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Focus

Perspectives of Ergonomics Research at Defence Institute of Physiology and Allied Sciences in India

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1. Introduction

Interest in ergonomics in India developed quite late after the II World War. The first reported work in industrial ergonomics was carried out in India in 1953, at a cotton textile mill in West Bengal. Organized scientific activities in ergonomics in India was started with the establishment of Defence Institute of Physiology and Allied Sciences (DIPAS) in 1962. During the last 36 years DIPAS has made significant contribution in various fields of ergonomics, especially for the Indian army personnel with spin off benefits reaching the society at large, which have been published in the national and international journals of repute. The ergonomics research activities of DIPAS are presented here in a nutshell.

2. Energy expenditure and nutritional requirements

India has a fairly large boundary areas with high mountainous terrain. The nature of the eastern and western Himalayas are quite different. It was one of the primary objectives of DIPAS activities to measure the daily energy expenditure of various corps and formulate ration scale especially for those who were posted at various altitudes.

The daily energy expenditure of the Infantry and Artillery personnel at altitudes in the eastern and western sectors, ranging from 3600 to 3960 m, was found to be between 3371 and 3480 cal whereas the mean daily food composition was above 4037 cal in these corps. Similar energy expenditure studies were carried out on troops at higher altitudes (4000 and 4600 m), for peace and field areas, for submarine crews both in sailing and exercise groups, for ambulatory and non-ambulatory groups of patients, for boys in the age groups of 11–16 yr in the Military schools, for various tradesman and pioneers in Borders Road Organization, for the coast guard and many more. Ration scale was formulated in each of these cases with 10% allowance plus the total daily energy expenditure values. Recommendations of calorie requirement with contents of carbohydrate (65%), fat (10–15%) and proteins (25%) have been suggested and implemented in each of these cases which resulted in considerable savings to the Government exchequers.

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3. Optimization of load

As early as 1964, variation in load march as influenced by steepness of the terrain traversed, on a group of subjects carrying loads of 2.7, 9.1, 22.7 and 31.8 kg at ground level and gradients of 12.5, 20.0 and 33.3% was studied. The optimum speed, at which the energy cost of carrying out a given amount of work minimum, was found to be about 1.33–1.55 m s^{-1}. Optimum value of carrying load for steepness of gradients, nature of terrain and speed of march has been predicted. The energy expenditure while walking on the snow is found to be three times more than that on the surface ground. Most economical way of carrying school bags for children in four different modes was studied and rucksack mode was found to be the best with a carrying load of 2.72 kg.

The physiological strain of lifting five loads (5, 10, 15, 20 and 25 kg) at three heights [floor to knuckle (F–K, 0.75 m), knuckle to shoulder (K–S, 0.68 m), floor to shoulder (F–S, 1.43 m)] in three frequencies (1, 4 and 8 lifts min^{-1}) were studied on a group of young, healthy male soldiers in the sagittal plane. Variations in physiological criteria made it difficult to suggest any specific limit for lifting task for the population studied. However, 33% VO_2max was found to be more reasonable criteria for recommending the lifting limits.

In a separate study, the maximum acceptable weight of lift (MAWL) in 180° turning asymmetric operations in three different heights and frequencies for 8 h operation was determined by psychophysical technique. The MAWL was highest (29.8 kg) in F–K height in 1 lift min^{-1} and lowest (14.6 kg) in F–S height in 8 lifts min^{-1}.

4. Physical fitness and maximum work capacity

Six hundred troops in the age range of 17–45 yr were studied at the plains and altitude upto 4000 m using physical efficiency variables. A new physical efficiency test for the high altitude, comprising of hill climbing efficiency involving a distance of 4.8 km with ascent and descent of 300 m was formulated as early as in 1966. The induction of sojourners to moderate to high altitude show deterioration in physical work capacity and the level of deterioration varies with respect to physical fitness status of the individual prior to induction. The effect of physical training, yoga and endurance exercises on adaptation to various altitudes has been carried out on different Corps of personnel and ethnic groups. Specific training schedule of the troops for at least 6–8 weeks before induction to altitude has been suggested.

Attempts were made to find out the differences in the physical fitness status of the combat and non-combat groups of army personnel of various age groups, to establish the relationship of physical standards with endurance and to formulate specific training programme based on physiological responses. It was observed that physical performance of the fire fighters in defence establishment showed a deterioration at 30 yr of age onwards. Significant deterioration noted at the age of 47–50 yr.

5. Anthropometry, body composition and design of clothing

Initially, an anthropometric survey of 4800 Indian Army personnel was carried out to arrive at proper sizes of clothing and personal equipment. A battery of 62 body measurements were obtained on each of the soldiers for 12 population groups of the Indian Army. They were of four age groups 18–22, 23–28, 29–33 and 34 yr and above. The study revealed that Indian Army personnel could be grouped into 15 sizes for the purpose of clothing.

A similar study was carried out on 2072 Indian Naval personnel. Twenty six anthropometric and 21 clothing measurements were selected for the purpose. Twenty-five sizes for tunics, trousers and shirts and 13 sizes for half-sleeve shirts have been provisionally selected for introduction in the Indian Navy. Later, the half-sleeve shirt sizes have been reduced from existing 13 to 9 for better inventory management. A reanalysis of the available data was made and vast heterogeneous Indian Military population was divided into nine size groups based on chest and waist girths. The response regarding fitment trials were highly encouraging. Recently, a larger anthropometric survey was carried out on 11 458 army personnel with

76 body measurements including body composition parameters.

Body composition changes during acclimatization in high altitudes were studied extensively on the army personnel for years together. Stepwise linear regression equations were derived relating 36 anthropometric measurements of body density and lean body mass.

6. Environmental ergonomics

6.1. Heat

During last three decades DIPAS researchers have carried out enormous studies on the effects of different thermal environments on the physical and mental performance and training, water intake, acclimatization process, formulation of work–rest schedule, effects of thirst suppressants during route march in hot weather, screening out ethnic groups which are better acclimatized to heat, physiological and metabolic changes during fixed submaximal and maximal workload, etc.

Indian soldiers including Gorkha troops were found to be well acclimatized to heat and could stand strenuous military training under 34°C WBGT or dry bulb temperature of 40°C with a maximum sweat rate of 1.9 kg h^{-1}. However, to ensure safety, 9–10 l of water intake per day was recommended without any supplementation of salt. Recently, during an exercise trial for 24 h, at Rajasthan desert with an ambient temperature of 45°C revealed that an intake of even 15 l of water was insufficient to keep the soldiers away from heat exhaustion. Prehydration was found to be most beneficial in reducing physiological strain for short exposure while at least 50% restoration of sweat loss for prolonged work in hot environment has been recommended. Other complex acclimatization phenomenon such as human responses in cross adaptation in heat and cold, heat and noise, role of potassium supplementation and renin–angiotensin–aldosterone system during exercise in heat were studied and specific recommendations have been made. Evaluation of various protective garments like NBC clothing, police body protector, body armour, NBC Casualty bag, etc. have been made.

6.2. Cold

Soldiers posted in the high altitude border areas face severe cardiovascular and thermoregulatory strain due to extreme cold. There are many reports of hypothermia and cold injuries especially frost bites among soldiers. It is therefore of prime importance for the prevention of cold injuries and hypothermia amongst soldiers. Studies were conducted on rats, monkeys and on humans in the field and simulated conditions to evaluate the effects of various drugs and vitamin C in the prevention of cold injuries.

Difference in cold acclimatization between native highlanders and sea level soldiers inducted to cold altitude regions was studied as early as in 1963. Twenty days deliberate cold exposure for 3 h daily was found to be adequate for cold acclimatization amongst soldiers at a particular altitude. In a separate study, index of heat output and cold-induced vasodilation has been recommended to screen the individuals who are prone to cold injuries.

Changes of body composition, physical fitness, acclimatization process, etc. have been studied on a group of Indian wintering personnel during 16 long months in Antarctica. Similar study was carried out in Arctic region on the local inhabitants and Indians inducted to such hostile environments. These studies have given the guidelines in solving the problems of tropical men living in polar regions.

6.3. Noise and vibration

Many of the work activities in defence services involve intense noise. DIPAS studies revealed that ammunition noise generated from main or small bore gun is more intense and damaging than industrial situation. In a significant study it was observed that more than three-fourth of the flight deck crew had mild-to-moderate degree of hearing loss.

The efficacy of indigenously made sonex and perforated stainless-steel disc earplugs were tested along with other commercially available ear defenders. Sonex earplugs showed highest attenuation quality at 4 and 6 KHz as compared to other. The effect of Carbogen (a gas mixture of 95% O_2 and 5% CO_2) in the protection against

noise-induced hearing loss was studied and found to be highly effective and useful.

Studies on the vibration research has concentrated on the evaluation of exposure to whole body vibration especially in the armoured vehicles and battle tanks. In most of the cases the vibrations were of mild-to-moderate intensity particularly in the lower frequencies and was within the acceptable limit.

7. Occupational health and safety

Human factors research in Main Battle Tank related to tank crew compartment design, evaluation of noise, vibration, toxicity of gases when ammunitions are fired have been assessed by DIPAS and necessary modifications were incorporated during the development of various prototypes.

An interesting study on mass psychogenic illness among lady telephone operators in Calcutta telephone exchange is an unique case study where psychological factors have been found to trigger non-specific health disorders. Ergonomic studies carried out in the refineries of Indian Oil Corporation has resulted in the implementation and improvement of several health and safety measures.

8. Facilities in DIPAS

DIPAS is well equipped to conduct research on the various fields of macroergonomics. It has the facilities to evaluate three-dimensional aspects of movements, energy expenditure, muscle strength testing, static and dynamic goniometers, physical fitness, body composition, EEG, EMG, biochemical parameters of body fluids, etc. It has got both the climatic as well as high altitude chambers for simulation studies.

9. Future perspectives

Lasers, microwaves and electromagnetic field are being used for various military and civil applications. Electropollution is emerging as an area of concern in occupational health research. DIPAS has already initiated research in these areas. Laser and microwave safety will be audited in laboratory and military environments. Human factors data input for the development of Light Combat Aircraft will be provided. Effects of shift working, work organization and work load assessment among military nurses are being studied. Psychophysiological approach will be followed. Further investigations on manual materials handling for the standardization of lifting loads for Indians are being carried out. An exhaustive study on the evaluation of musculoskeletal disorders and their prevention for the soldiers is planned. Studies on biomechanics and ergonomics have been initiated in many areas of defence and civil interest.