

Original article

## ANAEROBIC EXERCISE – INDUCED CHANGES IN SERUM MINERAL CONCENTRATIONS.

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Anaerobic exercise, a non  $O_2$  – dependent energy metabolism leads to transient metabolic changes, which are corrected gradually by homeostatic mechanism. We investigated in eight male subjects, the effects of anaerobic exercise after a day sedentary activity on serum mineral concentration. There was significant variation in the concentration of serum potassium ( $F=4.99, P<0.00$ ) and zinc ( $F=22.48, P<0.05$ ) on sedentary day. On the other hand, serum magnesium, and calcium were unchanged. Anaerobic exercise induced a significant increase in the serum concentrations of calcium ( $2.11\pm 0.13$  vs  $2.39 \pm 0.12$  mmol/L,  $P<0.05$ ), potassium ( $4.0\pm 0.4$  vs  $5.3 \pm 0.3$  mmol/L,  $P<0.05$ ), and zinc ( $12.01\pm 1.48$  vs  $15.96\pm 1.60$   $\mu$ mol/L,  $P<0.05$ ). Twelve hours later, magnesium ( $0.88\pm 0.05$ , mmol/L,  $P<0.05$ ) concentration remained high, potassium and calcium concentrations normalized, while zinc concentration decreased below the pre-exercise value ( $9.56\pm 0.81$   $\mu$ mol/L,  $P<0.05$ ). Urinary magnesium ( $4.68\pm 1.27$  vs  $2.60\pm 0.66$   $\mu$ mol/min,  $P<0.05$ ) and zinc ( $13.71\pm 3.77$  vs  $8.58 \pm 2.28$  nmol/min,  $p<0.05$ ) increased, while calcium ( $2.40\pm 1.14$  vs  $2.33\pm 1.10$   $\mu$ mol/min, NS), potassium ( $20.26 \pm 7.03$  vs  $24.26 \pm 4.82$   $\mu$ mol/min, NS) and the urinary output ( $0.93\pm 0.38$  vs  $0.78\pm 0.26$  ml/min, NS) did not change significantly on the day of exercise compared to the sedentary day. The result presented show clearly that mineral concentration vary greatly within given periods of time and more so after anaerobic exercise.

**Key words:** Magnesium-Calcium-potassium-zinc-anaerobic exercise

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### INTRODUCTION

Several reports have shown that duration and/ or intensity of exercise elicit different effects on minerals metabolism and that inadequate status of the body mineral composition can lead to a diminution of performance and endurance both in sportsmen and rats (McDonald and Keen, 1988; Rassiguier *et al*, 1990; Clardson, 1991). Magnesium flux from the erythrocyte to the extracellular fluid was reports (Lijnen *et al*, 1988). Other workers observed higher muscular magnesium levels after training, suggesting a shift in magnesium from plasma, erythrocyte and even bone to the muscle (Brilla *et al*, 1989; Cordova *et al*, 1992). Some other studies have however shown that maintained exercise leads to a diminution of magnesium in soft tissues that is not noticeable in serum, probably provoked by an increase in renal excretion (Navas and Corodova, 1996).

It thus seem that shift of magnesium provoked by exercise can produce a loss of intracellular magnesium, which could impair physical performance (Brautbar and Carpenter, 1984).

Exercise induces a loss of intracellular potassium and increases the extracellular potassium (Vollestad *et al*, 1994; Verburg *et al*,

1999), with the changes in intra or extracellular potassium concentration likely to influence force development (Sjogaard, 1990; Fitts and Balog, 1996; Cairns *et al*, 1997). Calcium loss was also reported during strenuous exercise (Chu *et al*, 1979).

Consistent elevations in blood Zn concentration after strenuous exercise, followed by decreases in blood Zn within 30 min or longer of strenuous exercise was reported (Aderson *et al*, 1995; Ohno *et al*, 1985; Bordin *et al*, 1993).

We describe for the first time, the time-course of mineral concentration in subjects engaged in high-intensity exercise and relative inactivity, with a view of understanding further mineral homeostasis.

### SUBJECTS AND METHODS

Eight male healthy subjects aged (mean  $\pm$  SD)  $22.9\pm 3.6$  years and BMI of  $23.3\pm 3.6$  kg/m<sup>2</sup> participated in this study. They gave their informed consent and the committee on human research of the National institute of Health and Nutrition approved this protocol.

Subject came in the evening before 18.30 hrs, and at 18.30 hrs emptied the bladder. First 24hr

urine was collected at timed-intervals from 21:00hrs, while the subjects were sedentary, with little or no activity. Another set of 24hrs urine collection began at 21:00hrs of day 2, and ended on the evening of day 3.

On day 3, the subjects exercised on bicycle ergometer for 3 minutes just before 9:00hrs in fasted condition. The work rate was adjusted as much as possible to ensure 3 minute sustained exercise. At least a pedal frequency of 90 rev/min was maintained and heart rate measured continuously.

The subject maintained the same dietary pattern for the three days and the diet formulated to give 60% carbohydrate, 26%, fats, and 14% protein. They had their supper at 18.30 hrs on the three days, lunch at 12.30 and 13.00hrs on day 2 and 3 respectively and breakfast at 8.30 hrs on day 2. On day 3, the subjects had their exercise in fasted condition.

Two fasting blood samples at 6:00 and 8:30 hrs were collected on day 2. Other samples were collected at 12:30, 15:30, 16:30 and 21:00hrs. On day 3, fasting samples were collected at 6:00 and 8:15hrs. Blood samples were also collected immediately after exercise at 9:00 and at the

following time, 9:15, 10:00, 13:00, 17:00 and 21:00 hrs. Blood lactate from fingers tip was monitored as an indicator of anaerobic exercise.

All the samples were referred to commercial laboratory for analysis. Atomic absorption spectrophotometer (Varian AA5 spectrophotometer) was used for the analysis of serum and urine magnesium, calcium, zinc, and potassium concentrations. Urine flow per minute was calculated from the urine volume and time for each collection. Data were analyzed using SPSS, sigmaplo and Microsoft excels statistics packages.

## **RESULT**

There were circadian in the urine excretion of Mg, Zn, and Ca, whereas no statistical significance was obtained for K (Fig 1). Excretion of Mg, Zn, and Ca were higher in the daytime. Exercise led to increase in urinary excretion of Mg, Ca, and Zn, whereas K excretion decreases (Fig 2). However, while the excretion of Mg and Zn were higher on exercise day than on sedentary day, Ca and K excretion were similar (Fig 2.) Twelve hours after exercise, the urinary excretion of the minerals (Zn, Ca and K), except Mg were normalized to that obtained on the sedentary day.

**Fig 1.** Urine mineral excretion on sedentary and exercise days in eight male subjects; \*P<0.05 between sedentary and exercise days.

**Fig 2.**

Urine mineral excretion over a period of time on sedentary and exercise days. In eight male subjects. \*P<0.05 between sedentary and exercise days.

**Fig 3.** Mineral concentrations in eight male subjects on sedentary and exercise days. \*P<0.05 between sedentary and exercise days.

There was variability in the serum concentrations of Zn and K on sedentary day, whereas serum Mg and Ca were unchanged (Fig

3.). Serum Zn increased from  $13.2 \pm 1.7$  to  $16.0 \pm 1.6$  and  $15.5 \pm 2.0$   $\mu\text{mol/L}$ ; P<0.05 immediately and 15 minutes after exercise. Serum Ca immediately

after exercise increased from  $2.1 \pm 0.1$  to  $2.4 \pm 0.1$  mmol/L,  $P < 0.05$ . Serum K increased as well from  $4.0 \pm 0.4$  to  $5.3 \pm 0.3$  mmol/L,  $P < 0.05$ , but within 15 minutes decreased to a value of  $3.7 \pm 0.2$  mmol/L,  $P < 0.05$ . Serum Mg increased and peaked after one hour post-exercise ( $0.80 \pm 0.16$  vs  $0.94 \pm 0.08$  mmol/L,  $P < 0.05$ ).

Twelve hours later, Ca and K concentrations normalized to the value obtained on sedentary day ( $2.1 \pm 0.1$  vs  $2.0 \pm 0.1$ , and  $3.8 \pm 0.2$  vs  $3.6 \pm 0.3$  mmol/L), serum Mg remained high ( $0.88 \pm 0.05$  vs  $0.79 \pm 0.04$ ,  $P < 0.05$ ), while Zn concentration was much lower ( $9.6 \pm 0.8$  vs.  $10.9 \pm 1.7$   $\mu$ mol/L,  $P < 0.05$ ). There were positive correlations between urinary excretion of magnesium and calcium ( $r = 0.96$ ,  $P < 0.05$ ), magnesium and zinc ( $r = 0.87$ ,  $P < 0.05$ ) and calcium and zinc ( $r = 0.86$ ,  $P < 0.05$ ) on exercise day.

## **DISCUSSION.**

In this study the homeostasis of each of the minerals studied were of similar pattern on sedentary and exercise days. Though subjects were restricted within the premises of the research institute and relaxed as much as possible, we cannot preclude the possibilities of increase in mental and body activities on sedentary day, which may have affected mineral metabolism (Nishimuta *et al*, 1988). Apart from the 3-minute anaerobic exercise on exercise day, the activities of the subjects were not different from that on sedentary day. Therefore, we could attribute any difference in mineral homeostasis to exercise related effects.

There was variability in the urinary excretion of the minerals on sedentary and exercise days, but the tendency was for a greater excretion in the daytime. However, exercise induced a significant increase in urinary excretion of Zn and Mg, a decrease of K and no significant effect on urinary excretion Ca. Interestingly, the excretion of the minerals normalized except Mg, which remained high 12 hours after exercise. On a 24 hr bases, Mg and Zn excretion were increased, while Ca and K did not change significantly on exercised day compared with sedentary day. This finding is similar to previous reports (Anderson *et al*, 1995; Navas and cordova, 1996), except that the reports focused only on 24hr excretion.

Previously magnesium flux from the erythrocyte to the extracellular fluid was reported (Lijnen *et al*, 1998). However, some other studies did show that maintained exercise leads to diminution of magnesium in soft tissues that is not noticeable in serum, despite an increase in renal excretion (Navas and Cordova, 1996). In this study, not only was urinary excretion of

magnesium increased, serum magnesium concentration increased as well and remained so 12 hrs after exercise. It thus seems that a shift of magnesium provoked by exercise, can produce a loss of intracellular magnesium (Brautbar and Capenter, 1984).

Exercise has also been shown to induce a loss of intracellular potassium and increases the extracellular potassium because of an efflux from the muscles (Vollestad *et al*, 1994; Verbug *et al*, 1999). However, reuptake by muscle then returns the concentration to normal after exercise (Vollestad *et al*, 1994). In this study serum K was not increased beyond the very first few minutes, as reported previously (Verbug *et al*, 1999), rather it decreased despite the decrease in plasma volume. In addition, exercises did not elicit significant increase in the urinary excretion of  $K^+$  rather the tendency was for a decrease following exercise.

Our finding is consistent with that of others, who reported in blood Zn concentration after strenuous exercise, followed by decreases in blood Zn within 30 min or longer (Ohno *et al*, 1985; Bordin *et al*, 1993; Anderson *et al*, 1995). In fact serum zinc concentration remained low 12 hours after exercise. It has been suggested that the initial increases in Zn is likely to be due to a combination of mobilization of Zn in response to the stress of acute exercise and the leakage of muscle fibres (Ohno *et al*, 1985). The subsequent decline in blood Zn following exercise is probably due to a sequestration of Zn in the liver and other tissues in responses to the stress of exercise (Anderson *et al*, 1995). However, while other workers reported only a small change in 24 hr urinary Zn following acute exercise (Anderson *et al*, 1995), our finding is the opposite. Despite the short duration of the exercise, it is very obvious that urinary excretion of zinc increased as a result of the exercise.

A lot of conditions are known to increase urinary calcium excretion in humans (Lemann *et al*, 1986) Grinspoon *et al*, 1995; Ashizawa *et al*, 1997). Increase in filtered load of calcium, a decrease in fractional renal reabsorption of calcium or a combination of the two are factor that lead to increase in urinary excretion of calcium (Ashizawa *et al*, 1997). Interestingly, in this study, though calcium excretion was increased following exercise, it was not significantly different from the excretion on sedentary day.

Other unknown factors apart from exercise could therefore have played a very significant role, especially when it was obvious that a similar increase in excretion was obtained without exercise. Furthermore, except for the slight increase in serum calcium within fifteen minutes after exercise, the concentrations were not

different from that of the previous day. This indeed supports the fact that serum levels of calcium are under strict homeostatic control and remain within narrow limits (Arnaud and Sanchez, 1990)

In conclusion, there are tendencies for some minerals either to increase or to decrease after exercise without any statistically significant difference related to basal conditions (Cordova et al, 1990). In this study, the changes in most of the minerals on the exercise day could be attributed to hemoconcentration provoked by exercise as a consequence of a decrease in plasma volume or the flux from muscle (Cordova et al, 1990) or erythrocyte (Lijnen et al, 1988; Cordova et al, 1992) to serum. However, it is obvious that other homeostatic mechanisms are involved in the regulation of serum Mg and Zn, as the concentrations remained increased and decreased instead of normalizing as were the case for other minerals.

## REFERENCES

- Anderson, R. A., Bryden, N. A., Polansky, M. M. and Deuster, P. A. (1995).** Acute exercise effects on urinary losses and serum concentrations of copper and zinc of moderately trained and untrained men consuming a controlled diet. *Analyst*. 120, 867-70s
- Arnaud, C. D., and Sanchez, S. D. (1990).** Calcium and phosphorus. In: *Present Knowledge in Nutrition*, 6<sup>th</sup> Ed., M. L. Brown (Ed.). Washington, DC: International Life Science Institute. Pp212-223.
- Ashizawa, N., Fujimura, R., Tokuyama, K., and Suzuki, M. (1997).** A bout of resistance exercise increases urinary calcium independently of osteoclastic activation in men. *J. Appl. Physiol.* 83, 1159-1163.
- Bordin, D., Sartorelli, L., Bonanni, G., Mastrogiacomo, I. and Scalco, E. (1993).** High intensity physical exercise induced effects on plasma levels of copper and zinc. *Biol. Trace Elem. Res.* 36,129-134
- Brautbar, N., Carpenter, C. (1984).** Skeletal myopathy and magnesium depletion; cellular mechanism. *Magnesium*. 3, 57-61.
- Brilla, L.R. Fredickson, J.H., Lombardi, V.P. (1989).** Effect of hypomagnesemia and exercise on slowly exchanging pools of magnesium. *Metabolism*. 38, 797-800.
- Cairns, S.P. Hing, W.A., Slack, J.R., Mills, R.G., and Loiselle, D.S. (1997).** Different effects of raised (K<sup>+</sup>)<sub>o</sub> on membrane potential and contraction in mouse fast- and slow-twitch muscle. *Am. J. Physiol.* 273, C598-C611.
- Chu, J. Y., Morgen, S., Calloway, D. H. Costa, F. M. (1979).** Intergumentary loss of calcium *Am. J. Clin. Nutr.* 57, 845-850.
- Cordona, A., Gimenez, M and Escanero, J.F. (1990).** Effect of swimming to exhaustion, at low temperature on serum Zn, Cu, Mg and Ca in rats. *Physiol. Behav.* 48, 595-598.
- Cordova, A., Gimenez, M., Escanero, J. F (1992).** Magnesium distribution after maximal exercise in air and under hypoxia conditions. *Magnesium Res.* 5, 23-27.
- Clarkson, P. M. (1991).** Minerals: exercise performance and supplementation in athletes. *J. Spots Sci.* 9, 91-116
- Fitts, R. H and Balog, E. M. (1996).** Effects of intracellular and extracellular ion changes on E-C coupling and skeletal muscle fatigue. *Acta. Physiol. Scand.* 156, 169-181.
- Grinspoon, S. K., Baum, H. B., Kim, V., Coggins, C., and Klianski, A. (1995).** Decreased bone formation and increased mineral dissolution during acute fasting in young women. *J. Clin. Endocrinol. Metab.* 80, 3628-3633.
- Lemann, J. Jr., Gray, R. W., Maierhofer, W. J., and Cheung, H. S. (1986).** The importance of renal net acid excretion as a determinant of fasting urinary calcium excretion. *Kidney Int.* 29, 743-746.
- Lijnen, P., Hespel, P., Fagrad, R., Lysens, R., Van den Eynde, E., Amery, A. (1988).** Erythrocyte, plasma and urinary magnesium in men before and after a marathon. *Eur. J. Appl. Physiol.* 58, 252-256.
- McDonald, R. and Keen, C. L. (1988).** Iron, zinc and magnesium nutrition and athletic performance. *Sports Med.* 5, 171-184.
- Navas, F. J., Cordova A. (1996).** Effects of magnesium supplementation and training of magnesium tissue distribution in rats. *Biol. Trace Elem. Res.* 53, 137-145
- Nishimuta, M., Kodama, N., Ono, K., Matsumoto, Y., Tera, T., Yamada, H. and Kobayashi, S. (1988).** Stress induced magnesiuressis in human. *J.J.S. Mg. R.* 7, 123-132.
- Ohno, H., Yamashita, K., Doi, R., Yamamura, K., Konols, T., and Taniguchi, N. (1985).** Exercise-induced changes in blood zinc and related proteins in humans. *J. Appl. Physiol.* 58, 1453-1458.
- Rayssiguier, Y., Guezennec, C. Y. and Durlach, J. (1990).** New experimental and clinical data on the relationship between magnesium and sport. *Magnesium Res.* 3, 93-102.
- Sjogaard, G. (1990).** Exercise-induced muscle fatigue: the significance of potassium. *Acta. Physiol. Scand.* 140 (Suppl 593).
- Verburg, E., Hallen, J., Sejersted. O. M., and Vollestad, N. K. (1999).** Loss of potassium from muscle during moderate exercise in humans: a result of insufficient activation of the Na<sup>+</sup>K<sup>+</sup>pump? *Acta. Physiol. Scand.* 165,357-367
- Vollestad, N. K., Hallen, J., Sejersted, O. M. (1994).** Effects of exercise intensity on potassium balance in muscle and blood of man. *J. Physiol.* 475, 359-68

*Received: May, 2001*

*Accepted in final form: Accepted in final form: December 2001*