Stress compatibility and electrolyte dynamics of sports majors (SM) and language majors (LM) at examination time

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Zusammenfassung

Es wurde versucht, sogenannten Schulstress durch Messung von Veränderungen von Blutgasen, Elektrolyten, Laktat und Blutglukose im Zuge einer standardisierten Fahrradergometerbelastung (Post Stress Provocation Test, *Porta* et al. 1993) ausgehend von verschiedenen Grundsituationen und zwei verschieden gearteten Probandengruppen objektiv zu messen. Da Katecholamine und viele ihrer Effekte sich addieren, hängen die Reaktionen auf Ergometerbelastungen von den Basalsituationen und von persönlichen Umständen ab. Die Basalsituation wurde dadurch variiert, dass ein und derselbe Test einmal im Herbst während relativ ruhiger Schulanfangszeit und einmal im Januar während der Hauptprüfungszeit durchgeführt wurde. Dem Einfluss persönlicher Umstände wurde Rechnung getragen, indem eine Gruppe einer wenig sportlichen Sprachenklasse mit einer fast professionell geführten Fußball-Sportklasse derselben Schule und desselben Alters von ca. 17 Jahren verglichen worden war.
Es stellte sich heraus, dass schon Basalwerte der verschiedenen Gruppen im Herbst und im Januar signifikant verschieden waren. Darüber hinaus war die Reaktion auf Belastung in beiden Gruppen im Januar viel deutlicher. Die Sportklasse vertrug allerdings die erhöhte Stressbelastung während der Hauptprüfungszeit signifikant besser, was wir anhand von signifikant höheren Basalwerten von pH und niedrigeren pO2 Niveaus, sowie sehr viel geringerer belastungsbedingter Veränderung von Laktat (ca. 50 %), viel geringerer Basenexzessveränderung und höherem end-pH feststellen konnten. Sportliches Training vermindert also offensichtlich die Effekte psychisch induzierter Katecholaminerhöhung signifikant.
Von ganz besonderer Bedeutung ist das generell niedrige Niveau von ionisiertem Serummagnesium bei den weiblichen Probanden und die viel bessere Situation in der Sportklasse, trotz intensiver körperlicher Belastung. Aufklärung durch Trainer dürfte hier ausschlaggebend sein, umso mehr, als der befriedigende Magnesiumstatus des Herbstes während der spielfreien Periode im Winter stark nachlässt. Die Effekte von Schulstress sind also nicht nur durch psychologische Verfahren, sondern auch auf serologischem Wege, vielleicht am besten durch eine Kombination von beiden messbar. Die beunruhigende Magnesiumsituation, besonders die der weiblichen, nicht sportbetreibenden Probanden sollte weiter verfolgt werden, um einem eventuellen generellen Magnesiumdefizit bei großen Gruppen Jugendlicher auf die Spur zu kommen.

Summary

Objectivation of a so called school stress was tried to be achieved by measuring blood gas, electrolyte, lactate and blood glucose alterations after standardized cycle ergometry (post stress provocation test, *Porta* et al. 1993) out of different basal situations and with two different groups of probands. Since catecholamines and many of their effects are additive, reaction to cycle ergometry depends upon basal values and personal circumstances. Basal values have been altered by applying one and the same test once during relative school stress free autumn and once during busy examination time in January. Personal circumstances were taken into consideration by testing a group of more sedentary female language majors against a group of nearly professionally managed soccer players from the same school and the same average age of about 17.
It turned out that already basal values in autumn and January were significantly different in many cases. Reaction to exercise was also much more pronounced in January in both groups. However, the sport group obviously could take higher stress levels at examination time significantly better than the language majors, a fact deducible by significantly different basal values of higher pH and lower pCO2 and much lower exercise induced alterations in lactate (ca. 50 %), much less decrease in base excess, higher pH and many other parameters. Physical training seems to diminish psychologically induced catecholamine effects significantly.
Of special importance seems to be the low magnesium status of the female probands and the much better situation in sportsmen, in spite of intensive training. Instructions by trainers could be the reason. The more so, as the satisfactory Mg status of autumn deteriorates in the winter off season time.
Thus, impact of school stress is measurable not only by psychological but also by serological methods, which may even be of mutual support. The upsetting magnesium situation, especially of our female probands should be carefully followed up concerning a possible general deficiency.

Introduction

Objective measurement of the effects of a so called school stress upon students or pupils is difficult. However, by means of a “post stress provocation test” (*Porta* et al. 1993) individual stress compatibility and stress intensity can be determined e.g. by testing catecholamine basal values and their reactions to standardized workloads. Moreover it could be shown, that catecholamine effects, like alterations in blood gases, parameters of carbohydrate metabolism like lactate or blood sugar and electrolyte changes in serum correlate significantly and in an individually characteristic way (*Porta* et al. 1997, *Porta* et al. 1999) with catecholamine alterations, so that those parameters could be used for

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stress screening purposes. The advantage over catecholamine measurement is i.a., that a changing pattern of about 15 different parameters can be interpreted on the spot by sampling only a few drops of capillary blood.
We hoped, that this method should be sensitive enough to yield objective results relative to alterations of the individual stress situation due to school stress.

Material and methods

During a comparatively leisurely time at school in late October and early November, without being yet subjected to stressful examinations, 19 male sports majors in an Austrian senior high school/college and 15 female language majors with the average age of 17.6 years underwent standardized bicycle ergometry (Monark 834E and Ergo-Line, Ergo-Metrics 800S). The program was nine minutes in duration, consisting of three 3-minute intervals of controlled power output of 50 watts, 100 watts and 200 watts, followed by 3 minutes of recreation for the male sportsmen and 4 minutes of 100 watts, 4 minutes of 150 watts followed by 4 minutes of recreation with the female probands. The intervals were completed in sequence and without resting between them. Before and after ergometry of both male and female probands, three drops of capillary blood were drawn from the fingertips 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).
In January, just before publication of their term – rankings, at the peak of examination stress, the experiment was repeated exactly as shown above.
The data from both groups of experiments were recorded and analyzed (t-test, linear correlations) using Microsoft Excel.
All participates gave their written informed consent according to the Helsinki Charter, being fully aware of the nature and the purpose of the experiment.

Results

1. Language majors

Averages: Already basal values in the more leisurely autumn and the stressfull January differ significantly in 6 parameters (see Tab. 1).
As mentioned above, in January already basal pH values are significantly lower than in autumn (Fig. 1).
Since there is on the one hand no sign of increased basal lactate (Tab. 1), but on the other hand significantly lower basal BE values (Tab. 1), the only alternative is an increase in ketone bodies due to increased lipolysis.
The fall in basal pH is not accom-

Tab. 1: Language Majors (LM)

	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
1-Pre	7.40	34.10	-2.95	20.47	64.19	91.47	142.00	0.46	1.30	2.31	97.47
1-Post	7.30	26.79	-11.76	12.75	86.39	94.51	141.47	0.44	1.23	6.15	88.87
2-Pre	7.35	38.23	-4.31	20.57	74.71	92.95	142.89	0.46	1.27	1.87	94.60
2-Post	7.25	31.77	-12.27	13.57	100.20	95.76	141.92	0.47	1.21	6.32	89.60

SEM	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
1-Pre	0.00	0.59	0.29	0.34	2.02	0.64	0.47	0.01	0.01	0.15	2.79
1-Post	0.01	0.72	0.65	0.47	2.10	0.35	0.51	0.01	0.01	0.48	2.33
2-Pre	0.01	1.05	0.44	0.52	3.21	0.77	0.51	0.01	0.01	0.05	21.97
2-Post	0.02	1.18	0.75	0.64	2.56	0.23	0.41	0.01	0.01	0.31	3.27

T-tests
*** Bold indicates a 95 % statistical significance

	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
Before 1:2	**0.00**	**0.00**	**0.00**	0.82	**0.00**	0.07	0.30	0.58	**0.00**	**0.02**	0.35
After 1:2	**0.01**	**0.00**	0.55	0.25	**0.00**	**0.01**	0.48	**0.00**	0.09	0.72	0.85
Bef 1:After 1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.40	**0.02**	**0.00**	**0.00**	**0.01**
Bef 2:After 2	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.18	0.38	**0.00**	**0.00**	0.19
Delta 1:2	**0.96**	0.46	0.33	0.36	0.25	0.72	0.67	**0.03**	0.23	0.23	0.34

1 Pre: Before exercise in autumn
1 Post: After exercise in autumn
2 Pre: Before exercise in January
2 Post: After exercise in January

Before 1:2 : Before exercise in autumn vs. before exercise in January
After 1:2 : After exercise in autumn vs. before exercise in January
Before 1: After 1 : Before exercise in autumn vs. after exercise in autumn
Before 2: After 2 : Before exercise in January vs. after exercise in January

panied by a compensatory fall in basal pCO_2 (Fig. 2), since basal pO_2 values are even found to be slightly higher in January. Thus, respiratory compensation is not effective at a basal state, although an increase in breathing frequency is indicated by increased basal pO_2 niveaus (Fig. 3)

Increased effects of catecholamines, which are indicated by the basal pattern of lower pH, lower base excess and increased pO_2 is further underlinded by decreased basal ionized serum Ca. Moreover, basal ionized Mg values of 0.46 mM/l before exercise are scarcely above the recommended minimum of 0.45 mM/l (Fig. 4)

As an effect of exercise, the pH value is even lower than in autumn, while pCO_2 – due to higher basal values and similar delta values – is higher. The same holds true for pO_2 and O_2sat. The strikingly low after-exercise Mg concentrations of less than 0.45 mM/l in autumn are slightly improved in January.

2. Sports majors

Their difference in basal values in January compared with autumn already comprises 7 parameters instead of the 6 seen in LMs (see Tab. 2).

The pattern of those differing parameters is not entirely the same as in language majors (pH, pCO_2, BE, HCO_3, Na, Mg and Ca).

The most important differences to the language majors were:

While LMs showed decreased basal *pH values, the SMs basal pH niveaus* increased (Fig. 5),

This is at least partially due to a more pronounced and significant fall in basal pCO_2 (Fig. 6). Thus, in case of SMs, respiratory control even of basal niveaus is effective.

Additional influences upon increasing basal pH values in January are, contrary to LMs, a significant decrease in HCO_3 and similar to LMs a decrease in BE (Tab. 2). Since lactate values do not differ at all, also here the effects of catecholamine induced lipolysis are the most conceivable instigators of compensatory action. The significantly

Fig. 1: (pH, LM)
1 pre: Before exercise, autumn;
1 post: After exercise, autumn;
2 pre: Before exercise, January;
2 post: After exercise, January.

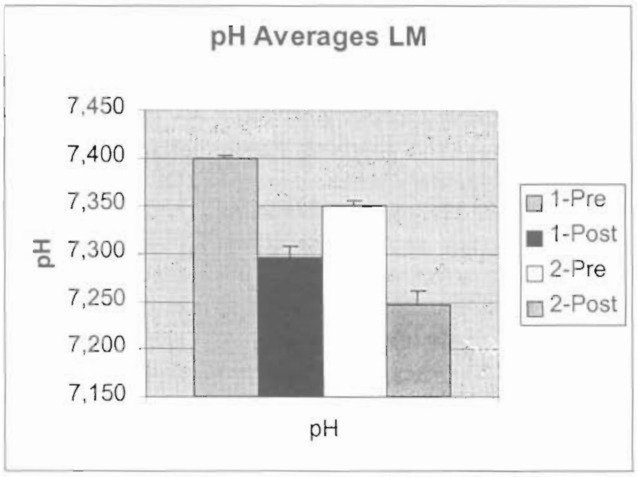


Fig. 2: (pCO_2, LM)
1 pre: Before exercise, autumn;
1 post: After exercise, autumn;
2 pre: Before exercise, January;
2 post: After exercise, January.

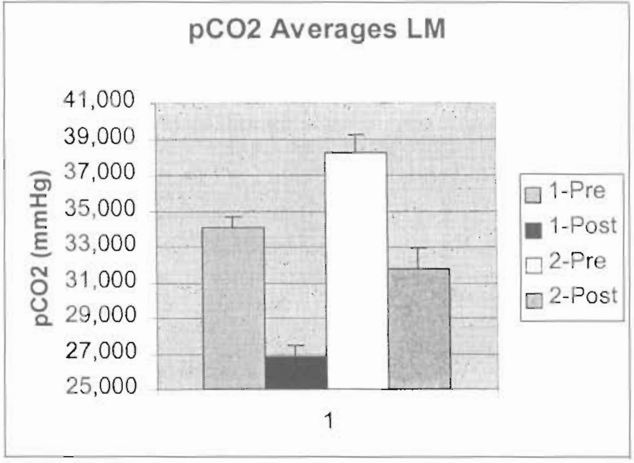
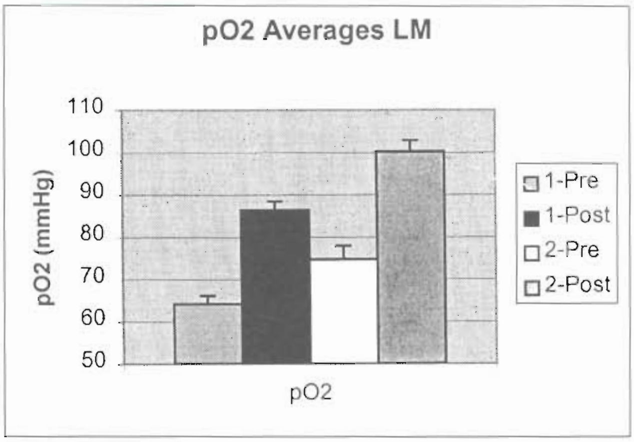


Fig. 3: (pO_2, LM)
1 pre: Before exercise, autumn;
1 post: After exercise, autumn;
2 pre: Before exercise, Jannuary;
2 post: After exercise, January.



Tab. 2: Sports Majors (SM)

Average	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
1-Pre	7.35	43.44	-1.71	23.78	74.64	93.45	143.71	0.51	1.32	1.86	99.58
1-Post	7.32	39.33	-5.56	20.05	88.63	95.11	142.59	0.50	1.26	3.55	85.74
2-Pre	7.37	37.47	-3.44	20.97	77.03	94.02	142.79	0.49	1.27	1.86	100.16
2-Post	7.32	34.14	-7.42	17.33	84.73	94.90	141.98	0.47	1.22	3.74	88.74

SEM	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
1-Pre	0.00	0.77	0.25	0.33	2.38	0.49	0.37	0.01	0.01	0.07	2.21
1-Post	0.01	0.52	0.39	0.38	3.02	0.55	0.36	0.01	0.01	0.24	1.82
2-Pre	0.00	0.71	0.28	0.37	2.60	0.51	0.27	0.01	0.01	0.07	1.74
2-Post	0.01	0.75	0.56	0.53	1.80	0.24	0.20	0.01	0.01	0.27	2.42

T-tests
*** Bold indicates a 95 % statistical significance

	pH	pCO_2	BE	HCO_3	pO_2	O_2sat	Na	Mg	Ca	Lactate	BS
Before 1:2	**0.00**	**0.00**	**0.00**	**0.00**	0.52	0.45	**0.03**	**0.01**	**0.00**	1.00	0.85
After 1:2	0.79	**0.00**	**0.00**	**0.00**	0.26	0.72	0.13	**0.01**	**0.00**	0.60	0.30
Before 1:After 1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.04**	**0.01**	0.12	**0.00**	**0.00**	**0.00**
Before 2:After 2	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.04**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**
Delta 1:2	0.11	0.53	0.85	0.17	0.16	0.39	0.43	0.64	0.73	0.60	0.59

1 Pre: Before exercise in autumn
1 Post: After exercise in autumn
2 Pre: Before exercise in January
2 Post: After exercise in January

Before 1:2 : Before exercise in autumn vs. before exercise in January
After 1:2 : After exercise in autumn vs. before exercise in January
Before 1: After 1: Before exercise in autumn vs. after exercise in autumn
Before 2: After 2: Before exercise in January vs. after exercise in January

higher values of ionized Mg, at least in autumn (Fig. 7), of SMs against LMs are striking. In January, this difference is much less expressed, due to a fall in Mg values in SMs and increased Mg values in LMs.
Superimposed exercise generally influences pH values of SMs much less than those LMs. This is mostly due to the much smaller increase in lactate, needing less respiratory compensation expressed by less expressed pCO_2 and BE alterations. Nevertheless, even in SMs the post exercise values are different in autumn and January, which is rather due to the change in basal values than to changes in delta values. Contrary to the LMs, the high ionized serum Mg concentrations in SMs seen in autumn decrease considerably in January and are then no more significantly distinguishable from hypomagnesemic thresholds (not shown).

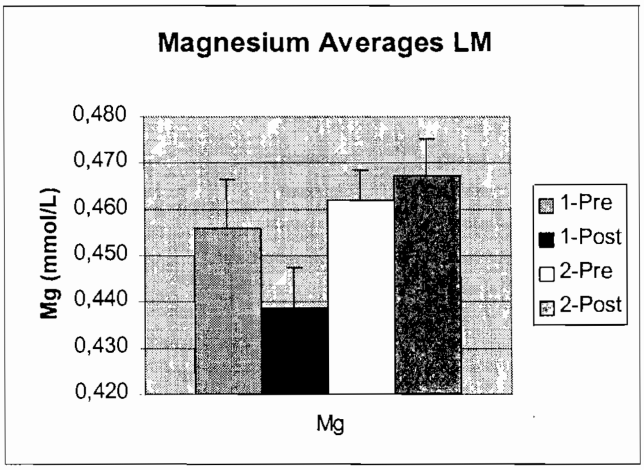


Fig. 4: (Mg, LM)
1 pre: Before exercise, autumn;
1 post: After exercise, autumn;
2 pre: Before exercise, January;
2 post: After exercise, January.

Discussion

General:
Blood gas determination along with electrolytes like Mg and Ca as well as carbohydrate parameters like blood glucose and lactate form a pattern which is different not only during illnesses or even in patients in intensive care units where this method is mainly applied, but it is also a sensitive stress indicator in normal life. Additional improvement in relation to classic catecholamine measurement is the low level of molestation (just some drops of capillary blood compared with at least 10 ml of venous blood), and therefore a much higher turnover of probands, the cheapness of determination and the transportability of equipment.

We were asked by educational authorities to investigate by those means, whether so called school stress, which is commonly referred to nowadays, could be objectively measured not only by psychological, but also by serological methods.
Since we were not at all sure, whether already basal values would show significant differences, we subjected the probands at certain term periods with and without alleged school stress to one and the same ergometric workload, to be able to measure individual stress compatibility too, according to the principle of the "post stress provocation test".
Moreover, a more sedentary group of female language majors should be compared with a nearly professionally managed group of soccer players from the same school.
A possible answer to the traditional question, whether the soccer players with 14 hours of training per week would be rather more exhausted and therefore more susceptible to school stress, or whether their training renders them even more adaptable, was tempting.
In detail, our first, rather surprising finding was, that in both groups already an appreciable amount of basal values were significantly different between autumn and January, whereby the latter values were strongly indicative of increased lipolysis due to increased catecholamine action (see results).
While the LM during examination time in January had decreased pH values along with increased pCO_2, SMs showed just the opposite behavior.
On the other hand, pO_2 and O_2sat did not differ between autumn and January in SMs, but were increased in LMs, whose very BE base values were already higher than those of the SMs.
The most striking difference in basal values were the very low ionized Mg levels of the LM versus good normal values in SMs, in spite of their sweaty 14 hours training per week.
Concerning exercise induced differences, superimposed upon the momen-

Fig. 5: (pH, SM) 1 pre: Before exercise, autumn; 1 post: After exercise, autumn; 2 pre: Before exercise, January; 2 post: After exercise, January.

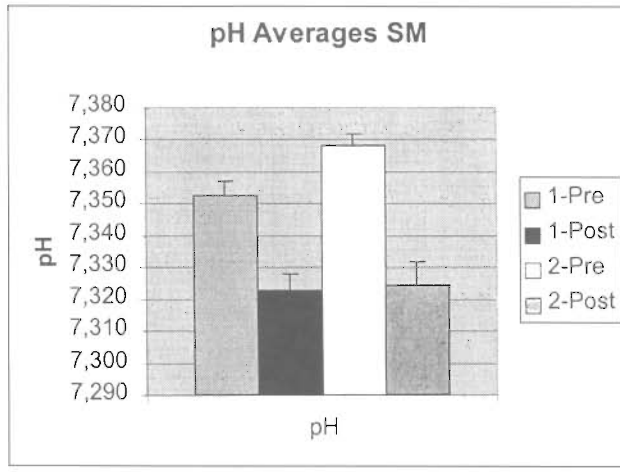


Fig. 6: (pCO_2, SM) 1 pre: Before exercise, autumn; 1 post: After exercise, autumn; 2 pre: Before exercise, January; 2 post: After exercise, January

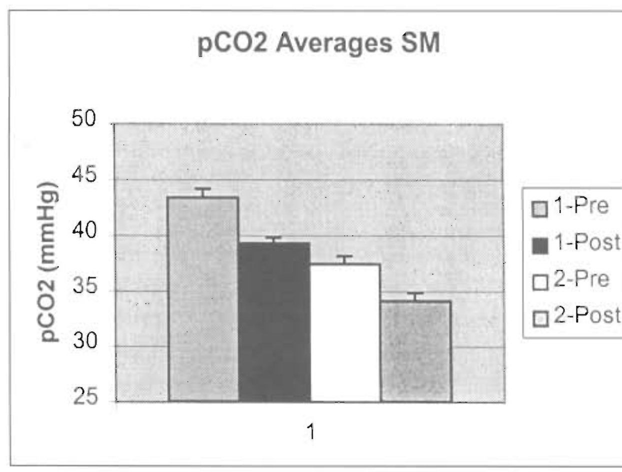
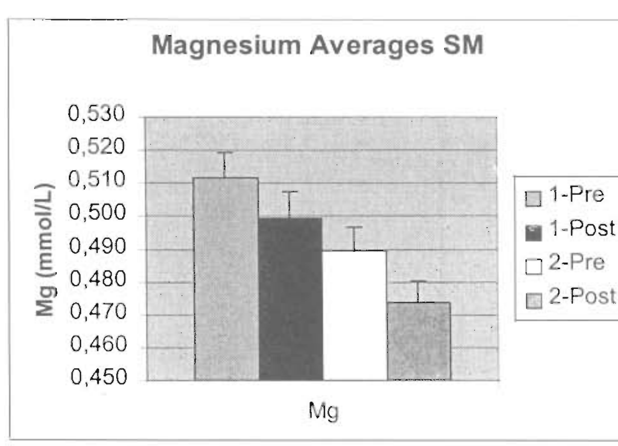


Fig. 7: (Mg, SM) 1 pre: Before exercise, autumn; 1 post: After exercise, autumn; 2 pre: Before exercise, January; 2 post: After exercise, January.



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tary situation and therefore indicative of the degree of stress compatibility in both leisurely autumn times and the stressful examination season in January, there were vast differences too. Lactate increase in both seasons was only slightly more than half in SMs, although their exercise was somewhat harder. This moderate lactate increase was easily overcorrected by respiratory pCO_2 decrease, resulting in significant pH increase (*Müller-Plathe* 1998). In LMs the much higher increase in lactate (and decrease in BE) needed a much more drastic relative fall in pCO_2, which was, however, not able to check a significant fall in blood pH. Not unexpectedly, the reactions of pO_2 and O_2sat were much more moderate in the SM group.

A different aspect seem to evolve with Mg behavior: The absolutely low Mg values in LMs in autumn (Austrian Consensus Conference about Magnesium, 1995) do increase in January, a reaction which might or might not be attributable to increased examination stress (*Rama* 1993). If so, then the SMs are either less sensible towards school stress, or their Mg supplementation, obviously carefully kept up by their physical fitness trainers is somewhat neglected during the off-season winter time, because their Mg concentrations gets dangerously near to that of the LMs (*Seelig M.* 1981).

Thus, it is obviously possible to determine school stress using certain serological parameters the type of which has been selected out of many possibilities, walking the gauntlet between oversensitivity and bluntness. Using this equipment we could see that the impact of school stress is surprisingly pronounced, a fact underlined by the base values of pH or BE in the LM group compared with SMs. Moreover, it becomes clear, that physically trained youngsters are also much better able to endure stressful examination times. Their reaction to superimposed ergometric exercise is much less pronounced than that of LMs, although their workload had to be less, so as not to provoke exhaustive reactions (*Porta* et al. 1997). The easier adaptation to a workload superimposed upon basal school stress of the SM group can be veryfied at the exercise induced fluctuations of nearly every single parameter (see table „averages"). The same holds true for basal values in autumn and January. A particularly alarming feature of the investigation are the dangerously low Mg levels in the LM group and also the alarming quickness with which a carefully kept up healthy Mg serum level in young sportsmen can vanish.

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