APPLIED PHYSIOLOGY

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INTRODUCTION

Man has long demonstrated an extraordinary capacity to adapt to the stresses imposed by the earth's environment. Physiological adaptations that provide us with the ability to tolerate, indeed to thrive in climates that might be considered "hostile" to human life, are complemented by man's ingenious ability to fabricate protective shields to further extend the environmental limits in which he may function both safely and productively. The disciplines of human biology identifty the challenges posed by environmental stressors on working man, and they welcome technological contributions in alleviating them. There is the risk, however, that valid physiological principles may be abbreviated and/or incorrectly interpreted by engineers in their enthusiastic attempts to reduce a biologically threatening situation to a problem that has a simple physical solution.

RESPIRATORY PROTECTION

The SCBA: *An* outstanding example of this can be seen in the technological advances being achieved in the field of respiratory protection. The most critical line of defense for the human organism is that of assuring an uninterrupted supply of respirable oxygen. Early high altitude balloonists were among the first to recognize this need in their specific environment, but respiratory protection has become a routine necessity for workers exposed to a wide variety of toxicants, whether or not they are accompanied by an oxygen-deficient atmosphere. The advent of modern breathing apparatus for firefighting and mine rescue operations demanded the cooperation of physiologists to define the respiratory needs of working man and the engineers to develop a breathing device that could provide for it Serious mistakes were made in the mixing of these disciplines. The work of Silverman in 1945 (1) provided the standard figure of 40 liters/minute to be used as the benchmark value for the minute ventilatory requirement of emergency workers. Once established, this standard pushed the technology of the self-contained breathing apparatus (SCBA) industry.

Government regulating agencies then based their certification requirements (2) on that figure and new generation SCBAs were tested by a breathing machine at that level of minute ventilation when divided by piston excursions into 24 "breaths" per minute. Thus, both the (a) duration of *air* supply, and (b) breathing resistance criteria were evaluated according *to* this ventilatory demand. Since then, a closer examination of the workloads actually imposed on firefighters (3) revealed that the device firefighters had been told would last for 30 minutes was actually running out of air in as little as 10 minutes. And although certified as providing a free-flow of *air* to the worker, it was actually imposing a level of resistance that became the limiting factor in emergency task performance.

Unlike a machine, the human respiratory system places demands on a SCBA that are more appropriately a function of peak flow rates rather than average flow rates. For example, an instrument can be certified for passing an exhalation resistance test if it performs well when challenged with a constant flow of 85 liters per minute. Physiologically, the velocity of a working firefighter's expiratory flow is closer to 250 liters per minute (3) . Consequently, it is not surprising that the system developed by engineers to provide respiratory protection to the firefighter became an instrument that imposed severe breathing resistance and, thus, worker distress. The mistake originated with the reliance on oversimplified data describing respiratory responses of working man.

The Escape Device: A similar problem surfaced in the development of an "escape device", an apparatus designed to provide short-duration respiratory protection for the emergency evacuatiuon of a hazardous environment Escape capsules (usually an air-supplied vinyl capsule that is pulled over the head and seals at the neck) in the early 1980's were designed to provide a constant flow of 28 liters of air per minute. Although this is a good estimate for the ventilatory requirements of an adult breathing fresh air, it failed *to* appreciate the fact that the capsule was very effective in storing most of the expired air in each respiratory cycle. Thus, the composition of the inspired air was not fresh at all, but rather closely resembled expired air in both CO_2 and O_2 content. Consequently, stimuli to the respiratory center included both the on-going production of metabolites plus the re-introduction of exhaled CO_2 to the lungs during the re-breathing process.

Indeed, such capsules were purchased and stocked in potentially hazardous work places primarily because of the assurance placed on the label. Further research (5) provided evidence that an air flow of about 60 liters per minute was required to assure the adequate flushing of the rebreathing bag to support the metabolic and ventilatory requirements of the worker during an emergency egress.

FITNESS FOR DUTY

Perhaps an even more disheartening event is when engineers develop a truly state-of-the-art protective device only to find that its failure can be @aced to its being evaluated when worn by a physically unqualified worker. Too often entry level fimess requirements for career fields where the worker can expect to be called upon to perform unusually strenuous physical tasks are often either inappropriate or invalid For example, since it was first described in the late 1920's, a measure of aerobic capacity has been hailed as the most valid indicator of overall physical fimess. Few physiologists would disagree with this rationale, but care must be taken not to allow it alone to govern the selection of workers for a wide variety of career fields. The limitations of aerobic capacity for describing fit-for-duty characteristics are seriously magnified when the test used to evaluate this fimess parameter is invalid in itself.

Consider the wide use of the 1.5 mile run to estimate aerobic capacity and, in turn, physical fimess. When the job applicant pushes him/herself to an exhaustive effort, the time required to complete this task becomes a fairly valid estimate of one's aerobic capacity. However, in an effort to reduce the risk of overexertion, the alternative of establishing a time standard for classifying fitness levels has become commonplace. Field research has shown that the recommended passing time of 14 min 30 sec for the 1.5 mile run is essentially meaningless for describing the physical work capacity of a 19-year old male (3,4).

Researchers must avoid falling into the dilemma of hying to evaluate prototypes of respiratory protection devices when wom by people who Iack the physical fitness even to perform the required task in a shirt-sleeve environment, and then attributing this failure to the burden imposed by the protective device. Lacking appropriate control of subject selection welcomes the pitfalls of trying to determine the tolerance time for groundcrew performing operational tasks while wearing thermally stressful protective ensembles only to find that a large percentage of those assigned to that task are so unfit that they cannot work long enough to even experience heat stress--whether or not they are wearing a protective ensemble.

CONCLUSION

Applied phyhsiology is an essential partner in the pursuit of technological advances in the field of Environmental Ergonomics. A valid appraisal of the merits of these advances must depend upon the appropriate interpretation of experimental evidence obtained under conditions that are relevant to the real-life application of this technology.

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