EFFECT OF MULTI-HOUR GLIDER FLIGHT ON ENERGY METABOLISM AND BODY FLUID BALANCE

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Summary

The performances achieved in modern glider flying reveal the pilot to be the limiting factor in the man-machine-interface system in the multi-hour flights now common.
It was the aim of this study to investigate the effects of such flights on energy and fluid-electrolyte metabolism and certain physiological parameters of stress and fatigue.
Twelve expeninced healthy pilots, of average age 28 years, were examined in three- to six-hour flights in typical cross-country conditions. Blood samples were taken before, during and after flight and later analysed. Urine discharged during flight was collected and later analysed and creighed. Heart rate, respiration rate and jaw movements were measured continuously. Oral fluid intake up to 2 litres/6 hours flight time was mandatory; otherwise no food was consumed.
Despite almost complete physical inactivity and low energy expenditure during flight the specific circumstances of glider flying lead to manifold metabolic alterations. These remain within the normal range in healthy pilots, but regular fluid and food intake is advised for long duration glider flights to keep pilot performance high.

Introduction

Flight durations of 5 hours and more are now common in glider flying, and in long-distance record flights en-route times of 12 hours and more have been attained. Compared to flying powered aircraft types, the pilot in a glider, being strictly immobilized in a semi-supine position in the narrow cockpit, is much more exposed to heat/cold, biodynamic factors (g-load, vibration) and emotional stress. To avoid toilet problems during flight, the uptake of food and fluid is often reduced considerably. The question arises, whether all these factors, contributing to the glider pilot's workload, induce metabolic changes and fluid-electrolyte imbalance with potential flight safety risk.

Method

This work was part of an extensive field study, aiming at the evaluation of pilot stress and fatigue in long duration glider flights. Test methods involved were measurement of heart rate, respiration rate, three axes iaw movement, body core temperature, vestibular performance, and psychological parameters.
Twelve healthy male glider pilots, of age 28.6 ± 7.2 years and flight experience of 665 ± 427 hours, volunteered as test subjects. Each pilot underwent a multi-hour glider flight in typical cross country flight conditions, including flight planning, task setting etc. All flights were performed using a two seater "JANUS" glider, with the test subject as pilot in command. An investigator in the rear seat, also flight experienced for safety reasons, conducted experimental procedures during flight, and occasionally post-flight at remote landing sites. The Janus was equipped with a multi-channel PCM (Pulse Code Mode) device, allowing continuous recording of certain physiological parameters and the actual flight parameters, e.g. altitude, horizontal and vertical speed, normal acceleration factor ("g-load") and external temperature. The rear cockpit was prepared for blood and urine sample handling and stowage in a deep freezer.
The following biochemical parameters were evaluated: serum triglycerides, cholesterin, free fatty acids, free glycerin, urea, creatinine, sodium and potassium, and easinophile leucocytes from pre- and postflight venous blood samples. Capillary blood from the ear lobe was drawn for blood glucose concentration measurements, pre-, post-, and hourly during flight, and for hematocrit pre- and postflight only. The urine output for 2-hourly intervals was measured and urine samples from pre-, in-, and postflight urinations were collected and deep frozen immediately, allowing evaluation of renal epinephrine, norepinephrine and 17-OHCS excretion, creatinine clearance and urine specific gravity. Oral fluid uptake up to 2.5 litres/6 hours flight time was mandatory, otherwise no solid food was consumed during flight.

Results

Mean elapsed flight time in twelve glider flights, launched by aerotow, was 4h 13 min ± 1h 36min. The mean daily temperatures at ground level ranged between 16° Celsius and 31° Celsius; the mean temperature over all test days was 24° Celsium. Seven flights were judged by the pilots as difficult, three flights as medium, and two flights as easy. Muscle tension pain, thirst and hunger, heat stress and vestibular sensations were mentioned by several pilots, all complaints being well-known as typical for long lasting flights.
Despite fluid intake body, weight losses up to 2.2% occurred in all pilots; the body weight loss correlated with flight time $r = -.49$. The urine flow during flight amounted between 20 ml and 139 ml per hour flight time, with a negative correlation coefficient or $r = -.78$ cockpit temperature. Urine specific grafity decreased significantly by .007 g/l from pre- to postflight, indicating a relative increase in water diuresis. In parallel, blood hematocrit changed from mean 46.2% to 48.3%, showing that hemoconcentration occurred during flight. This hemoconcentration coincided with significant increases of serum creatinine ($p < .05$) and decreases of serum urea ($p < .0005$). Serum potassium decreased significantly ($p < .005$) from 4.2 mmol/l preflight to 3.7 mmol/l postflight, while the sodium concentration in serum remained unchanged.
In the lipid metabolism a significant decrease ($p < .025$) of serum triglycerides from 98.1 ± 45.9 mg/dl preflight to 68.6 ± 16.5 mg/dl postflight was found, paralleled by significant increases of free fatty acids ($p < .0005$) and free glycerin ($p < .05$), the two metabolites correlating $r = .77$. The percent increases of free fatty acids and free glycering correlated well with increasing flight durations. Serum cholesterol concentration remained constant from pre- to postflight.
Blood glucose increased slowly from mean 88.7 ± 7.1 mg/dl preflight to 129 ± 7.1 mg/dl at the end of flight, rapidly falling to preflight level after landing. Due to large variations in flight duration and in initial glucose levels a statistical significance is not determinable, except in the decrease from the last inflight to the early postflight glucose values ($p < .005$).
Eosinophile leucocytes decreased from initially 197.4 ± 101.1/mm^3 by mean 32%, signalling increased cortisol activity. The mean 17-OHCS excretion, computed for renal creatinine clearance, showed a tendency to increase, but due to strong inter-individual variations no significance was found. Mean epinephrine (A) and norepinephrine (NA) excretion per creatinine clearance was similarly wide-ranging with an overall increase of A by 16.4% and NA by 22.9%.

Discussion and Conclusions

In multi-hour glider flights body weight losses in the pilots occur, which are beyond the order of magnitude accounted for the pilots energy expenditure. As shown by former studies of Beier and Schönherr, who directly measured energy expenditure in the different flight phases of gliding, a caloric output of approximately 4000 kj/6 hours flight time will not be exceeded. The hemoconcentration in the present study, which was not correctible by oral fluid uptake of 2.5 litres/6 hours flight time, indicates that the body weight losses comply with body fluid losses by urine output and sweat production. The increased water diuresis, characterized by lower specific gravity of the urine, is probably triggered via the HENRY-GAUER-reflex. The present results confirm the observations of LEENEN, who first saw a decrease of urine specific gravity after cross country glider flights, signalling the involvement of the blood volume regulatory system. The HENRY-GAUER-reflex describes the adaptive changes in the fluid volume of the circulatory system following change of central venous pressure. In the supine position of glider pilots, blood volume in the low pressure system of the human body redistributes from the lower extremities towards the lungs, increasing central venous and left arterial pressure. Water diuresis by reflex action is increased in order to recover the normal venous pressure level. Nervous and humoral components of the blood volume regulatory system work together to compensate for any change in human body homeostasis following body position change. During glider flight, not only supine body position, but also heat exposure is identified as an important factor influencing the blood volume regulatory system and the fluid-electrolyte balance. The decrease in the serum potassium, usually inconsistent with changes in the electrolyte balance induced by the HENRY-GAUER-reflex, signals a strong superposition of aldosterone activity. The combined stresses of flying, where heat stress must be considered as the major component in the present study, seem to increase aldosterone activity considerably.

The augmented adrenal activity, which could be shown by increases in epinephrine, norepinephrine, and 17-OHCS in urine excretion, induces changes in the energy metabolism. Stress hormone induced lipolysis and glucose liberation raise the blood levels of free fatty acids, free glycerin, and blood glucose. Lowered blood levels of urea indicate that protein turnover plays no major role in the metabolic outlet, but must also be seen, like creatinin, under the view of hemoconcentration.

The changes in fluid-electrolyte-balance and in energy metabolism, seen in glider pilots exposed to long-duration flights, are well tolerable by a healthy organism. In the preserce of latent or manifest diseases, however, metabolic derailments seem possible. The results of this study justify the search for metabolic diseases in the frame work of pilot medical examinations. In addition, the results imply a strong recommendation that sufficient fluid and food should be taken during multi-hour glider flights. Aircraft designers should meet the physiological requirements by installing urine disposal devices.