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EFFECT OF GLUCOSE ELECTROLYTE INGESTION ON PHYSIOLOGICAL CHANGES DUE TO SEVERE HEAT STRESS

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Summary : Severe heat stress experienced by aircrew during summer months can cause deterioration in performance. Acute heat stress can also lead to dehydration and loss of electrolytes. Previous studies emphasised the need of K^+ replacement. This study was carried out to determine the effect of glucose electrolyte ingestion (ELECTRAL) on thermal strain parameters.

Ten healthy male subjects in the age group of 19-43 years were exposed to an acute thermal environment of 50°C Tdb with relative humidity of 30% for 40 min. twice each day on two different days with an interval of one hour in between the exposures. At the begining of rest period electrolyte solution was ingested during electrolyte trials and water under control trials. Physiological parameters of Tsk, T or, HR and electrolyte concentration of Na^+ and K^+ in sweat did not show any significant difference in both the trials. Sweat loss was significantly higher during electrolyte trials.

Key words : acute heat exposure; sweat loss; water and electrolyte ingestion; body heating parameters

INTRODUCTION

In high speed low level flying, aircrew are subjected to severe heat stress specially in summer months (1). Acute heat stress can lead to a mean dehydration level of 1% of body weight along with electrolyte loss during low level sorties (2). Various studies stress the need of fluid replacement to minimise the ill effects due to dehydration.

Fluids in the form of water (3), electrolyte solution, specially in the form of K^+ salts (4) were used to minimise the deleterious effect of dehydration. At Institute of Aviation Medicine, energy electrolyte replenishment fluids were tried without much effect (5). "Electral", a commercial preparation, the major constituents of which are all electrolytes including Na^+, K^+, Ca^{+2}, Mg^{+2} and glucose is preferred by physicians and physiologists in dehydration studies This needs physiological evaluation. Hence, this study is aimed at determining the beneficial effect if any or otherwise of ingesting Electral solution in alleviating the physiological strain under hot environmental condition.

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METHODS

Ten healthy volunteers in the age group of 19-43 years were selected for the present study. Age and physical characteristics of the subjects are shown in Table I. The subjects were briefed about the details of experimental proceedure and informed consent was obtained from all the subjects.

TABLE I : Physical characteristics of the subjects (n=10).

Sl. No.	*Subject*	*Age (yrs)*	*Height (cms)*	*Weight (kgs)*
1.	RSY	30	163	64.8
2.	PKB	39	178	67.7
3.	DDR	29	172	67.5
4.	BRN	39	168	68.7
5.	ACC	21	176	53.9
6.	NSB	43	172	71.4
7.	RR	19	178	57.9
8.	SR	29	179	85.0
9.	SM	19	180	61.4
10.	RM	20	172	63.8
MEAN		28.8	173.8	65.8
± SD		9.1	5.4	8.5
RANGE		19-43	163-180	53.9-85.0

The subjects reported to the laboratory at 0800 hrs. Their initial nude body weight was measured with the help of Avery personnel weighing balance (Avery India Ltd., Delhi) to the nearest ounce. Thereafter, the subjects put on cotton overalls, inner "g" helmet and canvas shoes and were instrumented for the measurement of skin temperature, oral temperature and heart rate from ECG tracings.

Their base line values of skin temperature and oral temperature were recorded after 30 min stay in a thermoneutral environment of Tdb : 25°C.

In this study, a thermal environment of 50° Tdb with relative humidity of 30% was selected in a simulator (locally designed & fabricated). The subjects were exposed on two different days for a duration of 40 min twice on each day with an interval of one hour in between the trials. During this period the subjects were in a thermoneutral environment of 25° db. At the begining of rest period 400 ml plain water was given to drink in the control trials and 400 ml of electrolyte solution was given in the electrolyte trials. (32 g of electral FAIR DEAL CORPORATION in 400 ml of water containing Na^+, K^+, Ca^{2+}, Mg^{2+} and glucose). A minimum of 3–7 days elapsed between the two days of exposure.

Physiological parameters viz., skin temperature, oral temperature and heart rate (HR) were recorded every ten min. during 40 min of two heat exposures and at every 5 min during the first 15 min of recovery periods. Skin temperature was recorded from the chest, arm, thigh and calf with the help of Naina Electronics Digital Temperature Indicator Naina Electronics Ltd., Chandigarh and the mean skin temperature (Tsk) was computed following Ramanathan's index (6). Oral temperature (Tor) was read out on Ellab electrical thermometer (Elektrolaboratariet, Copenhagen) and HR was calculated from ECG tracings. Forearm sweat was collected in polythene collection bags strapped over the left forearm during the second heat exposure. Na^+ and K^+ concentration in the sweat was determined on EEL flame photometer. The difference between the initial body weight (before the first heat exposure) and the final body weight (following recovery after heat exposure) was determined and to this the weight of the fluid ingested during the interval between the trials was added. Thus, the overall sweat loss was calculated for both the trials.

The experiments were carried out as per the standards of Ethical Committee.

RESULTS

Physiological thermal strain parameters at 40 min of heat exposures at 5, 10 and 15 min of recovery in control trials and electrolyte trials are shown in Table II.

Total sweat loss and electrolyte concentration (Na^+ & K^+) in sweat following thermal stress under control trials and electrolyte trials are shown in Fig. 1. The overall sweat loss was 598 gm ± 194.2

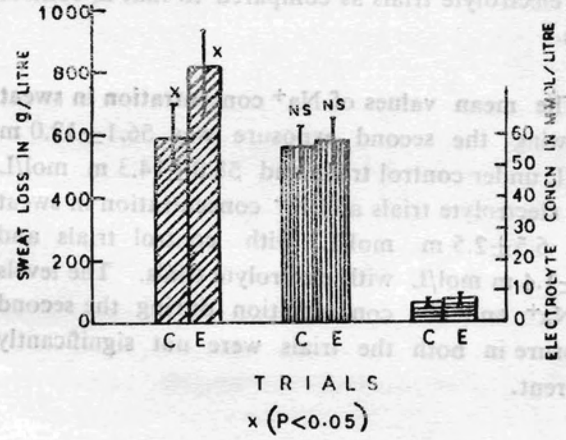

Fig. 1 : Mean sweat loss and electrolyte concentration in sweat in control and electrolyte trials.

TABLE II : Physiological thermal strain parameters at 40 min of heat exposure and 5, 10, 15 min recovery - A comparative analysis between control and electrolyte trials values are mean±SD (n=10).

Thermal strain para-meters	*Trials*	*1st Exposure*					*2nd Exposure*				
		Initial (0 min)	*Terminal (40 min)*	*5*	*10*	*15*	*Initial (0 min)*	*Terminal (40 min)*	*5*	*10*	*15*
MST (Mean skin temp-erature)	Control	33.3 ±0.8	37.82 ±0.89	35.59 ±1.65	34.1 ±0.72	33.24 ±1.14	33.54 ±0.82	37.74 ±0.53	35.18 ±1.00	34.13 ±1.30	33.52 ±1.57
	Electrolyte	33.5 ±0.79	37.60 ±0.83	34.70 ±1.67	33.89 ±0.75	33.44 ±0.79	33.25 ±0.62	37.33 ±0.69	34.75 ±0.94	33.84 ±0.89	33.33 ±0.93
	Mean diff.		−0.22	−0.89	−0.21	0.20		−0.41	−0.42	−0.29	−0.19
Oral temp.	Control	36.80 ±0.50	37.66 ±0.23	37.27 ±0.27	37.19 ±0.20	37.05 ±0.34	36.70 ±0.40	37.67 ±0.19	37.22 ±0.27	37.10 ±0.21	37.70 ±0.32
	Electrolyte	36.90 ±0.30	37.68 ±0.27	37.39 ±0.30	37.19 ±0.22	37.10 ±0.19	36.85 ±0.30	37.70 ±0.32	37.35 ±0.29	37.20 ±0.29	37.12 ±0.24
	Mean diff.		0.02	0.12	0	0.05		0.03	0.13	0.10	0.05
Heart rate	Control	82.80 ±14.46	106.60 ±18.00	93.60 ±15.66	90.40 ±13.72	87.00 ±12.20	79.80 ±15.30	105.20 ±17.10	87.20 ±14.70	84.90 ±12.20	83.20 ±13.30
	Electrolyte	83.80 ±13.70	108.80 ±13.40	97.00 ±14.02	91.00 ±12.75	88.80 ±12.60	85.00 ±14.80	105.00 ±14.20	91.00 ±15.10	87.20 ±18.40	86.20 ±15 50
	Mean diff.		3.20	3.40	1.20	1 80		−0.20	3.80	2 30	3.00

Differences are 'Not Significant' statistically.

in control trials compared to 822 gm ± 230.9 in electrolyte trials. The mean value of total sweat loss was found to be significantly higher ($P<0.05$) with electrolyte trials as compared to that in control trials.

The mean values of Na^+ concentration in sweat following the second exposure was 56.1 ± 12.0 m mol/L under control trials and 58.0 ± 14.3 m mol/L with electrolyte trials and K^+ concentration in sweat was 6.5 ± 2.5 m mol/L with control trials and 6.6 ± 1.4 m mol/L with electrolyte trials. The levels of Na^+ and K^+ concentration during the second exposure in both the trials were not significantly different.

DISCUSSION

In a tropical country like India, heat stress has posed a serious aero-medical problem. From time to time, various measures have been tried to either totally or partially mitigate the effects of heat stress on aircrew. To quote a few, the measures were precooling (7), 100% oxygen breathing (8), and ingestion of glucose electrolyte solution (9).

Ill effects of heat stress are due to the effects of dehydration by way of loss of sweat. Harrison *et al* in their study reported a body weight loss of approximately 1% during a moderately severe heat load (10). Sastry *et al* in their study observed residual effects of first exposure as evidenced from a higher peak oral temperature and HR value during second heat exposure. In their study, the subjects were rested in a non-air-conditioned room (9). In the present study, there was no appreciable change in Tsk, HR, Tor in the second heat exposure when compared to the first exposure during both the trials. This could indicate a complete recovery from the heat induced strain accrued during first exposure.

To minimise the ill effects of heat exposure, various studies were conducted with replacement fluids. Costil *et al* in their work concluded that addition of glucose electrolyte solution is of minimal value on physiological parameters during acute heat exposure (11). Kennon (12) studied the effects of water/electrolyte replacement during exercise in heat and observed no beneficial effects on administering electrolyte solution. Cade *et al* replaced the fluid loss with water, electrolyte solution and glucose solution during exercise (3). No significant change in body temperature was reported with the three protocols. In the present study too, the ingestion of Electral solution during the electrolyte trials did not confer any additional advantage. The physiological parameters of Tsk, Tor and HR did not show any significant change.

Sweating is an important physiological mechanism aimed to prevent the body temperature from rising to dangerous levels during heat exposures. Banerjee *et al* and Costil *et al* in their study found an increase in sweating with prior ingestion of electrolytes (NaCl & KCl solution) without altering other physiological strain parameters. (5, 13) In the present study also, the overall sweat loss was found to be higher during electrolyte trials (822 gm) as compared to control trials (598 gm) ($P<0.0.5$).

The sweat loss in this study was measured from the time the subjects were resting in thermoneutral environment before the first heat exposure till 15 min after second exposure. The plausible reasoning for increased sweating during electrolyte trials could be any one of the following either acting independently or synergistically with others :

(a) Some level of acclimatisation could have resulted following control trials.

(b) Some degree of dehydration could have existed leading to increased sweating in the subsequent heat exposure. Pichan *et al* (14) in their study conclusively brought out the fact that upto 2% hypohydration there is an increase in sweating in heat acclimatised subjects in subsequent exposure to heat.

(c) Nielson reported an increase in body temperature with decrease in sweating with ingestion of NaCl solution, and decrease in body temperature and increase in sweating with $CaCl_2$ solution. This was attributed to the specific effect of ions on body temperature (15). The presence of calcium in electral solution could have directly or indirectly acted on the central receptors in the hypothalamous resulting in increased sweating.

In a short duration heat exposure, ingestion of Electral solution did not offer any additional advantage over water.

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