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19 Some Swedish research developments in gravitational physiology

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Since we started research in the physiology of gravitational stress in 1955 at the Karolinska Institute, utilizing its high performance human centrifuge facility, several problem areas have been studied. Among these are disturbances of the gas exchange in the lungs, the antigravity action of the leg muscle pump and the effects of G stress on cardiovascular and respiratory adjustments to dynamic leg exercise, the effects of beta-adrenergic and double blockade on cardiovascular responses to G stress, and, more recently, the effects of high sustained G forces in modern combat aircraft and their amelioration.

Initially, techniques were developed to record continuously and simultaneously the arterial O_2 saturation and hydrogen ion concentration during exposure of anesthetized dogs to G_z acceleration. An important 'first' was achieved in demonstrating in 1958 that severe hypoxemia was produced although 100% O_2 was breathed and hyperventilation was present, pointing to the induction of a large intrapulmonary shunt. Subsequently, the technique for arterial blood gas recording was used in humans on the spinning centrifuge, and it could be shown that exposure to +5 G_z of subjects wearing G-suits resulted in considerable arterial hypoxemia, with arterial pH remaining essentially unchanged although respiratory minute volume was greatly increased. The alveolar-arterial O_2 difference increased to 4 times its normal value, and calculated arterial O_2 tension fell to values well below 50mm Hg, which in combination with the reduced cerebral blood flow is not compatible with undisturbed brain function. Inhalation of 100% O_2 delayed but did not prevent the occurrence of arterial O_2 desaturation.

The action of the leg muscle pump as an auxiliary heart was amply demonstrated in subjects who performed cycle exercise while being exposed to increased G_z stress. Tolerance to such stress was substantially increased if combined with even mild leg exercise. At +3 G_z, transition from rest to exercise at 50 W caused an increase in stroke volume by no less than 81%. It was further found that maximal O_2 uptake is lowered by G-stress and that the primary limitation imposed on the O_2 transport system by such stress occurs in the lungs. Thus, the G-induced changes in pulmonary gas exchange present a greater handicap to oxygen transport and work capacity than do changes in the systemic circulation.

In subjects exposed to a force environment of the G_z type, heart rates as high as 180 or more are not uncommon at high sustained G levels. To study the role of Gz-cardioacceleration in maintaining cardiac output and systemic arterial pressure, subjects were given propranolol intravenously and the responses of the arterial pressure at heart level, heart rate and cardiac output (indicator dilution technique) recorded during prolonged exposure to 3 G_z. The response of the heart rate was greatly diminished by the beta-adrenergic blockade, and the cardiac output decreased somewhat more than before the drug. However, systemic arterial mean pressure was well maintained; therefore sympathetic chronotropic stimulation of the heart does not seem essential for the circulatory defense against gravitational stress. Addition of intravenous atropine, resulting in complete autonomic blockade of the heart, did not entirely 'freeze' the heart rate: on exposure to +3 G_z there was still an average increase from 85 to 96 bpm. However, G tolerance was only slightly reduced, indicating that the suppression of the heart rate response was compensated for by a more potent vasoconstrictor response; thus the regulation of the mean arterial pressure was remarkably well preserved.

During the last decade the development of fighter aircraft capable of attaining highsustained accelerative forces has made human tolerance to such forces a problem of critical importance in flight safety and efficiency. We have found that strength training, leading to improved ability to perform respiratory straining maneuvers and isometric muscle contractions increase the pilot's capability to endure high-G_z forces encountered in aerial combat maneuvers. Studies are under way to elucidate the mechanisms underlying the beneficial effects of strength training. We have investigated methods of increasing the protective effects of anti-G suits by modifications in their construction, and by combining such suits with positive pressure breathing (PPB) at different pressure levels, also with pneumatic counter-pressure to the chest afforded by inflatable bladder-type pressure waistcoats (assisted PPB), which minimizes respiratory disturbances and fatigue.

20 The critical temperature of the Japanese in various conditions

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The lower critical temperature has been regarded as a sensitive index for estimating cold adaptability of homeothermia, since Scholander et. al. (1950) suggested it to be near 27°C in most tropical species and with a range from -50°C to 15°C in arctic species. The lower critical temperature of male and female Japanese was estimated at various conditions including dressed in clothing, during maximal work, and at hypoxia.

The lower critical temperature changed with clothing conditions. In the case of young female adults, the regression equation of the lower critical temperature (LCT) on clo value (I) of clothing ensembles was calculated to be LCT = 28.93 exp(-0.2825 I) within the range of clo value between 0.44 and 2.14. If the lower critical temperature at 0 clo could be extrapolated along this equation, it would be 28.9°C. The rate of changes in the lower critical temperature (dLCT/dI) was suggested to be dependent on the clothing conditions as dLCT/dI = -7.01 exp(-0.2424 I).

The lower critical temperature of adult Japanese showed a tendency to have a relation with the yearly mean air temperature of their home towns, despite a narrow range of air temperature differences of the native places in western Japan. The correlation between the lower critical temperature and surface area of the subjects was confirmed to be significant. Therefore, the above tendency was suggested to be derived from a close relation between the yearly mean air temperature and surface area of the subjects.

The maximum oxygen intake was confirmed to be dependent on air temperature at which the measurements of it was performed. The polynomial regression equation of maximal oxygen intake (Vo_2max) on air temperature (Ta) was calculated as $Vo_2max = 28.345 + 0.87466Ta - 0.013713Ta^2$ for female adults and $Vo_2max = 71.967 - 3.1157Ta + 0.19825Ta^2 - 0.0047435Ta^3 + 0.000037458Ta^4$ for male adults. The correspondent air temperature to the lower value of 95% confidence interval of the extreme value was estimated from the regression to be 24.2°C and 39.6°C for female adults and 23.6°C and 36.7°C for male adults. These values suggest the sex difference in the lower and upper critical temperature for maximal oxygen intake.

The lower critical temperature at hypoxic conditions was examined from the viewpoint of the influence of nonshivering thermogenesis.