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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 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. 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. 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.

INTRODUCTION

When the work environment cannot be controlled adequately or during emergencies, respiratory protection equipment must be relied on to protect the worker. 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 quantitative 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. While research does exist on the physiological effects of respirators (Goldman, 1984; Louhevaara, 1985), little is known concerning cognitive and psychomotor decrements. This study included an evaluation of performance decrement due to respirator wear on three levels of performance - physical, as well as cognitive and psychomotor.

METHOD

A comprehensive study was conducted to investigate test procedures which could be used to quantitatively determine a decrement in work performance due to the use of respirators. The subjects' responses were monitored while they successively wore three popular types of respirators and successively performed three tasks intended to simulate the majority of activities in a typical industrial workplace setting. The three types of respirators chosen 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 selected to simulate a moderate workload, for an average healthy subject, of approximately four to five kcal/min. Work decrement was estimated indirectly by the increase in oxygen consumption, which was correlated to measured heart rate.

Psychomotor performance involves motor behavior, typically combining manual manipulation and decision making, and forms the basis of much repetitive industrial work. Four of Fleishman's eleven factors (Fleishman, 1975), describing the spectrum of psychomotor abilities, were selected as being most critical and representative of the types of performance required while wearing respirators. These four factors, arm-hand steadiness, control precision, finger dexterity and reaction time, were tested with an electronic feedback stylus-in-hole steadiness instrument, a light-tracking photoelectric pursuit-rotor, a closed electrical circuit One-Hole Tester (Salvendy, 1975) in which pins are repeatedly inserted into a small hole, and a four choice reaction time response unit.

The selection of cognitive tasks was limited to those which would show no obvious effects of practice, as well as on the availability of material to occupy subjects for the total experimentation time without repetition. These constraints led to the selection of standardized Miller Analogies, hypothesis tests and GRE logical and analytical tests.

Twelve young, healthy, non-smoking university students participated in the experiment. The purpose of the experiment was to compare the performance of these twelve subjects on various tasks while using the three types of respirators compared to the control condition

of no respirator. To maximize the power for these comparisons, a repeated measures design was used, with each subject performing each task with each of the respirator conditions. Each one of these sessions lasted two hours, with the order of the twelve sessions per subject randomized. The design was a rather complex Graeco-Latin square.

The experimental null hypothesis that the task performance parameter scores would be the same for the four experimental conditions (three types of respirators and the control) was examined by an analysis of variance model. If the null hypothesis was rejected or the contrast showed a significant difference between the control and the average of the three masks, a Bonferroni multiple comparison procedure was conducted to examine which pairs of mask conditions differed significantly.

RESULTS

The increase in oxygen consumption (VO_2) as an indicator of increased work effort and thus, less effective work, with respirators when compared to no respirator was statistically significant. 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 10% more VO_2.

The analysis of variance comparing masks worn during the steadiness test revealed a statistically significant difference between respirators. Further examination indicated the source of the difference to be from the full-face respirator which had a 31% performance decrement. While there were no practically significant effects on reaction time and pursuit rotor tests, the movement time of the One-Hole Test was statistically significantly lengthened with all three respirators (average of 16% increase) indicating a significant performance decrement. While the other measurements of the multiple variables One-Hole Test, three elemental time measures and total pin insertion, did not show statistically significant performance decrements, it is interesting to note the trend that all measures had performance drops of from 3% to 12% for all respirator types.

After all bias was accounted for, there did not appear to be any performance effect of respirators on the cognitive tests used in the study.

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 affect on steadiness and large movements and less affect on movements requiring precision. Most differ-ences 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 results 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.

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