Human field experiments about the interrelationship of magnesium, electrolyte and blood gas changes proportional to the intensity of accumulated workload – a diagnostic approach

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Zusammenfassung

Von 26 freiwilligen Grundwehrdienern des Österreichischen Bundesheeres wurden 50 µl Blut aus der Fingerbeere entnommen, unmittelbar nach Morgensport und leichtem Jogging. Daraufhin wurden sie einer Fahrradergometrie bis 200 Watt, im Sinne eines Post Stress Provocation Tests (*Porta* et al. 1993) unterworfen, gefolgt von einer weiteren Blutabnahme, wobei Elektrolyte, Blutgase und Laktat bestimmt wurden. Eine weitere Gruppe von 20 Freiwilligen, die zwar nicht unmittelbar vor dem Test belastet worden waren, jedoch einige Stunden vorher von einer Nachtübung mit Schlafmangel, sowie morgendlicher Gefechtsübung kamen, wurde denselben Testanordnungen unterworfen. Die wichtigsten Ergebnisse: In der ersten Gruppe war das ionisierte Mg wesentlich niedriger als in der zweiten, was nicht auf verschiedene Diät, sondern auf verschiedene vorhergehende Streßintensität zurückgeführt wird. Lineare Korrelationen zwischen den gemessenen Blutgas- und Elektrolytparametern waren deutlich häufiger in den schwerer belasteten Gruppen. Darüber hinaus bildeten sich Korrelationsmuster (ICPs) aus, d.h., daß gewisse Korrelationen, die bei schwerer belasteten Gruppen vorkamen, bei leichter belasteten nicht auftraten, wobei Mg eine wesentliche Rolle spielte. Deshalb teilten wir die Teilnehmer in drei neue Gruppen auf, wobei das Teilungskriterium ausschließlich in absteigender, gleichbleibender oder ansteigender Reaktion des ionisierten Mg auf Ergometrie bestand. Es stellte sich heraus, daß Mittelwerte, Korrelationshäufigkeit und ICPs der ansteigenden Mg-Gruppe deutlich auf eine bessere körperlich Verfassung hinwiesen als in der absteigenden Gruppe.

Summary

Of 26 young volunteers on national service 50 µl of capillary blood were taken just after light gymnastics and a 3 minutes jogging. Bicycle ergometry up to 200 watts (post stress provocation test, *Porta* et al. 1993) was superimposed immediately, followed by a second blood sampling for determination of electrolytes, blood gases and lactate. A group of 20 more volunteers who did not undergo immediate previous stress, but sleep depriving night exercises followed by a field combat maneuver some hours beforehand, underwent the same procedure. The most important results: Ionized Mg was low in the first group and much higher in the second group, a feat not due to diet but to previous stress. Linear correlation between the parameters were the more plentiful, the higher the intensity of accumulated stress has been. Moreover, characteristic stress related interparameter correlation pattern (ICP) evolved, whereby Mg played an important role. Consequently, we formed 3 new subgroups, regardless of the previous workload, only characterized by the fact of an increasing or decreasing or stable reaction of ionized Mg to the ergometric test. Average values, correlation numbers and ICPs pointed to the fact, that the increasing Mg group consisted mainly of subjects in a significant better bodily shape than in the decreasing group.

Introduction

In former papers we could show, that cumulating stress leads to cumulating catecholamine secretion, without a direct, negative feedback, a feature we used, to develop a so called post stress provocation test (*Porta* et al. 1993), to assess the stress of a person in the immediate past. Moreover, we could show (*Porta* et al. 1997), that easier measurable effects of catecholamines, like change in baseexcess, are linearly proportional to catecholamine levels, and therefore could be used as quick, cheap but still sensitive screening parameters. The change of circulating Mg and Ca levels during and after stress is also known. Therefore we thought, that by measuring 10 different, stress related parameters, we may be able to get a more complex picture of the effects of stresses of different intensity and duration in more or less immediate past, which may even allow quantitative assessment, whereby stress – typical involvement of situation characteristic proportionalities between parameter reactions (correlations) may evolve.

Material and methods

46 male soldiers of the Austrian Army (average age: 20.2, average height: 177.3 cm, average weight: 75.5 kg) were randomly divided into two subgroups. The first subgroup (26) was subjected to a standardized ergometric program (Monark 834E and Ergo-Line, Ergo-Metrics 800S). The program was nine minutes in duration, consisting of three, three-minute intervals of controlled power output of 50 watts, 100 watts and 200 watts, respectively. The intervals were completed in sequence and without resting between them.

Immediately before the beginning of the ergometry, the first subgroup participated in a short (3-5 minute) run after having light morning activity as required by the army schedule. Before and after ergometry, three drops of capillary blood were drawn from the fingertip for determination of lactate (Boehringer-Mannheim) (mM/L), pH, partial pressure of carbon dioxide

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(pCO_2) (mmHg), base excess (BE) (mM/L), hydrogen carbonate (HCO_3) (mM/L), partial pressure of oxygen (pO_2) (mmHg) and percent oxygen saturation (O_2sat) (AVL Compact 3) as well as ionized sodium (Na) (mM/L), ionized magnesium (Mg) (mM/L), and ionized calcium (Ca) (mmol /L) (AVL988-4).

The next day, the second subgroup of subjects (20) performed the same standardized ergometric training. The same procedure for collection and analysis of the blood was followed. However, the physical activity of the second subgroup, prior to the ergometric program, was not the same as that of the first subgroup. The second subgroup did not participate in a short run (3-5 minutes) immediately prior to the experiment. However, they did undergo rigorous training the previous night, consisting of night exercises that lasted until 01:00 hours. Additionally after five hours of sleep, they participated in four hours of field combat maneuvers. The data from both subgroups were recorded and analyzed (t-test, F- tests, nonparametric tests, linear correlations) using Microsoft Excel. All participants gave their written 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, for both subgroups (see Tab. 1). In both subgroups, the basal Mg levels were indistinguishable from their respective post-ergometric values. However, between the subgroups there was considerable significant difference. The values of subgroup 1 (approx. 0.5 mM/L) were significantly lower than those of subgroup 2 (over 0.54 mM/L) ($p = 0.000009$). In all subgroups, the pH values decreased significantly after ergometry ($p= 0.00006$). Subgroup 1 had slightly, but significantly, decreased basal pH values ($p = 0.0276$). pCO_2 significantly decreased in both subgroups after ergometry ($p = 0.000042$). There were no significant differences between the two subgroups concerning their basal or post-ergometric values. Ergometry lowered BE significantly in both subgroups. The highest basal values were seen in subgroup 2 whereas the lowest values were seen in subgroup 1 ($p = 0.00015$). HCO_3 was also significantly lowered by ergometry in both subgroups where the lowest basal levels are again seen in subgroup 1 ($p = 0.0002$). Post-ergometric levels did not differ significantly between the subgroups. Both subgroups experienced a significant increase in PO_2 after ergometry. There was no significant difference between the subgroups as to the basal values. O_2sat did only significant increase at day 2 ($p = 0,016$). Lactate values were increased by ergometry in both subgroups. The basal values and post-ergometric values of the different subgroups were statistically indistinguishable. Na exhibited the same pattern of results. Ca decreased significantly only in subgroup 1 ($p = 0,02$), the basal and post-ergometry values were statistically identical.

Workload usually alters the concentration of circulating ionized magnesium (*Porta* et al. 1997, *Zirm* et al. 1992). In our case however the average magnesium values remained exactly the same. This was caused by a mixed increase and decreased ionized magnesium within both subgroups. In the course of the experiment 50% (13/26) of subgroup 1 reacted to ergometry with an increase in Mg, 27% (7/26) reacted with a decrease in Mg, and 23% (6/26) showed no change in Mg levels. In subgroup 2 the respective percentages are: 35% (7/20) increase, 30% (6/20) decrease and 35% (7/20) no change (Fig. 1). Tab. 2 delineates the average values of all measured parameters for these three experimentally determined subgroups.

The original data therefore were sorted into three new subgroups based solely upon the observed behavior of magnesium: the increasing magnesium subgroup (MgI), the decreasing magnesium subgroup (MgD) and the stable magnesium subgroup (MgS) (Fig. 2). Average values from both the pre- and post-ergometry blood samples for all of the original parameters were determined. All subgroups showed a decrease in pH following ergometry. The post- and pre-ergometric values for all three subgroups were statistically indistinguishable, with the exception of the increasing and the stable subgroup ($p = 0.009$). All subgroups exhibited a significant decrease in pCO_2 following ergometry. pCO_2, BE and

Tab. 1: Average Values for Day 1 and Day 2

All tables: "pre" means preergometric, "post" means postergometric
pCO_2 in mmHg, BE in mM/l, HCO_3 in mM/l, pO_2 in mmHg, O_2sat in %
Lactate in mM/l, Na in mM/l, Mg in mM/l, Ca in mM/l

Average	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Lactate	Na	Mg	Ca
1-Pre	7.348	41.0	-3.2	21.9	77.0	94.0	1.9	146.3	0.50	1.29
1-Post	7.243	34. 7	-11.6	14.7	94.5	94.8	6.5	147.8	0.50	1.26
2-Pre	7.373	42.1	-0.6	23.8	74.9	93.2	2.4	145.7	0.55	1.29
2-Post	7.263	35.8	-10.1	16.0	98.3	95.8	6.2	147.4	0.55	1.26

(Eventual significant differences and their p-values are shown in the text.)

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Tab. 2: Average Values for MgI, MgD, and MgS

Average	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Lactate	Na	Mg	Ca
MgI-Pre	7.346	42.3	-2.3	22.5	74.5	92.9	1.9	145.9	0.50	1.28
MgI-Post	7.237	33.9	-12.2	14.2	97.3	95.3	6.9	148.7	0.53	1.27
MgD-Pre	7.356	41.7	-2.4	22.7	77.6	94.2	2.3	145.7	0.54	1.29
MgD-Post	7.267	36.0	-9.8	16.2	96.2	95.6	5.7	146.0	0.50	1.23
MgS-Pre	7.381	40.1	-1.4	23.1	77.0	94.3	2.3	146.6	0.53	1.31
MgS-Post	7.261	36.1	-10.1	16.0	94.3	94.9	6.2	147.5	0.53	1.28

(Eventual significant differences and their p-values are shown in the text.)

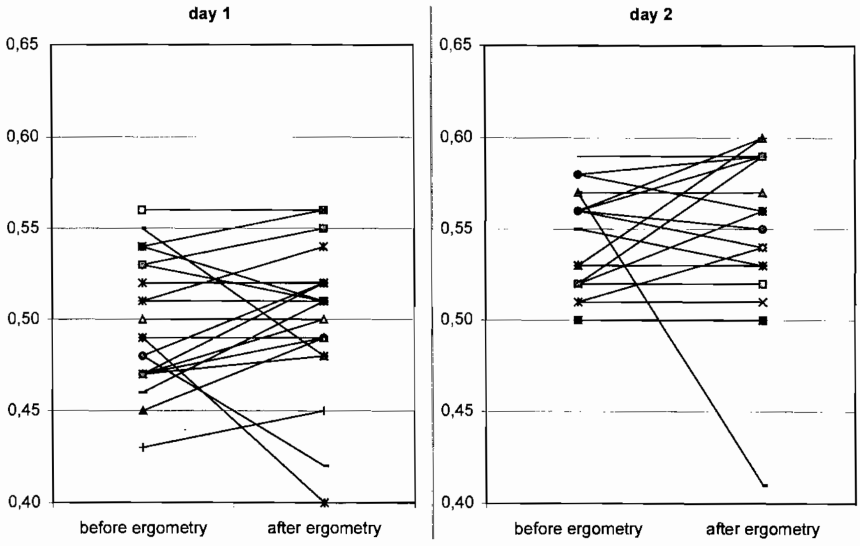

Fig. 1

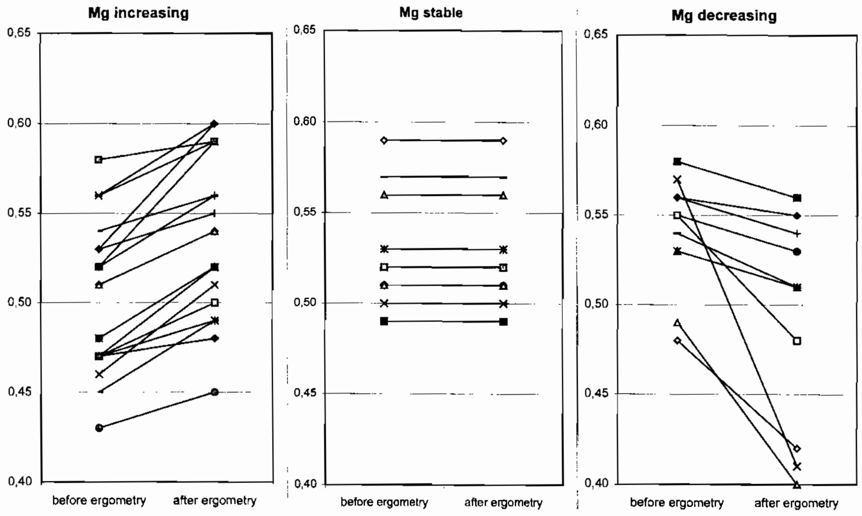

Fig. 2

Fig. 1 and Fig. 2: Abscissa: values before and after ergometry
Ordinate: Ionized Serum Mg in mMol/l

HCO_3 showed significant decrease after ergometry, but no difference in basal or post-ergometric values. PO_2 and O_2sat average values showed significant increase in the Mg D subgroup, PO_2 also in the MgS subgroup. Each subgroup showed a marked increase in lactate average values however no values were significantly different between subgroups. The MgD and the MgS subgroup showed no significant change in average Na values following ergometry, while MgI subgroup showed a significant increase after ergometry ($p = 0.000012$). Na basal values for all three subgroups were indistinguishable. The increase in Mg of MgI was determined to be significant ($p = 0.00000006$) as was the decrease in Mg of MgD ($p = 0.0019$). Concerning Ca levels, the MgI subgroup did not experience significant change; however, the MgD subgroup showed a marked (approx. 0.06 mM/L) significant decrease ($p = 0.0141$). The MgS subgroup showed a slight (approx. 0.025 mM/L) significant decrease ($p = 0.0232$). The only significant difference in basal values for Ca was that the MgS subgroup had significantly higher values than the MgI subgroup ($p = 0.016$). The only significant difference between the subgroups following ergometry was that the MgS subgroup values were significantly higher than the MgD subgroup values ($P = 0.022$). In former papers (*Bacher* et al. 1998, *Classen* et al. 1995, *Porta* et al. 1994) it has been shown that the interpretation of ionized magnesium levels in blood serum may be dependent upon

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Tab. 3: Interparameter Correlation Pattern (ICP) Before Ergometry (Day 1 and Day 2)

Day 1

pH	*-0.4895	**0.6066	0.2081	0.2976	**0.5256	0.0426	-0.2312	0.0107	0.2974
	pCO_2	*0.3954	***0.7504	***-0.6301	***-0.6279	*-0.4195	-0.1909	0.0267	0.0616
		BE	***0.9032	-0.2576	-0.0166	-0.3265	*-0.4192	0.0320	0.3832
			HCO_3	*-0.4767	-0.3025	*-0.4397	-0.3870	0.0365	0.2924
n = 26				**pO_2**	***0.9299	0.1402	0.1673	0.2916	0.0009
$p < 0.05$	*	0.3882			**O_2sat**	0.0963	0.0387	0.1824	0.0785
$p < 0.01$	**	0.4958				**Lactate**	0.3158	-0.2721	0.2628
$p < 0.001$	***	0.6073					**Na**	-0.0457	-0.0292
								Mg	0.1197
									Ca

Day 2

pH	***-0.6983	*0.4707	**0.6697	-0.0656	0.4354	0.2756	0.3662	0.0007	0.0971
	pCO_2	-0.0739	0.0608	-0.1238	*-0.4650	-0.1104	-0.2935	-0.1648	-0.2141
		BE	**0.5776	-0.0992	0.1441	0.1665	0.2004	0.0424	0.2477
			HCO_3	-0.2110	0.1338	0.2913	0.1882	-0.1469	-0.0782
n = 20				**pO_2**	***0.8374	0.0448	0.0578	-0.1129	-0.0945
$p < 0.05$	*	0.4438			**O_2sat**	0.2667	0.1456	-0.0312	-0.0792
$p < 0.01$	**	0.5614				**Lactate**	0.2299	0.1148	0.1079
$p < 0.001$	***	0.6788					**Na**	0.1013	0.3874
								Mg	0.2902
									Ca

the momentary stress situation of the subject – a situation which could be sufficiently characterized by the blood gas constituents. This would suggest a situation-dependent, proportional reaction of magnesium with one or more of the blood gas parameters. Therefore, linear correlations between all of the measured parameters within each subgroup both pre- and post-ergometry were calculated (see Tab. 3, 4, 6, 7). Moreover, linear correlations were made, within each subgroup, of the before and after values of each parameter (i.e. the pre-ergometic value of pH for subgroup 1 was correlated with the post-ergometric value of pH of subgroup 1, Tab. 5, 8.

Discussion

The first area of notice concerns the obvious difference in ionized magnesium levels between day 1 and day 2. The participants from day 1 went on a short run, which resulted in a slight decrease in BE (Tab. 1). This run should have led to an increase in serum Mg; however, the pre-ergometric average value was uncommonly low (Tab. 1). This low average does not mean that the run had no effect on the level of serum Mg. It is possible that the true average basal values (those before the run) were even lower than the measured pre-ergometric levels, perhaps to the point of being clinically hypomagnesemic. Young conscripts, being subjected to unaccustomed bodily exertions, some sleep deprivation along with weekend frolicking and long car trips to distant homes have been long suspected by us to be candidates for low levels of circulating Mg. The considerably higher average Mg level seen on day 2 was unlikely to be due simply to a differing dietary magnesium uptake, as all of the participants were part of the same regiment, thereby receiving the same food. Therefore, the unexpected levels must have been due to an increase in Mg elimination into the bloodstream by soft tissue organs, such as muscles, heart and liver, superceding elimina-

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Tab. 4: ICP After Ergometry (Day 1 and Day 2)

Day 1

pH	0.1481	***0.9484	***0.8567	0.0345	***0.6817	-0.3066	-0.3676	-0.3278	-0.3076
	pCO$_2$	*0.4471	***0.6318	*-0.4317	-0.1873	***-0.6893	-0.1282	-0.1890	*-0.4215
		BE	***0.9747	-0.1235	**0.5399	**-0.5125	*-0.3945	-0.3548	*-0.3935
			HCO$_3$	-0.1940	*0.4366	***-0.6099	-0.3803	-0.3581	*-0.4559
n = 26				**pO$_2$**	***0.7236	*0.4766	0.1889	-0.0429	0.0688
$p < 0.05$	*	0.3882			**O$_2$sat**	0.1431	-0.0922	-0.2472	-0.2142
$p < 0.01$	**	0.4958				**Lactate**	*0.4525	0.2409	0.2237
$p < 0.001$	***	0.6073					**Na**	0.3285	0.3435
								Mg	0.3013
									Ca

Day 2

pH	0.2996	***0.9414	***0.8433	-0.2720	***0.7789	-0.4307	**-0.6473	*-0.5048	-0.2801
	pCO$_2$	**0.5947	***0.7536	0.1168	0.3597	**-0.5962	-0.3988	-0.3911	0.2755
		BE	***0.9747	-0.1772	***0.7791	**-0.5890	***-0.6895	**-0.5834	-0.1081
			HCO$_3$	-0.1217	***0.7173	**-0.6571	**-0.6742	**-0.5953	0.0228
n = 20				**pO$_2$**	0.3753	-0.1028	0.2845	0.2468	0.0202
$p < 0,05$	*	0.4438			**O$_2$sat**	-0.4094	-0.4014	-0.3116	-0.3079
$p < 0,01$	**	0.5614				**Lactate**	*0.4534	0.3874	-0.2887
$p < 0,001$	***	0.6788					**Na**	***0.7220	0.1574
								Mg	-0.0599
									Ca

Tab. 5: Correlations Before Ergometry Versus After (Day 1 and Day 2)

	Correlations									
	pH	**pCO$_2$**	**BE**	**HCO$_3$**	**pO$_2$**	**O$_2$sat**	**Lactate**	**Na**	**Mg**	**Ca**
Day 1	*0.4627	0.0406	0.0391	-0.1390	0.0664	*0.3905	0.3736	**0.5780	*0.4905	***0.7067
Day 2	0.3847	-0.0097	0.1049	0.4225	0.0641	0.0218	-0.1238	*0.5547	0.2141	*0.5109

tion brought about by the activities of day 2 prior to the experiment, namely the night and morning exercises. This difference in basal values was the reason for the creation of the day 1 and day 2 subgroups. Since we are of the opinion that the difference in Mg levels was because of the two subgroups having different prior stresses, we examined the other blood parameters for support for this assertion. The lower pre-ergometric pH of subgroup 1, as well as the lower pre-ergometric BE value, both supported the idea that subgroup 1 had experienced an immediate physical stress (Tab. 1). The lower HCO$_3$ values seen in subgroup 1 could be attributed to an increased respiratory rate (i.e. increased CO$_2$ expiration).

The difference between the two subgroups was also seen in their respective interparameter correlation patterns (ICPs). Subgroup 1 exhibited more than

Tab. 6: ICP Before Ergometry (Mg Increasing Subgroup, Mg Decreasing Subgroup, and Mg Stable Subgroup)

Mg Increasing Subgroup

pH	***-0.5473**	0.2131	0.4240	-0.1107	0.1700	0.2541	0.0147	0.1659	0.1588
	pCO$_2$	0.3018	***0.5246**	-0.1971	-0.3359	-0.4199	-0.2082	0.2995	0.1970
		BE	***0.5554**	-0.1465	-0.0548	-0.1775	-0.1795	****0.6149**	***0.5193**
			HCO$_3$	-0.3252	-0.1865	-0.1893	-0.2029	***0.4991**	0.3738
n = 20				**PO$_2$**	*****0.9354**	0.1191	0.0420	0.0103	0.1156
p < 0.05	*	0.4438			**O$_2$sat**	0.1520	0.0255	0.0949	0.1577
p < 0.01	**	0.5614				**Lactate**	0.2919	-0.3417	0.0206
p < 0.001	***	0.6788					**Na**	-0.1545	-0.1590
								Mg	0.1295
									Ca

Mg Decreasing Subgroup

pH	0.2196	*****0.8695**	****0.7464**	-0.3839	-0.0913	0.0732	0.0565	-0.1188	0.3172
	pCO$_2$	***0.6722**	*****0.8118**	***-0.6108**	-0.5169	***-0.6593**	***-0.6271**	0.1773	0.0603
		BE	*****0.9774**	***-0.5979**	-0.3274	-0.2714	-0.2804	0.0121	0.2798
			HCO$_3$	***-0.6456**	-0.4070	-0.4011	-0.4053	0.0757	0.2299
n = 13				**PO$_2$**	*****0.9356**	0.5015	0.4172	-0.1505	-0.2708
p < 0.05	*	0.5529			**O$_2$sat**	***0.5874**	0.4114	-0.2387	-0.1380
p < 0.01	**	0.6835				**Lactate**	0.3711	-0.0428	0.3544
p < 0.001	***	0.8010					**Na**	***-0.6133**	0.0706
								Mg	-0.0067
									Ca

Mg Stable Subgroup

pH	***-0.6047**	*****0.8373**	0.5281	0.4219	*****0.8255**	-0.2634	-0.4367	0.2934	-0.4938
	pCO$_2$	-0.0718	0.3561	***-0.6627**	****-0.7590**	0.1060	0.0670	-0.1100	-0.1621
		BE	*****0.9062**	0.0758	0.5136	-0.2450	-0.5014	0.3009	****-0.7286**
			HCO$_3$	-0.1978	0.1663	-0.1861	-0.4430	0.2359	****-0.7532**
n = 13				**PO$_2$**	*****0.8324**	-0.1180	0.1552	0.1178	0.0888
p < 0.05	*	0.5529			**O$_2$sat**	-0.1568	-0.2237	0.2613	-0.1978
p < 0.01	**	0.6835				**Lactate**	0.1494	0.0198	0.1316
p < 0.001	***	0.8010					**Na**	0.1947	0.5209
								Mg	-0.0381
									Ca

Tab. 7: ICP After Ergometry (Mg Increasing Subgroup, Mg Decreasing Subgroup, and Mg Stable Subgroup)

Mg Increasing Subgroup

pH	0.3457	***0.9795	***0.9282	-0.1541	***0.8153	-0.3051	-0.3839	-0.2024	*-0.5569
	pCO_2	*0.5191	**0.6612	-0.2686	0.1672	-0.3718	0.1076	-0.1936	0.1350
		BE	***0.9833	-0.2136	***0.7616	-0.3715	-0.3374	-0.2240	*-0.4536
			HCO_3	-0.2336	***0.7066	-0.4136	-0.2840	-0.2323	-0.3466
n = 20				PO_2	0.4334	0.1838	-0.1177	0.3647	-0.0376
$p < 0.05$	*	0.4438			O_2sat	-0.1605	-0.4107	-0.0086	*-0.5367
$p < 0.01$	**	0.5614				Lactate	0.1700	-0.0172	-0.2879
$p < 0.001$	***	0.6788					Na	0.1207	0.0778
								Mg	0.2741
									Ca

Mg Decreasing Subgroup

pH	0.3818	***0.9664	***0.9181	-0.2120	*0.6099	-0.5452	-0.5432	-0.4060	0.1811
	pCO_2	*0.5962	**0.7071	-0.2857	0.0697	*-0.6834	-0.1221	-0.2745	-0.2770
		BE	***0.9884	-0.2182	*0.5744	*-0.6696	-0.5007	-0.4105	0.1054
			HCO_3	-0.2354	0.5221	**-0.7119	-0.4627	-0.4078	0.0442
n = 13				PO_2	*0.6349	0.1608	0.4831	0.0777	0.2941
$p < 0.05$	*	0.5529			O_2sat	-0.2491	-0.0239	-0.2961	0.3498
$p < 0.01$	**	0.6835				Lactate	*0.5625	0.2788	0.2405
$p < 0.001$	***	0.8010					Na	0.3637	0.3214
								Mg	-0.1534
									Ca

Mg Stable Subgroup

pH	0.0820	***0.8964	**0.7384	0.1713	**0.7323	-0.2315	-0.4203	-0.2008	-0.5034
	pCO_2	0.5098	**0.7268	0.0568	0.0348	**-0.7988	-0.4913	-0.0705	0.0358
		BE	***0.9604	0.1669	*0.6443	*-0.5647	*-0.5889	-0.2217	-0.3994
			HCO_3	0.1662	0.5363	**-0.7010	*-0.6228	-0.2016	-0.3018
n = 13				PO_2	**0.7760	0.2593	0.2469	0.2297	-0.0734
$p < 0,05$	*	0.5529			O_2sat	0.1131	-0.0656	0.0562	-0.3685
$p < 0,01$	**	0.6835				Lactate	*0.6508	0.4455	-0.1637
$p < 0,001$	***	0.8010					Na	0.3722	0.2054
								Mg	-0.4722
									Ca

Tab. 8: Correlations Before Ergometry Versus After (Mg Increasing Subgroup, Mg Decreasing Subgroup, and Mg Stable Subgroup)

	Correlations									
	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Lactate	Na	Mg	Ca
Inc	0.2093	-0.2927	-0.3183	-0.2860	-0.1935	0.3042	-0.0446	**0.6127	***0.9216	**0.6072
Dec	0.3233	-0.2842	0.2561	0.1679	0.0041	-0.1093	0.5052	**0.6836	*0.6121	**0.7244
Stable	*0.6645	0.4968	*0.6507	*0.6499	0.2859	0.5333	0.1372	**0.7176	***1.0000	0.5212

two times as many significant pre-ergometric correlations as did subgroup 2 (Tab. 3). The correlations of lactate with pCO_2 and HCO_3, specifically, might point to recent physical stress (Tab. 3). After ergometry, the number of correlations seen in both subgroups 1 and 2 increased, especially subgroup 2 (6 to 19, Tab. 4). Thereby, it is safe to conclude that immediate stress increased the number of correlations between parameters. The high number of pre- ergometric correlations exhibited by subgroup 1 supports this. While the number of post-ergometric correlations was the same in subgroup 1 and subgroup 2, the interparameter correlation pattern (ICP) was different. In subgroup 1, there were no correlations of Mg with any other parameter (Tab. 4). However, Ca did show correlations with pCO_2, BE and HCO_3. Subgroup 2, however, showed no correlations with Ca, while it did have Mg correlations with pH, BE, HCO_3, and Na. Additionally, in subgroup 2, there are double the number of postergometric correlations with Na as there are with Na in subgroup 1 (Tab. 4). Correlations of the parameters before and after ergometry show a similar pattern, i.e. 5 correlations in subgroup 1 and only 2 in subgroup 2 (Tab. 5).

The assertion that the increase seen in the ICP is attributed to stress can be validated by the realization that a linear proportionality of reactions always points to their increased rigidity and should, therefore, be an indication of an approach towards a lower or upper limit of a system. Because we know that stress effects within a given time may well accumulate (*Porta* et al. 1993), different stresses in the immediate past should compound with ergometry, creating a different degree of fatigue characterized by a different ICP.

In both subgroup 1 and subgroup 2, the pre- and post-ergometric average Mg values did not change. However, upon further examination, it was discovered that within each subgroup there were participants whose Mg levels increased, whose levels decreased, and whose levels remained constant (Fig. 1). As a working hypothesis, we attributed increased serum magnesium to be the outcome of a positive balance between increased magnesium loss from soft tissue organs and magnesium elimination from the blood. Decreased serum magnesium levels therefore should point to a negative balance, perhaps brought about by an already decreased ability of magnesium liberation from soft tissue organs into the blood stream due to previous stress induced demands. The MgS subgroup could be considered then as a MgI situation in transition to MgD status. As a result the day 1 / day 2 subgroups were combined and redivided according to the participant's Mg behavior (Fig. 2).

Upon analysis of the new subdivisions, it was determined that both the increase and the decrease in Mg were significant, thereby justifying the creation of the new subdivisions. The ICPs of the MgI and MgD subgroups differed significantly (Tab. 6). MgD experienced a greater decrease in Ca than did MgI – a difference that showed that these participants reacted more strongly to the standardized ergometric workload (Tab. 7). It is known that during stress Ca moves from the bloodstream into the cells, resulting in a decrease in serum Ca levels. Therefore, the greater decrease seen by MgD implied that the ergometry was more stressful for this subgroup than for MgI. It is possible that stressed persons can not perform the ATP-ADP reaction as readily as those can who are not stressed. Mg is an essential part of this energy releasing reaction. Therefore, if the body's Mg supplies are being depleted (as seen by blood Mg levels that are decreasing due to faster elimination from the bloodstream by the kidneys than release into the bloodstream by soft tissue organs) then this reaction can not take place as readily. It is possible, therefore, that decreasing Mg levels are indicative of a higher level of pre-existing stress.

A further significant difference between MgI and MgD was the highly significant increased post-ergometric Na exhibited only by the MgI subgroup. This could point to a higher water loss by sweating or breathing. It is not clear as yet, whether this fact supports or contradicts our working hypothesis.

The difference between MgI and MgD was also seen in their ICPs. Similar to subgroup 1 (Tab. 9), MgD had more significant correlations (11) than did MgI (7, Tab. 10). As seen in subgroups 1 and 2, MgI and MgD both showed an increase in significant correlations following ergometry. MgD showed significant pre-ergometric correlations between pO_2 and HCO_3, BE and pCO_2, which were not seen in MgI. MgD showed significant post-ergometric correlations between lactate and HCO_3, BE and pO_2, which also were not seen in MgI. MgI did exhibit three significant post-ergometric correlations with Ca which were not seen in MgD (Tab. 7). Correlations between pre- and postergometric values in MgI, MgS and MgD showed – not dissimilar to those in subgroups 1 and 2 strong proportionalities concerning electrolyte dynamics. That MgS additionally exhibited significant correlations between pre- and postergometric pH, BE and HCO_3 is – at the moment – hard to explain. It is possible, that the stable quotient between input and output from circulation, characteristic for the MgS group, could express itself in this way (Tab. 8).

The greater number of correlations in the pre-ergometric levels of MgD could be explained by our postulation that high numbers of correlations are indicative of greater stress. It is possible that the MgD subgroup was in worse physical condition, thereby they reacted more strongly to the standardized workload. Therefore, the members of MgD who were a part of subgroup 1 would have been more affected by the pre-ergometric run. Those who were originally a part of subgroup 2 would have been more affected by the night and morning exercises. This would have resulted in a decreased ability to cope with a standardized physical stress. These assumptions were strengthened by the situation of the MgS subgroup with mostly showed reactions in between MgI and MgD subgroups.

In summary, the following points seem to be important:

1. The measurement of ionized magnesium alone depicts the momentary stress situation of a person and is therefore unsuitable for the depiction of the overall magnesium state.
2. Simultaneous measurement of blood gas parameters as markers of the stress situation (*Porta* et al. 1993) enables the investigator to make allowances for the stress situation when judging upon the origin of a certain magnesium level.
3. In our experiment, immediate pre-ergometric exertion led to an increased number of correlations seen in the ICPs.
4. More strenuous but less recent pre-ergometric fatigue does not show itself in a different number of post-ergometric correlations but in a clearly different pattern (Ca, Mg, lactate etc.)
5. Regardless of the degree of pre-ergometric fatigue, ergometry could lead to either an increase or decrease of circulating ionized magnesium. Whereby, more strenuous previous fatigue corresponds to a greater number of subjects who reacted to superimposed ergometry with a magnesium decrease.
6. Since subjects with decreasing magnesium – regardless of the intensity of pre-ergometric exercise – showed many more of the typical values which we attribute to fatigue, we think that the exercise induced reaction of magnesium points to the momentary bodily shape of a subject.

Thus, from the idea of simultaneous measurement of electrolytes and blood gases combined with a post-stress provocation test (*Porta* et al. 1993) the basis of a diagnostic tool has been formed. This new tool would allow for an estimation of stress intensity and stress compatibility. Magnesium plays an important role in this system.

Tab. 9: Number Of Correlations Before And After Ergometry (Day 1 and Day 2)

	Subgroup 1	**Subgroup 2**
Basal values	13	6
After ergometry	19	19

Tab. 10: Number Of Correlations Before And After Ergometry (Mg Increasing Subgroup, Mg Decreasing Subgroup, and Mg Stable Subgroup)

	Subgroup Mg I	**Subgroup Mg S**	**Subgroup Mg D**
Basal values	7	9	13
After ergometry	11	13	12

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