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Time Course of Plasma Growth Hormone During Exercise in Man at Altitude

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Several studies (5,6) tend to demonstrate that hypoxic conditions enhance the release of growth hormone (GH). However, results obtained in highlanders in Peru suggest that stimulation of GH release during exercise is not increased by altitude hypoxia (4). The present study was designed to define more accurately the time course of plasma GH concentration and that of other metabolites related to muscular exercise and to compare them in lowlanders at sea level, in subjects fully adapted to altitude hypoxia, and in lowlanders acutely exposed to hypoxia either by breathing a low pressure O_2 gas mixture or by a process of acclimatization after translocation to high altitude.

Subjects and Methods

Three groups of subjects were studied: (1) nine highlanders (HL) at high altitude (HA) (La Paz, 3850 m); (2) 20 lowlanders (LL) at sea level (SL) (Paris); and (3) five of the lowlanders, (a) on the third to sixth day after arrival at Pic du Midi (2850 m) and (b) 15 days after returning to Paris, in acute hypoxia, breathing 15% O_2 gas mixture which corresponds to the partial pressure of O_2 at 2850 m.

The following energetic and hormonal parameters were measured at rest, during a 1-h submaximal exercise performed on a bicycle ergometer, and during a period of 1-h recovery: blood glucose (BG), free fatty acids (FFA), lactic acid (LA), and growth hormone (IRHGH) plasma concentration as a function of time at the intervals indicated in Fig. 24-1 and $\dot{V}_{O_2}$ at steady state of exercise. Growth hormone was measured by radioimmunoassay. The time course of [IRHGH] is described in terms of peak concentration, delay of rise, and half-life. The area delimited by the curve of [IRHGH] above baseline during exercise

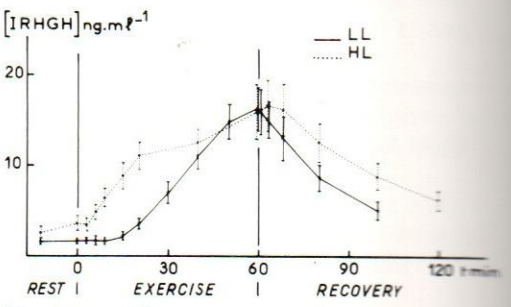

Fig. 24-1. Time course of [IRHGH] (mean ± SE) in 15 LL (*solid line*) and 8 HL (*dotted line*).

was determined by planimetry, thus providing a measurement which takes into account both delay and shape of the ascending curve. Two values of this area were calculated: one at 30, the other at 60 min of exercise.

Results

The results of the experiments are shown in Table 24-1. The mean maximal values of [LA] do not differ in LL and HL. However, LA_{max} is slightly higher in LL when they are placed in acute hypoxic conditions, compared to values under normoxia. The resting value of [BG] is significantly lower in HL compared to LL. The fall which occurs at the beginning of exercise is of the same order of magnitude in HL and LL. The time course of [FFA] is similar in the two groups in that [FFA] increases only at the end of the 1-h exercise period and the maximal value occurs during recovery. This maximal value is higher in HL than in LL.

The mean resting value of [IRHGH] is significantly higher in HL than in LL. During exercise, the time sequence of [IRHGH] shows differences when the conditions of oxygenation change (Fig. 24-1): in LL at SL, resting concentrations are maintained for some time during exercise, then [IRHGH] rises and reaches maximal value at the end of exercise. In HL, the delay is significantly reduced and half-life is much longer. The mean maximal value is not different from that of LL. Figure 24-2 confirms that the initial rise in [IRHGH] is definitely earlier and faster in HL than in LL despite comparable peak values: the mean area at 30 min is significantly ($p > 0.01$) larger for HL than for LL, and the mean area at 60 min in HL is also larger but the difference is not confirmed statistically. The five LL studied in acute hypoxic conditions exhibit similar variations in the time course of IRHGH to those of HL: faster rise in concentration is confirmed by the comparison of surface integrals of [IRHGH] as a function of time (Fig. 24-2).

Table 24-1. *Experimental Results in Highlanders and Lowlanders.*

	LL (SL)	HL (3850 m)	LL		
			SL	Acute hypoxia	2850 m
$\dot{V}_{O_2 s.st.}$	0.870±	0.820±	0.830±	0.829±	0.825±
(liter · min^{-1} · m^{-2})	0.05	0.08	0.05	0.07	0.05
Relative work load	54.3±	51.9±	59.8±		
(percent $\dot{V}_{O_2 max}$)	3.3	4.0	5.1		
$[LA]_{max}$ at exercise	4.1±	4.3±	4.2±	5.2±	5.4±
(mM · liter^{-1})	0.3	0.2	0.4	0.7	0.6
[BG] at rest	0.95±	0.77±			
(g · liter^{-1})	0.02[b]	0.04[b]			
$[FFA]_{max}$ at exercise	760±	1276±			
(μEq · liter^{-1})	65[a]	254[a]			
[IRHGH] at rest	1.58±	3.58±	1.50±	1.80±	1.75±
(ng · ml^{-1})	0.65[b]	0.88[b]	0.40	0.65	0.35
$[IRHGH]_{max}$ at exercise	16±	16.5±	16.6±	19.8±	22.6±
(ng · ml^{-1})	2.3	2.9	5.3	4.8	6.1
Delay of rise	15±	5.5±	20±	16±	10±
(min)	2.2[a]	1.2[a]	4.3	4.1	3.5
Half-life	16±	34±	19±	16±	15±
(min)	2[a]	6[a]	2	2	5

Mean ± SE.
[a,b] $p < 0.05$ and $p < 0.01$, respectively, for LL at SL and HL at 3850 m.

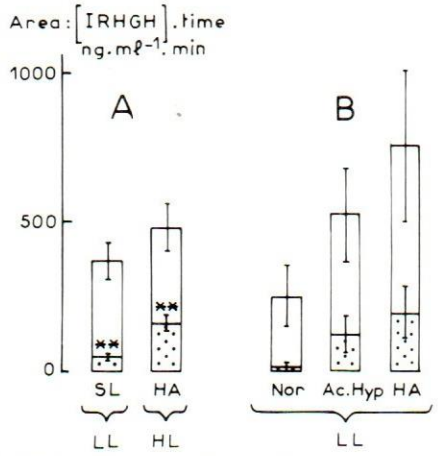

Fig. 24-2. The top of the columns correspond to the mean value of the areas determined by time and [IRHGH] above resting baseline (Fig. 24-1). Dotted columns correspond to the surface areas determined by 30 min of exercise, and open columns to the surface areas determined by 60 min of exercise.

Discussion

The following observations emerge from these results:

1) The similar time course and maximal values of [LA] which are observed in HL and LL favor the argument that anaerobic metabolism is the same for all subjects of similar physical fitness provided they are fully acclimatized to their environment, whatever the altitude.

2) At rest, the lowering of [BG] in HL as compared to LL was also noticed by Picon-Reategui et al. (2) in natives of 4000 m, but the mechanism is not clear.

3) The fact that the sudden rise in [FFA] during the early stages of recovery is more marked in HL suggests that FFA output is more important at HA than at SL. A similar finding is reported by others (3,5).

4) Two differences appear in [IRHGH] in LL and HL (Fig. 24-1): (a) the resting value is significantly higher in HL than in LL; and (b) the time sequences during muscular activity differ in that HL have a shorter delay in the onset of rise in concentration and a longer time constant of disappearance. However, the mean peak value reached after 1 h of exercise is similar to that of LL. This pattern of the [IRHGH] curve is also observed at exercise during the early stages of acclimatization to HA or during hypoxic mixture breathing. Thus, a shorter delay and a slower disappearance seem to be constant responses to exercise in hypoxia. Which hypotheses could be advanced to explain these results? At rest, the relatively but chronically low glycemia in HL might be responsible for the higher resting level of [IRHGH]. At exercise, no correlation is found between $[LA]_{max}$ and [IRHGH] peak values (1). Moreover, the time courses of [LA] are superimposable in LL and HL, precisely in the same time when the time courses of [IRHGH] differ. It would be hazardous also to assume that the slight drop in [BG] observed at the beginning of exercise, which is of the same magnitude in LL and HL, is responsible for the different time courses of [IRHGH]. In contrast, the present experiments seem to support the action of growth hormone as a stimulus in releasing FFA during exercise, since an earlier rise in [IRHGH] precedes a faster and greater output of FFA in HL.

In all the cases, stopping exercise plays a major role in the time course of [IRHGH]: its rise stops, followed by a decrease. This sudden change suggests that a balance between hormone release and catabolism, which is responsible for the observed variations in blood concentration, is immediately altered. This might be due to the sudden increase in hepatic blood flow as exercise stops, which would augment hormone clearance. We propose that the differences observed during exercise in the time course of [IRHGH] between LL and HL, which consist in a faster rise and a slower disappearance, are likely due to a more pronounced reduction in hepatic blood flow in HL as compared to LL.

In general, this study points out the importance of (1) characterizing the release pattern of IRHGH by variables other than maximal concentration, such as delay of rise, elevation rate, and half-life; and (2)

dealing with long periods of exercise. If, in the present case, exercise duration had been reduced to 20 min, for instance, the actual difference observed at this time between the time sequence in HL and LL would have led to the conclusion that hormonal release was more important at HA that at SL, whereas the conclusion is different 40 min later.

References

1. Lassarre, C., Girard, F., Durand, J., and Raynaud, J.: Kinetics of human growth hormone during submaximal exercise. J. Appl. Physiol. 37:826, 1974.
2. Picon-Reategui, E., Buskirk, E.R., and Baker, P.T.: Blood glucose in high altitude natives and during acclimatization to altitude. J. Appl. Physiol. 29:560, 1970.
3. Stock, M.J., Chapman, C., Stirling, J.L., and Campbell, I.T.: Effects of exercise, altitude, and food on blood hormone and metabolite levels. J. Appl. Physiol. 45:350, 1978.
4. Sutton, J.R.: Scientific and medical aspects of the Australian Andean expedition. Med. J. Aust. 2:355, 1971.
5. Sutton, J.R.: Effect of acute hypoxia on the hormonal response to exercise. J. Appl. Physiol. 42:587, 1977.
6. Sutton, J.R., Jones, N.L., and Toews, C.J.: Growth hormone secretion in acid-base alterations at rest and during exercise. Clin. Sci. Mol. Med. 50:241, 1976.