator. The exact cause of this decrement may be due to the cumbersomeness of the larger mask with its associated valve and airline, or from the distraction of airflow noises or the inability to control slow breathing.

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5. EXPERIMENT 3- EVALUATION OF COGNITIVE EFFECTS

5.1. TASKS

5.1.1. Hypothesis Testing

The hypothesis testing task selected was based on Levine's 1966 research with a minor alteration. A problem set consisted of 16 stimulus cards where four are probe or feedback trials and the remainder are no feedback trials. The stimuli have four dimensions each with two values. The four dimensions are letter - two types used such as R and S-, size of the letter - 3/4" or 1/2"-, color - two colors used like red and green-, and the position of a line - above or below the letter. Capital self stick colored letters were centered on 4" by 4" cards. Problem sets were constructed so that there were 3:1 response patterns when accurately solved by the subjects. In any given problem subset of one probe and three blank trials there would be eight possible hypotheses. Thus twenty-four total sets were made, varying color and letter, with subjects never seeing any set twice.

5.1.2. Miller Analogies

Four sample practice tests published in 1986 (Bader and Burt) were selected. Each practice test had one hundred questions from which three thirty question tests were randomly constructed for the three tests to be used in each mask condition. Since there were four respirator conditions, four practice tests were used to compile twelve tests with thirty questions each.

5.1.3. GRE Analytical

Four sample practice tests published in 1983 (Educational Testing Service) were chosen. The four tests were divided to yield three tests each with eight questions which could be used in each mask condition, for a

total of twelve tests. Questions were assigned to the tests randomly to insure equal difficulty across the sessions and conditions.

5.1.4. GRE Logical

Four practice tests published in 1983 (Educational Testing Service) were picked to serve as a pool of questions to construct the twelve tests needed for the experiment. Questions from a test were randomized and then selected at random so that each test had eight questions.

5.2. PROCEDURE

For any given mask condition each of the twelve subjects had a random order for the presentation of the cognitive tests. Experimental sessions were divided into three sections, each containing the four cognitive tasks. A session was timed to take thrity minutes: seven minutes for GRE logical, seven minutes for GRE analytical, ten minutes for Miller and six minutes for the Hypothesis testing. Allocation of time per standardized test was derived from published guidelines taking into account the number of questions used in this experiment since we altered the original lengths of each test. After the first session section, subjects had a five minute rest break. A second thirty minute block of testing followed with a third rest break which in turn was followed by the third thirty minute section of testing.

At the beginning of the subject's first experimental session, the experimenter read the following instructions:

> "There will be three tests and a problem solving task. Each segment is timed. Please don't worry if you can't finish a test, they're set up that way. If you do finish early, please wait. The answer sheets are in order and when you get to the hypothesis test, I will show you the cards and you should try to decide which one is correct. In the hypothesis test, there are four dimensions which are changing - the size of the letter, letter type, color and the position of the bar. Each dimension has two values. Left and right

don't matter. On the first card you have to guess and I will say right or wrong. The important thing is to be consistent. Each time you come in, we will do the same kinds of tests but not the exact same tests."

5.3. RESULTS

Four one way ANOVA were run examining the effects of respirators. The means and standard deviations for the four tasks for the three experimental conditions and the control group are presented in Table 9.

The analysis of the GRE logical, the GRE analytical and the hypothesis testing were all not significant. The ANOVA for the number correct on the Miller test was significant, $F(3,44)=41.78$, $p<.0001$. The commparison of experimental groups to the control was significant $F(1,44)=14.55$, $p<.0003$. The mean scores for subjects wearing half and full masks were significantly different from the control condition, with decrements in performance of 20% and 26% respectively.

5.4. DISCUSSION

The failure of the GRE tests to show work decrement may be due to the extreme difficulty level of the tests as well as the low number of questions used. Subjects rarely finished all eight problems. Although respirators might produce work decrements, these tasks were apparently too difficult to allow for the detection of those decrements.

Of the four tests used, only the Miller appeared to show any statistically significant performance decrement. Care must be exercised in the interpretation of these results because of the possibility that the four practice tests may not have been of equal difficulty. The test segments were extracted from four practice tests. Since the same practice test was used for all subjects wearing each particular mask, and if the

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tests were not of equal difficulty, then test difficulty could confound the results.

To investigate this possibility of confounding, the four sets of three thirty question tests were given to four individuals who took the timed tests in random order and with no respirators. Although a small subset of subjects, the averages of the scores appeared to follow the same pattern as was seen with respirators. The scores for test 2 (used for the dust mask) were 1.6% higher than test 1 (used for no mask). The scores for tests 3 and 4 (used for the half and full facemask respirators, respectively) were 23% and 26% lower than test 1. Thus, it appears that different difficulty levels between tests were significant enough to confound the results of the twelve subject experiment. For all practical purposes, it appears that this bias could cancel out the original results, indicating that the Miller analogies, used in this manner, did not detect work effects due to respirators.

In general, cognitive tests are difficult to administer for this type of experimental design due to the carryover effects from condition to condition. Cognitive tasks which are not ability measures might show performance decrements caused by respirators.

6. SUMMARY DISCUSSION

The goal of this study was to experimentally identify one or more testing procedures that could detect the possible effects of wearing respirators during the performance of a task. An additional goal was to determine if such procedures were sensitive enough to differentiate among different types of respirators. The study was designed so as to provide the greatest possibility of success by examining a wide range of

respirators and job tasks in a carefully controlled situation.

Effects on performance were seen in the physical work task, with increased exertion and in the psychomotor tasks, with lessened steadiness and slower arm-hand movements, but not seen in the cognitive tasks. In general, the tests did not differentiate well among the effects of different respirator types.

It is important to realize that the tests that did not demonstrate any significant differences in performance provide equally useful information. These tests indicate that, based on the study's results, respirators appear to have no effect on the performance of certain tasks, such as cognitive and reaction time skills.

The general findings of this study would indicate that tasks used to evaluate performance must be chosen carefully. The tasks should model specific tasks as opposed to modeling general situations and should measure specific abilities. General tasks such as a reaction time task may not be sensitive enough to be used as future diagnostic tools in respirator evaluation. Respirator usage would seem to have more of an effect on steadiness and large movements and less effect on movements requiring precision. Most differences appear with the full face and half face respirators and future studies should concentrate on those types of masks.

The increase in energy (VO_2) required to perform work when wearing respirators and working at moderate exercise levels is in itself an interesting finding. However, coupled with the reselts of the steadiness and One-Hole Test results, this study suggests that a statistically as well as economically significant decrement in work performance may occur when many types of respirators are worn.

7. CONCLUSIONS AND RECOMMENDATIONS

Further cognitive studies should be conducted to determine if other tests can detect differences in performance due to respirators, or if not, to confirm the suggestion of the results of this study that respirators may not have a significant affect on cognitive performance.

Further psychomotor studies should be conducted to continue testing the One-Hole Test for use in evaluating respirator effects on performance. The significant results of this study should be further validated by testing with heterogeneous subject group in a laboratory setting as well as with groups of working in a field situation. Because of the significant results seen with the steadiness test, further testing should be considered for this test also. Other population's which may prove useful to study include females, older workers and experienced respirator wearers.

One of the most important outcomes of the physical task results in addition to replicating previous research showing a work decrement, is to validate the results of the other two task domains, cognitive and psychomotor. The positive results seen in the physical domain within the chosen two-hour study time period support the results seen in the other two domains.

Figure 1

Experimental Design for Combined Experiments

	Order 1 S1 S2	Order 2 S3 S4	Order 3 S5 S6	Order 4 S7 S8	Order 5 S9 S10	Order 6 S11 S12
	Psychomotor Tasks	Cognitive Tasks	Physiological Tasks	Psychomotor Tasks	Cognitive Tasks	Physiological Tasks
Session 1	Control	Control	Control	Dust Mask	Full Face	Half Face
Session 2	Dust Mask	Full Face	Half Face	Full Face	Half Face	Dust Mask
Session 3	Half Face	Dust Mask	Full Face	Half Face	Dust Mask	Full Face
Session 4	Full Face	Half Face	Dust Mask	Control	Control	Control
	Cognitive Tasks	Physiological Tasks	Psychomotor Tasks	Physiological Tasks	Psychomotor Tasks	Cognitive Tasks
Session 1	Control	Control	Control	Full Face	Half Face	Dust Mask
Session 2	Half Face	Dust Mask	Full Face	Half Face	Dust Mask	Full Face
Session 3	Full Face	Half Face	Dust Mask	Dust Mask	Full Face	Half Face
Session 4	Dust Mask	Full Face	Half Face	Control	Control	Control
	Physiological Tasks	Psychomotor Tasks	Cognitive Tasks	Cognitive Tasks	Physiological Tasks	Psychomotor Tasks
Session 1	Control	Control	Control	Half Face	Dust Mask	Full Face
Session 2	Full Face	Half Face	Dust Mask	Dust Mask	Full Face	Half Face
Session 3	Dust Mask	Full Face	Half Face	Full Face	Half Face	Dust Mask
Session 4	Half Face	Dust Mask	Full Face	Control	Control	Control

TABLE 1

ANALYSIS OF VARIANCE MODEL

Source		degrees of freedom
Group	G	1
Order(Group)	O(G)	4
Individuals(Order)	s(O)	4
Mask Type	M	3
Group*Mask	G*M	3
Order*Mask(Group)	O*M(G)	12
Trial	t	2
Group*Trial	G*t	2
Order*Trial(Group)	O*t(G)	8
Mask*Trial	M*t	6
Group*Mask*Trial	G*M*t	6
Order*Mask*Trial(Group)	O*M*t(G)	24
Error	Error	44

Table 2

MEANS AND STANDARD DEVIATIONS FOR

PHYSICAL TASK

Task	Control	Dust Mask	Half Face	Full Face
VO$_2$ (liters)	1.075[*] 0.111	1.119 0.157	1.167 0.146	1.191 0.125
Systolic BP (mmHg)	135.6 10.8	137.0 8.9	138.5 9.4	140.9 11.5
Diastolic BP (mmHg)	74.0 8.1	74.3 8.1	74.8 5.3	78.4 5.5

Top number is mean, bottom number is standard deviation

TABLE 3

SUMMARY OF P-VALUES FOR ANOVA RESULTS FOR PHYSICAL TASK

Task	Mask	Control vs. Mask
VO_2	.0002	.0002
Systolic	.0017	.0094
Diastolic	.0001	NS

TABLE 4

BONFERRONI COMPARISON P-VALUES

FOR PHYSICAL TASK

Task	Control vs. Dust Mask	Control vs. Half Face	Control vs. Full Face	Dust Mask vs. Half Face	Dust Mask vs. Full Face	Half Mask vs. Full Face
VO_2	.0957	.0008*	.0001*	.0754	.0082*	.3614
Systolic	.3865·	.0422	.0002*	.2774	.0056	.0649
Diastolic	.7392	.4762	.0001*	.7011	.0001*	.0001*

*statistically significant, critical value ≤ 0.0083
(based on $\alpha = 0.05$)

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TABLE 5

SUMMARY OF SELECTED TASK DECREMENT[+] PERCENTAGES

TASK	Respirator Type		
	DUST	HALF	FULL
<u>Cognitive</u>			
Miller Analogy	+4.6	-20*	-26*
<u>Psychomotor</u>			
Steadiness	+0.8	+3.1	-31*
One-Hole Test			
Pin Count	-4	-6	-6
Grasp Time	+3	0	+10.5
Movement Time	+19*	+15*	+14*
Position Time	+7	+7	+11
Reach Time	+11	+11	+12
<u>Physical</u>			
VO_2	+4	+9*	+11*

[+]*Percent difference between respirator type and control*

Statistical significance based on comparison of means

TABLE 6

MEANS AND STANDARD DEVIATIONS FOR PSYCHOMOTOR TASKS

Task	Control	Dust Mask	Half Face	Full Face
Hand Dynamometer	48.3*	48.9	49.5	49.4
(kilograms)	11.7	11.1	12.2	12.7
Steadiness	2.13	2.12	2.07	2.79
(times touched)	1.9	1.4	1.3	2.2
Pursuit Rotor	11.9	12.3	12.1	11.6
(seconds on target)	2.9	3.6	3.2	3.4
Pursuit Rotor	42.1	42.0	41.5	43.0
(no. of slips)	8.0	8.3	8.7	8.2
Reaction Time	0.481	0.473	0.472	0.474
(seconds)	0.046	0.035	0.041	0.039
One Hole				
Pins	41.81	40.07	39.41	39.23
(count)	8.20	10.82	9.59	10.60
Grasp Time	0.246	0.254	0.247	0.272
(seconds)	0.069	0.100	0.079	0.111
Movement Time	0.365	0.436	0.421	0.415
(seconds)	0.115	0.188	0.132	0.151
Position Time	0.205	0.220	0.220	0.227
(seconds)	0.099	0.140	0.096	0.118
Reach Time	0.660	0.724	0.723	0.736
(seconds)	0.199	0.329	0.275	0.327

*Top number is mean, bottom number is standard deviation

TABLE 7

SUMMARY OF P-VALUES FOR ANOVA RESULTS FOR PSYCHOMOTOR TASKS

Task	Mask	Control vs. Mask
Hand Dynometer	NS	NS
Steadiness	.004	NS
Pursuit Rotor (seconds on target)	.027	NS
Pursuit Rotor (slips)	NS	NS
Reaction Time	NS	.042
One Hole		
Pins	.045	.01
Grasp Time	NS	NS
Movement Time	.0005	.0001
Position Time	NS	NS
Reach Time	.077	.016

TABLE 8

BONFERRONI COMPARISON P-VALUES

FOR PSYCHOMOTOR TASKS

Task	Control vs. Dust Mask	Control vs. Half Face	Control vs. Full Face	Dust Mask vs. Half Face	Dust Mask vs. Full Face	Half Mask vs. Full Face
Hand Dynamometer	0.3718	0.0657	0.1087	0.3344	0.4687	0.8070
Steadiness Test	0.9388	0.9388	0.0032*	0.7832	0.0026*	0.0016*
Pursuit Rotor Seconds on Target	0.9750	0.9350	0.0140	0.9595	0.0134	0.0137
Pursuit Rotor No. of Slips	0.8948	0.5033	0.4754	0.5895	0.3992	0.1752
Reaction Time	0.1523	0.0491	0.1264	0.5489	0.8844	0.6587
One Hole Pins	0.1593	0.0175	0.0160	0.3699	0.2794	0.8413
Grasp Time	0.6420	0.9846	0.0422	0.6474	0.1316	0.0377
Movement Time	0.0001*	0.0006*	0.0022*	0.4929	0.2698	0.6522
Position Time	0.3422	0.2603	0.1014	0.9060	0.5323	0.5881
Reach Time	0.1401	0.0418	0.0137	0.6324	0.3584	0.6324

*Statistically significant, critical value ≤ 0.0083 (based on $\alpha = 0.05$)

TABLE 9

MEANS AND STANDARD DEVIATIONS FOR

COGNITIVE TASKS

Task	Control	Dust Mask	Half Face	Full Face
Miller	17.030[*]	17.818	13.636	12.606
(no. correct)	2.807	2.588	2.601	2.101
GRE Logical	3.889	3.722	3.833	3.028
(no.correct)	1.690	1.455	1.494	1.259
GRE Analytical	3.417	3.611	3.333	4.083
(no. correct)	1.787	1.090	1.484	1.876
Hypothesis test	1.389	1.500	1.264	1.333
(errors)	1.205	1.389	1.309	1.231

Top number is mean, bottom number is standard deviation

TABLE 10

SUMMARY OF P-VALUES FOR ANOVA RESULTS FOR COGNITIVE TASKS

Task	Mask	Control vs. Mask
Miller (# right)	.0001	.0003
GRE Anal (#right)	NS	NS
GRE Logic (#right)	.0611	NS
Hypothesis Test	NS	NS

TABLE 11

BONFERRONI COMPARISON OF P-VALUES

FOR COGNITIVE TASKS

Task	Control vs. Dust Mask	Control vs. Half Face	Control vs. Full Face	Dust Mask vs. Half Face	Dust Mask vs. Full Face	Half Mask vs. Full Face
Miller	.1715	.0001*	.0001*	.0001*	.0001*	.0510
GRE Log	.6374	.8751	.0171	.7533	.0527	.0523
GRE Anal.	.5702	.8075	.0546	.4179	.1704	.0315
Hypoth.	.7961	.4654	.7705	.3189	.5769	.6257

*statistically significant, critical value $\leq$ 0.0083
(based on α = 0.05)

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APPENDIX A

MEDICAL EVALUATION QUESTIONNAIRE

PURDUE UNIVERSITY
RESPIRATOR PROJECT
EVALUATION
INITIAL MEDICAL QUESTIONNAIRE

1. Name _____ 2. Date _____

3. Social Security # _____ - _____ - _____

4. Present Address _____

5. Permanent Address _____

6. Year _____ 7. School _____

8. Major: _____

9. Current Telephone Number _____

10. Date of Birth _____
                   Month Day Year

11. Place of Birth _____

12. Sex   1. Male   ____
                                     2. Female ____

13. What is your marital status?   1. Single ____
                                     2. Married ____
                                     3. Widowed ____
                                     4. Separated/Divorced ____

14. Race   1. White   ____
                                     2. Black   ____
                                     3. Asian   ____
                                     4. Hispanic ____
                                     5. Indian   ____
                                     6. Other   ____

    What is the highest grade completed in school? _____
    (For example, 12 years is completion of high school)

15. Height (inches): _____ 16. Weight (lbs.): _____

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OCCUPATIONAL HISTORY

17A. Have you ever worked full time   1. Yes ___ No ___
     (30 hours per week or more) for
     6 months or more?

     IF YES TO 17A:

B. Have you ever worked for a year   1. Yes ___ No ___
   or more in any dusty job?   3. Does not apply ___

   specify job/industry_____ Total years worked ___

   Was dust exposure: 1. Mild ___ 2. Moderate ___ 3. Severe ___

C. Have you even been exposed to gas or   1. Yes ___ 2. No ___
   chemical fumes in your work?
   Specify job/industry _____ Total Years Worked ___

   Was exposure: 1. Mild ___ 2. Moderate ___ 3. Severe ___

D. What has been your usual occupation or job--the one you have
   worked at the longest?

   1. Job occupation _____

   2. Number of years employed in this occupation _____

   3. Position/job title _____

   4. Business, field or industry _____

(Record on lines the years in which you have worked in any of these
industries, e.g. 1960-1969)

Have you ever worked:

		YES	NO
E.	In a mine?	___	___
F.	In a quarry?	___	___
G.	In a foundry?	___	___
H.	In a pottery	___	___
I.	In a cotton, flax or hemp mill?	___	___
J.	With asbestos?	___	___

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19. PAST MEDICAL HISTORY

   A. Do you consider yourself to be in good health? . . ____ ____

      If "NO" state reason _____

   B. Have you any defect of vision? . . . . ____ ____

      If "YES" state nature of defect _____

   C. Have you any hearing defect? . . . . ____ ____

      If "YES" state nature of defect _____

   D. Are you suffering from or have you ever suffered from:

      a. Epilepsy (or fits, seizures, convulsions)?   ____ ____

      b. Rheumatic fever?   ____ ____

      c. Kidney disease?   ____ ____

      d. Bladder disease?   ____ ____

      e. Diabetes?   ____ ____

      f. Jaundice?   ____ ____

      g. Tuberculosis   ____ ____

19. CHEST COLDS AND CHEST ILLNESSES

19A. If you get a cold, does it usually go   1. Yes___ 2. No___
to your chest? (Usually means more   3. Don't get colds___
than 1/2 the time)

20 . During the past 3 years, have you had   1. Yes___ 2. No___
any chest illness that have kept you
off work, indoors at home, or in bed?

21. Did you have any lung trouble before   1. Yes___ 2. No___
the age of 16?

22. Have you ever had any of the following?

    1A. Attacks of bronchitis?   1. Yes___ 2. No___

        IF YES TO 1A:
      B. Was it confirmed by a doctor?   1. Yes___ 2. NO___
                                             3. Does not apply___

      C. At what age was your first attack?   Age in years ___
                                           Does not apply___

    2A. Pneumonia (include bronchopneumonia)? 1. Yes___ 2. No___

        IF YES TO 2A:
      B. Was it confirmed by a doctor?   1. Yes___ 2. No___
                                             3. Does not apply___

      C. At what age did you first have it?   Age in years ___
                                           Does not apply___

    3A. Hay Fever?   1. Yes___ 2. No___

        IF YES TO 3A:
      B. Was it confirmed by a doctor?   1. Yes___ 2. No___
                                             3. Does not apply___

      C. At what age did it start?   Age in years ___
                                           Does not apply___

23A. Have you ever had chronic bronchitis?   1. Yes___ 2. No___

    IF YES TO 23A:

    B. Do you still have it?   1. Yes___ 2. No___
                                           3. Does not apply___

    C. Was it confirmed by a doctor?   1. Yes___ 2. No___
                                           3. Does not apply___

    D. At what age did it start?   Age in years ___
                                           Does not apply___

24A. Have you ever had emphysema?   1. Yes___ 2. No___

    IF YES TO 24A:
    B. Do you still have it?   1. Yes___ 2. No___
                                           3. Does not apply___

    C. Was it confirmed by a doctor?   1. Yes___ 2. No___
                                           3. Does not apply___

    D. At what age did it start?   Age in years ___
                                           Does not apply___

25A. Have you ever had asthma?   1. Yes___ 2. No___

     IF YES TO 25A:
   B. Do you still have it?   1. Yes___ 2. No___
                                                       3. Does not apply___

   C. Was it confirmed by a doctor?   1. Yes___ 2. No___
                                                       3. Does not apply___

   D. At what age did it start?   Age in years ____
                                                       Does not apply___

   E. If you no longer have it, at what   Age stopped _____
      age did it stop?   Does not apply___

26A. Any other chest illness?   1. Yes___ 2. No___

     If yes, please specify_____

   B. Any chest operations?   1. Yes___ 2. No___

     If yes, please specify_____

   C. Any chest injuries?   1. Yes___ 2. No___

     If yes, please specify_____

27A. Has a doctor ever told you that you   1. Yes___ 2. No___
     had heart trouble?

     IF YES TO 27A:
   B. Have you ever had treatment for heart   1. Yes___ 2. No___
      trouble in the past 10 years?   3. Does not apply___

28A. Has a doctor ever told you that you   1. Yes___ 2. No___
     had high blood pressure?

     IF YES TO 28A:
   B. Have you had any treatment for high   1. Yes___ 2. No___
      blood pressure (hypertension) in   3. Does not apply___
      the past 10 years?

29. When did you last have your chest   (year) ___ ___ ___ ___
     x-rayed?   25 26 27 28

30. Where did you last have your chest
     x-rayed (if known)?_____

     What was the outcome?_____

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FAMILY HISTORY

31. Were either of your natural parents ever told by a doctor that
    they had a chronic lung condition such as:

	Father			Mother		
	1. Yes	2. No	3. Don't Know	1. Yes	2. No	3. Don't Know
A. Chronic Bronchitis?	___	___	___	___	___	___
B. Emphysema?	___	___	___	___	___	___
C. Asthma?	___	___	___	___	___	___
D. Lung cancer?	___	___	___	___	___	___
E. Other chest conditions?	___	___	___	___	___	___
F. Is parent currently alive?	___	___	___	___	___	___

G. Please Specify   ___ age if living   ___ age if living
                     ___ age at death   ___ age at death
                     ___ don't know   ___ don't know

H. Please specify cause of death_____

COUGH

32A. Do you usually have a cough? (Count   1. Yes___ 2. No___
     a cough with first smoke or on first
     going out of doors. Exclude clearing
     of throat.) (If no, skip to question
     32C.)

  B. Do you usually cough as much as 4 to   1. Yes___ 2. No___
     6 times a day 4 or more days out of
     the week?

  C. Do you usually cough at all on getting   1. Yes___ 2. No___
     up or first thing in the morning?

  D. Do you usually cough at all during   1. Yes___ 2. No___
     the rest of the day or at night?

IF YES TO ANY OF ABOVE (32A, B, C, D). ANSWER THE FOLLOWING. IF NO TO ALL
CHECK DOES NOT APPLY AND SKIP TO NEXT PAGE

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E. Do you usually cough like this on   1. Yes___ 2. No___
most days for 3 consecutive months   3. Does not apply___
or more during the year?

F. For how many years have you had a cough?   Number of years____
                                        Does not apply_____

EPISODES OF COUGH AND PHLEGM

33A. Have you had periods of episodes of   1. Yes___ 2. No___
(increased*) cough and phlegm
lasting for 3 weeks or more each year?
*(For persons who usually have cough
and/or phlegm)

     IF YES TO 33A:
B. For how long have you had at least   Number of years____
one such episode per year?   Does not apply_____

WHEEZING

34A. Does your chest ever sound wheezy or whistling:

       1. When you have a cold   1. Yes___ 2. No___
       2. Occasionally apart from cold?   1. Yes___ 2. No___
       3. Most days or nights?   1. Yes___ 2. No___

     IF YES TO 1,2, or 3 in 34A:
B. For how many years has this been present?   Number of years____
                                         Does not apply_____

35A. Have you ever had an attack of   1. Yes___ 2. No___
wheezing that has made you feel
short of breath?

     IF YES TO 35A:
B. How old were you when you had your   Age in years_____
first such attack?   Does not apply____

C. Have you had 2 or more such episodes?   1. Yes___ 2. No___
                                         3. Does not apply_____

D. Have you ever required medicine or   1. Yes___ 2. No___
treatment for the(se) attack(s)?   3. Does not apply_____

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BREATHLESSNESS

36. If disabled from walking by any
condition other than heart or lung
disease, please describe and proceed
to question 38A.
Nature of condition(s)_____

37A. Are you troubled by shortness of   1. Yes___ 2. No___
breath when hurrying on the level
or walking up a slight hill?

    IF YES TO 37A:
B. Do you have to walk slower than   1. Yes___ 2. No___
people of your own age on the   3. Does not apply____
level because of breathlessness?

C. Do you ever have to stop for breath   1. Yes___ 2. No___
when walking at your own pace on the   3. Does not apply____
level?

D. Do you ever have to stop for breath   1. Yes___ 2. No___
after walking about 100 yards (or   3. Does not apply____
after a few minutes) on the level?

E. Are you too breathless to leave the   1. Yes___ 2. No___
house or breathless on dressing or   3. Does not apply____
climbing one flight of stairs?

TOBACCO SMOKING

38A. Have you ever smoked cigarettes?   1. Yes___ 2. No___
(No means less than 20 packs of
cigarettes or 12 oz. of tobacco
in a lifetime or less than 1
cigarette a day for 1 year.)

    IF YES TO 38A:
B. Do you now smoke cigarettes (as of   1. Yes___ 2. No___
one month ago?   3. Does not apply____

C. How old were you when you first   Age in years _____
started regular cigarette smoking?   Does not apply____

D. If you have stopped smoking   Age stopped   ____
cigarettes completely, how   Check if still smoking ____
old were you when you stopped?   Does not apply   ____

E. How many cigarettes do you   Cigarettes per day   ____
smoke per day now?   Does not apply   ____

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F. On the average of the entire time you smoked, how many cigarettes did you smoke per day?

Cigarettes per day _____
Does not apply _____

G. Do or did you inhale the cigarette smoke?

1. Does not apply _____
2. Not at all _____
3. Slightly _____
4. Moderately _____
5. Deeply _____

39A. Have you ever smoked a pipe regularly? (Yes means more than 12 oz. of tobacco in a lifetime.)

1. Yes___ 2. No___

IF YES TO 39A:

FOR PERSONS WHO HAVE EVER SMOKED A PIPE

B. 1. How old were you when you started to smoke a pipe regularly?

Age _____

2. If you have stopped smoking a pipe completely, how old were you when you stopped?

Age stopped _____
Check if still smoking pipe _____
Does not apply_____

C. On the average over the entire time you smoked a pipe, how much pipe tobacco did you smoke per week?

___ oz. per week (a standard pouch of tobacco contains 1 1/2 oz.)
___ Does not apply

D. How much pipe tobacco are you smoking now?

oz. per week _____
Not currently smoking a pipe _____

E. Do you or did you inhale the pipe smoke?

1. Never smoked _____
2. Not at all _____
3. Slightly _____
4. Moderately _____
5. Deeply _____

40A. Have you ever smoked cigars regularly? (Yes means more than 1 cigar a week for a year)

1. Yes___ 2. No___

IF YES TO 40A:

B. 1. How old were you when you started   Age ____
     smoking cigars regularly?

   2. If you have stopped smoking cigars   Age stopped ____
     completely, how old were you when   Check if still
     you stopped.   smoking cigars____
      Does not apply____

C. On the average over the entire time   Cigars per week ____
   you smoked cigars, how many cigars   Does not apply ____
   did you smoke per week?

D. How many cigars are you smoking   Cigars per week ____
   . per week now?   Check if not
     smoking cigars
     currently ____

E. Do or did you inhale the cigar smoke?   1. Never smoked ____
     2. Not at all ____
     3. Slightly ____
     4. Moderately ____
     5. Deeply ____

GENERAL FITNESS

41A. Do you exercise on a regular basis?   Yes   No

    IF YES TO 41A:

B. How many times do you exercise per week? _____

C. What is the average time spent per exercise session?_____

D. What activities typically constitute your exercise sessions?

Jogging/Running	Softball	Golf
Bicycling	Swimming	Tennis
Basketball	Soccer	Other_____

Signature _____   Date _____

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