Typical behavior of Mg, electrolyte, blood gas, and blood glucose in physically and psychically stressed individuals

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Zusammenfassung

Bei 21 Militärakademikern wurden vor und nach einer 12 minütigen Fahrradergometerbelastung von maximal 250 Watt Blutgase (AVL compact 3), Mg, Na und Ca (AVL 988-4) und Blutzucker (Glukoseoxidase-Methode) gemessen. Die Ergebnisse wurden mit den gleichen Parametern verglichen, die von 13 Probanden knapp vor einem Bungee-Sprung gewonnen worden waren, nachdem die Versuchspersonen stundenlange Erwartungsangst ausgestanden hatten.
Die wichtigsten Ergebnisse: Mit der Ausnahme von 2 Teilnehmern konnten alle Bungee-Springer ihre signifikant niedrigeren Basenexzesse respiratorisch kompensieren, was in der Fahrradergometergruppe nicht der Fall war. Darüber hinaus zeigten die länger psychisch gestressten Bungee-Springer – im Gegensatz zur Ergometergruppe – deutlich und signifikant erhöhte Blutzucker und Na Werte (Risikofaktoren für koronare Herzkrankheiten (KHK)).
Lineare Interparameter-Korrelationsmuster innerhalb der Gruppen entstanden dort, wo Kompensationen nicht mehr möglich waren. In diesem Zusammenhang scheinen gerade Korrelationen zwischen Magnesium und pO_2 sowie pCO_2 in der Gruppe mit hoher Glukose und Na auf bereits limitierten Energieumsatz, vermutlich bedingt durch den länger dauernden psychischen Stress vor dem Sprung hinzudeuten.

Summary

Blood gases (AVL compact 3), Mg, Na, Ca (AVL 988-4) and blood glucose (glocoseoxidase method) was measured out of 21 officer trainees before and after a cycle-ergometric workload of up to 250 watts for 12 minutes. The data were compared with the same parameters taken from 13 subjects shortly before accomplishing a bungee jump, thus having been subjected to hours of anxious waiting.
Most important results: With the exception of 2 subjects, the bungee jumpers were able to respiratorily compensate their significantly lowered BE values without significant pH changes, which the ergometric group was unable to do. Furthermore, the psychologically stressed jumpers exhibited a marked and significant increase in blood glucose and Na, risk factors for ischemic heart disease. Those were absent in the ergometric group.
Linear interparameter correlation patterns within the groups showed, that linear correlations evolved preferably within those groups, which were unable to compensate. In this context, correlations with Mg and pO_2 and pCO_2 in the group with high glucose and Na seem to mark already limited metabolic turnover, probably related to pre-jumping anxiety stress of longer duration.

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Introduction

Contrary to the situation at physical workload, psychological induced increase in catecholamines is rarely coupled with increased energy turnover in muscle. On the other hand, psychical irritations – at least within the usual scope of our society – are generally more prolonged than physical loads.
To investigate both situations, it was tempting to compare a fatiguing 12 minutes cycle-ergometric workload with pre-bungee jumping anxiety during long hours, whereby our transportable measuring systems enabled us to perform on the spot determinations.
Of special interest for us was the behavior of ionized Mg in context with other blood gas or electrolyte values, because we knew from an earlier paper (*Porta* et al., same issue), that eventual correlation of circulating ionized Mg with some of the other parameters within so called "Interparameter Correlation pattern", (IPC), should be a reliable indicator for changing metabolic conditions, probably brought about by stress effects.

Materials and methods

21 male soldiers of the Austrian Army were subjected to a standardized ergometric program (Monark 834E and Ergo-Line, Ergo-Metrics 800S). The program was twelve minutes in duration, consisting of four, three-minute intervals of controlled power output of 100 watts, 150 watts, 200 watts and 250 watts, respectively. The intervals were completed in sequence and without resting between them. Before and after ergometry, three drops of capillary blood were drawn from the fingertip for determination of lactate (Boehringer-Mannheim) (mmol/L), pH, partial pressure of carbon dioxide (pCO_2) (mmHg), base excess (BE) (mmol/L), hydrogen carbonate (HCO_3) (mmol/L), partial pressure of oxygen (PO_2) (mmHg) and percent oxygen saturation (O_2sat) (AVL Compact 3) as well as ionized sodium (Na) (mmol/L), ionized magnesium (Mg) (mmol/L), and ionized calcium (Ca) (mmol/L) (AVL988-4) and Blood Glucose (Glucose-Oxidase Method) (mg/dL).
The group of soldiers both before ergometry (group Sb) and after ergometry (group Sa) was compared with a group of 13 civilian (group BJ) tested immediately prior to bungee jumping 82 and ½ meters from a railroad bridge. Three drops of capillary blood were

drawn from the fingertips immediately before the subjects completed their jump. The blood was tested for the same parameters as previously stated for the soldiers.
The data were recorded and analyzed (t-test and linear correlations) using Microsoft Excel. All participants gave their consent according to the Helsinki Charter, being fully aware of the nature and the purpose of the experiment.

Results

Average values were determined from blood samples, taken before and after ergometry in groups Sb and Sa respectively and before the jump in group BJ (see Tab. 1, 2). The average basal pH value in group BJ was statistically indistinguishable from the average basal value of group Sb. Ergometry decreased the pH value significantly as seen in group Sa ($p < 0{,}001$). Although the pH values of groups BJ and Sb were statistically indistinguishable, the BE in group BJ was significantly lower then in group Sb ($p < 0{,}001$), but significantly higher then group Sa ($p < 0{,}001$). Accordingly, pO_2 increased ($p < 0{,}001$), but pCO_2 and HCO_3 values in group BJ were significantly lower than in Group Sb ($p < 0{,}001$ and $p < 0{,}001$ respectively). However, average values for these three parameters were statistically indistinguishable between groups BJ and Sa. O_2sat values in group BJ were significantly higher than pre-ergometric values in group Sb ($p < 0{,}001$) as well as post ergometric values in group Sa ($p = 0{,}03126$). Concerning electrolytes, Na levels were higher in the BJ group compared to both the Sb group ($p = 0{,}00291$) and the Sb group ($p = 0{,}00451$). Ca exhibited a similar relationship ($p = 0{,}01023$ and $p = 0{,}03846$). Average Mg values in all groups were statistically indistinguishable. The group BJ showed the highest glucose values while the Sa group showed the lowest, significantly lower than the BJ group ($p = 0{,}00201$).
Although there was no difference in average ionized Mg values between the groups, linear correlations between the measured parameters within the three groups (IPCs, see *Porta* et al., same issue), show differing behavior (see Tab. 3, 4, 5). Notably, there was no significant correlation of BE with either pCO_2, pO_2, or pH in the Sb and BJ group, while all three correlated with BE in the Sa group. Moreover, significant positive linear correlations were seen only in the BJ group with pO_2 and pCO_2.

Discussion

In a former paper it could be shown that from a combination of electrolyte, blood gas, and glucose analysis along with a post stress provocation test it is possible to discern between different workloads causing stress in the immediate and not so immediate past. Similar methods can be applied to discern between a physical stress and a psychical stress. In this case a comparison between a diffficult 12 minute ergometric workout and a few hours of anxiety before a bungee jump. There existed some characteristics of the two groups that made the nature of their stresses clearly distinguishable. We saw, for example, that psychically stressed individuals exhibited the same pH values as a group of rested individuals, although their BE was considerably lower. The behavior of their pCO_2 and pO_2 values confirmed successful respiratory control. It must be noted that two of the psychically stressed individuals were already clearly

Tab. 1: Average Values for Group BJ, Group Sb and Group Sa; pCO_2 in mmHg, Na in mM/l; BE in mM/l, Mg in mM/l; HCO_3 in mM/l, Ca in mM/; pO_2 in mmHg, Glucose in mM/l; O_2sat in %

Average ±SEM	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Glu
BJ	7,337	38,5	-4,9	20,1	60,0	87,6	146,5	0,49	1,32	96
	±0,011	±1,6	±0,6	±0,7	±2,3	±1,2	±0,6	±0,01	±0,02	±3
Sb	7,326	53,4	0,2	27,0	32,1	54,9	144,2	0,48	1,25	89
	±0,005	±0,9	±0,2	±0,3	±1,4	±3,0	±0,2	±0,01	±0,01	±3
Sa	7,208	40,9	-11,6	16,0	63,6	79,4	145,6	0,49	1,28	85
	±0,013	±1,8	±0,9	±0,8	±4,3	±3,4	±0,4	±0,01	±0,01	±2

Tab. 2: t-Values for Group Differences (Units like table 1)

t-Test	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Glu
BJ vs. Sb		p<0,001	p<0,001	p<0,001	p<0,001	p<0,001	p<0,01		p<0,05	
BJ vs. Sa	p<0,001		p<0,001	p<0,001		p<0,05				p<0,01
Sb vs. Sa	p<0,001	p<0,001	p<0,001	p<0,001	p<0,001	p<0,001	p<0,01		p<0,05	

Tab. 3: Interparameter Correlation Pattern (ICP) of Group BJ (Units like Tab. 1)

pH	*-0,6059	0,4001	-0,0007	-0,4271	-0,0462	-0,1319	-0,5256	0,3768	-0,4756
	pCO_2	0,4486	**0,7943	0,5628	0,3912	0,4275	*0,592	-0,1506	0,1705
		BE	***0,8723	0,0086	0,1895	0,4356	0,0772	0,2879	-0,3565
			HCO_3	0,3636	0,4394	0,4525	0,3495	0,1399	-0,1405
n = 12				pO_2	***0,9088	-0,0929	**0,7448	-0,4211	0,1381
p < 0.05	*	0,5760			O_2sat	-0,107	0,5623	-0,2622	0,0222
p < 0.01	**	0,7079				Na	0,3545	0,384	0,2422
p < 0.001	***	0,8233					Mg	-0,0002	0,2069
								Ca	-0,2655
									Glucose

Tab. 4: Interparameter Correlation Pattern (ICP) of Group Sb (Units like Tab. 1)

pH	***-0,8017	0,4247	-0,1656	*0,5014	**0,5672	-0,3595	0,1738	-0,3501	0,3652
	pCO_2	0,1976	***0,7202	**-0,6168	**-0,6639	0,3195	-0,0067	0,3665	0,3631
		BE	***0,8216	-0,1256	-0,0834	-0,1046	0,2837	-0,0346	-0,0437
			HCO_3	*-0,4350	-0,4328	0,1183	0,1947	0,1877	0,1371
n = 21				pO_2	***0,9930	-0,1065	0,1578	-0,1038	-0,274
p < 0.05	*	0,4329			O_2sat	-0,126	0,1757	-0,1453	-0,2851
p < 0.01	**	0,5487				Na	0,1162	0,3662	0,1371
p < 0.001	***	0,6653					Mg	0,3204	-0,274
								Ca	-0,2851
									Glucose

Tab. 5: Interparameter Correlation Pattern (ICP) of Group Sa (Units like Tab. 1)

pH	-0,0206	***0,8071	**0,5759	-0,1188	0,1353	-0,3999	-0,0491	0,0019	-0,1741
	pCO_2	**0,5764	***0,8045	***-0,8058	***-0,8219	0,2612	0,2701	0,2035	-0,2483
		BE	***0,9474	**-0,5739	-0,3752	-0,1743	0,053	0,0971	-0,2123
			HCO_3	***-0,7303	**-0,5916	-0,0257	0,1054	0,1308	0,0758
n = 21				pO_2	***0,8933	-0,0351	-0,1747	-0,0741	0,2821
p < 0.05	*	0,4329			O_2sat	-0,0248	-0,0389	0,072	0,0141
p < 0.01	**	0,5487				Na	0,1918	**0,6405	0,0758
p < 0.001	***	0,6653					Mg	0,0544	0,2821
								Ca	0,0141
									Glucose

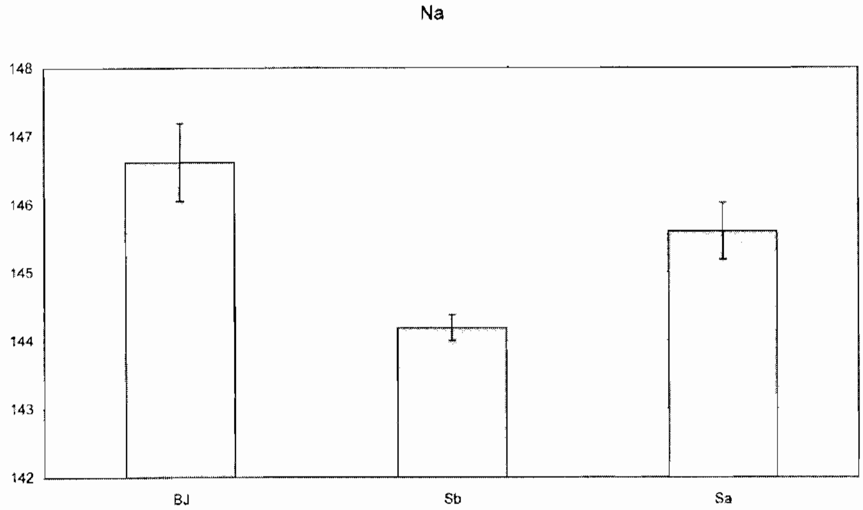

Fig. 1: Abscissa: BJ = Bungee group
Sb = Before ergometry
Sb = after ergometry
Ordinate: Ionized Serum Na in mMol/l

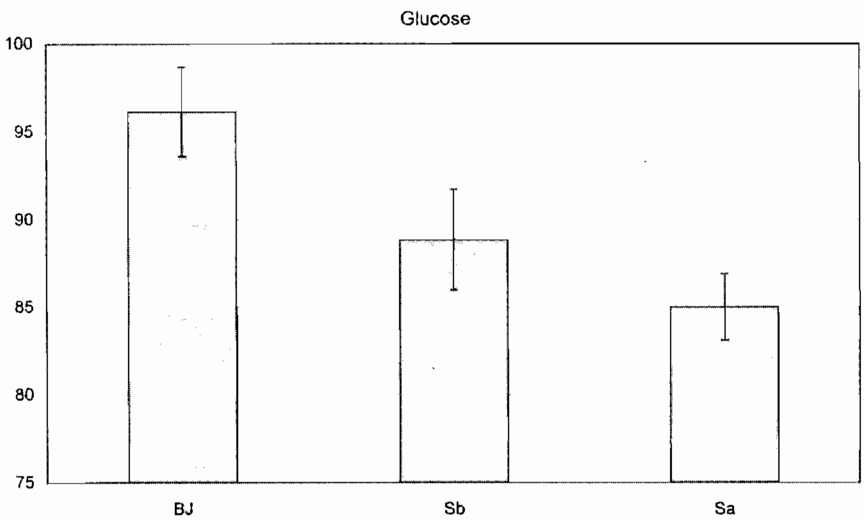

Fig. 2: Abscissa: BJ = Bungee group
Sb = Before ergometry
Sa = after ergometry
Ordinate: blood glucose in mg/dl

unable to exert respiratory control as shown by pH values below 7.3. Concerning electrolytes, the psychically stressed group showed significantly increased Na levels (Fig. 1) which may indicate increased water loss by increased breathing frequency. The same group showed significantly higher glucose levels (Fig. 2). This can be explained by increased glycogenolysis and increased catecholamine secretion which inhibits glucose uptake into myocytes by inhibition of insulin secretion. Thus even psychical stress of a few hours duration leaves the subjects with increased glucose and Na levels, both parameters prominently included as risks for ischemic heart disease (*Herold*, 1995). Ca exhibited similar behavior to Na, but there were no significant differences in the average ionized Mg levels between the groups. However, if one looks at the intraparametric correlations within the different groups only the supposedly long term psychically stressed persons exhibited linear correlations between Mg and pCO_2 as well as pO_2. This may show that intracellular energy turnover represented by Mg increase in the blood is forced to progress at the same rate as O_2/CO_2 exchange. This would probably mean that a process limiting velocity has been reached, curbing the flexibility of the system. A similar explanation can be attributed to the correlations between BE and pCO_2 and pO_2 within the different groups: only the Sa group, the subjects of which were not able to compensate through respiration, showed linear correlations between BE and pCO_2 and pO_2. Consequently, there were no such correlations during resting conditions and successful respiratory control in the psychically stressed group. Summing up the most important results are 1. a combination of blood gas, electrolyte, and blood glucose determination along with proper statistical evaluation is able to discern psychical from physical stress and 2. A psychical stress contrary to physical stress is characterized by successful respiratory compensation, increased glucose and Na values and evolving linear correlations between Mg and blood gas parameters. Thus psychically stressed people with increased glucose and Na levels always seem to show linear correlations between Mg and blood gas parameters pointing towards restricted metabolic flexibility.

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