IS THE BODY AFFECTED BY AN ALTITUDE OF 6,000 FT.?

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It is well-known that on ascending to very high altitudes the lowering of the partial pressure of the inspired air brings about an anoxic anoxaemia. The body may be so affected by the oxygen lack that "mountain sickness" occurs and it is only after residence at such an altitude for a time that adaptation of the body to the anoxaemia is completed. The mountain expeditions led by Mosso, Zuntz, Haldane, Barcroft, Dill and others, the aeroplane flight studied notably by Schneider and his associates and the decompression chamber experiments of most of the above-mentioned investigators, following the pioneering experiments of Paul Bert, have elucidated to a large extent the nature of the bodily reactions to very high altitudes both before and after acclimatisation.

Johannesburg is situated at a height of 5,750 ft. above sea-level and it is a matter of some debate whether at this altitude the decrease in oxygen pressure is of sufficient degree to bring about reactions similar to those accompanying ascents to the very much higher altitudes studied in the investigations mentioned above. Questions frequently asked are, firstly, whether acclimatisation is necessary at this altitude and, secondly, even if acclimatised, whether an individual is capable of performing severe muscular work with the same degree of efficiency and with no more intensity of physiological adaptation than at sea-level. These questions are worthy of attention. The lay press continually writes of Johannesburg's "altitude bogey" while visiting athletes observe its ravages to a degree commensurate with their success in the sporting arena. Further, it is an often expressed opinion, that individuals suffering from the anoxaemia of various illnesses are placed at a disadvantage by the rarefaction of the atmosphere at this altitude.

Investigations which throw light on the problem of acclimatisation in Johannesburg itself are restricted to the enquiries of Emmerson (1933) and Liknaitsky (1934). Emmerson states that the number of red cells is increased in adults resident on the Rand and shows that descents to great mining depths decreases the number. Liknaitsky finds the mean value of his observations of the red cell count to be above the mean for sea-level values found by several authors. He mentions also the high figures found by Acton and Harvey at an altitude of 6335 ft. Starling gives 7,000,000 as the red cell count of subjects living at Arosa, about 5800 ft. above sea-level.

An increase in the red cell count and in the haemoglobin percentage is generally accepted as a manifestation of permanent acclimatisation to high altitude anoxaemia. Hence, it would appear that the stimulus of lowered oxygen partial pressure at 6,000 ft. is sufficient to bring about this compensatory increase in erythrocyte concentration. However, data at variance with the above is not lacking. Thus Andresen and Mugrage (1936) at 5,000 ft., find the mean values for both men and women to fall within the limits compiled by Wintrobe for places not more than 1,000 ft. above sea-level. Nevertheless, they find the mean corpuscular content of haemoglobin greater than at sea-level. Hurtado (1932) states that the red cell count and haemoglobin percentage is greater in only a percentage of cases. The classic observations of Miss Fitzgerald (1913), (1914), however, furnish the basis for the conclusion that both the red cell count and haemoglobin content increase with altitude from as low as 4,000 ft. above sea-level. Liknaitsky's (1934) observation would indicate an increase in haemoglobin percentage on the Rand.

Animal experimentation bears out the increase in erythrocytes at moderately high altitudes. Schneider (1921) states that Jacquet at 5,000 ft. and Aberhalden at 6,100 ft. found increased red cell counts in dogs and rabbits.

The consensus of opinion, therefore, favours an increase in the oxygen carrying capacity of the blood at the altitude of Johannesburg. One must conclude that the effects of the altitude is to induce reactions similar to those of higher altitudes in that the indication of acclimatisation afforded by the erythrocyte count appears definitely established. There remain for consideration the immediate physiological reactions which require and lead to permanent acclimatising processes. These reactions involve mainly the respiratory and circulatory systems.

Respiration.

The adaptations of the respiratory system to high altitudes comprise an increase in pul-
monary ventilation, a decrease in alveolar CO₂ pressure and an increase in alveolar O₂ pressure. These are the established results of investigations at heights considerably above 6,000 ft.

The increased depths of respiration brings more oxygen in contact with the lung capillaries and leads to an increased alveolar O₂ tension. This is a response to the initially lower oxygen tension. At 6,000 ft. the oxygen tension is lowered to 80 mm. Hg., as compared with 100 mm. at sea-level. New arrivals at 6,000 ft. give this figure (Douglas et al., 1913). The secondary increase does not appear from a comparison of the values for new-arrivals with old inhabitants if one uses the figures found by Fitzgerald (1913) on permanent residents at the same place.

That the ventilation does increase is shown by the decreased alveolar CO₂ tension in the alveolar air. This is true for the slow mountaineering ascent (Douglas et al.) and for swift exposure in aeroplane flights (Schneider and Clarke, 1926) or in rebreather and decompression experiments (Lutz and Schneider). The latter found changes in alveolar CO₂ tension as low as 4,000 ft.

A lowered alveolar CO₂ tension signifies an increased elimination of CO₂ as compared with its production. The consequence of this washing out of CO₂ by the hyperpnoea is the inducement of an alkalosis. One finds no evidence in the literature of an increased alkalinity of the blood at 6,000 ft. Nevertheless, indirect evidence may be given. The compensatory reaction of the body to the alkalosis is an increased output of base by the kidney, a retention of acid substances and a decreased alkali reserve. This constitutes another mechanism of acclimatisation. There are no records of decreased acidity of urine following exposure to an altitude of 6,000 ft., but Bock and Dill (1931) quote the finding of a decreased alkali reserve in the blood of dogs kept at 1,559 metres by Aberhalden and his associates, and in the blood of dogs and rabbits kept at 1,560 metres above sea-level by Winterstein and Gollwitz-Meier. Confirmatory evidence for human beings is lacking.

Circulation.

The stimulus of anoxaemia is transmitted to the circulatory system. Schneider and Truesdell (1924) conclude that circulatory changes are not a means of compensation for the anoxaemia but indicate in their extent the degree of fatigue to the anoxaemia.

At great heights new arrivals, unless they are in excellent physical condition, have resting pulse rates faster than at sea-level. At 6,000 ft. (Hingston, 1925) and even at 10,000 ft. (Dill, 1931) the resting pulse is unaffected. Slight exertion in newly-arrived, unfit and unacclimatised individuals will generally bring about an undue acceleration. This may be seen in the response to standing up or performing a standard exercise (Hingston). Rapid exposure to altitudes in decompression experiments may bring about a quickened pulse rate as low as 5,000 ft. in resting subjects (Schneider and Truesdell, 1924).

A fall in the venous blood pressure due, in part, to dilatation of splanchnic blood vessels under the stimulus of anoxaemia was found by Schneider and Truesdell (1924) in rebreathing experiments to begin at an altitude corresponding to about 6,000 ft.

Other Responses.

In acclimatised subjects, moderate work brings about a state of affairs indistinguishable from that at sea-level. Severe exercises, however, leads to exhaustion due to lactic acid accumulation sooner than at sea-level. These represent the findings of Dill and his co-workers (1931) at an altitude of 10,000 ft. above sea-level. Such results would appear to be applicable to an altitude of 5,750 ft. No observations as to the physiological response to muscular exercise at this altitude are to be found in the literature. It would be of interest to compare the athletic performances at Johannesburg with those at coastal towns.

Changes in the differential white cell count determined by Stammers (1933) at the altitude of Johannesburg are held by him to be due probably to the high degree of ultra-violet radiation.

Van Liere (1936) states that normal adults show a definite prolongation of the emptying time of the stomach when subjected to anoxaemia, the threshold for this response lying between 6,000 and 8,000 ft.

Conclusion.

It seems definite even at the moderately high altitude of Johannesburg that the lowered partial pressure of oxygen induces changes in the respiration and circulation qualitatively similar to those obtaining at very high altitudes.
where actual mountain sickness occurs. There is also evidence for the existence of permanent acclimatising processes at this altitude.

REFERENCES.

Hingston (1921) Geographical Journ., 65, 4.
Stammers, A. D. (1933) J. Physiol., 78, 335.