Application of Blood Ammonia Concentration Measurement in Training Monitoring

Yvonne Yuen
The Hong Kong Sports Institute

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Final Report

Part 1 - Blood ammonia level of elite athletes during exercise

Background

Ammonia production by muscle during exercise was first documented by Parnas as early as 1929 (Parnas, 1929). Since then, a large number of studies showed that blood ammonia increases after various exercise protocols. Previous studies (Buono et al, 1984; Snow et al, 1991) demonstrated that blood ammonia level increases after incremental exercise up to exhaustion. Dudley (1983) was able to demonstrate increase in blood ammonia level after short exhausting exercise. Long duration exercise at submaximal intensity was also able to increase blood ammonia level (Wilkerson et al, 1977; Graham et al, 1987; Broberg & Sahlin, 1989; MacLean et al, 1991).

Similar to blood lactate, the exercise-induced rise in blood ammonia depends on the exercise duration and intensity. Previous studies have demonstrated the relative lack of ammonia changes during low-intensity aerobic exercise under 70 per cent of the VO2max (Buono et al, 1984; Wilkerson et al, 1977). However, blood ammonia level increases continuously at all intensities, whereas blood lactate level reaches steady state or decreases on prolonged exercise of intensity below the threshold level. Measurement of blood ammonia level during long duration exercise is a potential subjective criterion to monitor duration of endurance training.

Previous studies on the effect of exercise on blood ammonia level were not done on elite athletes. Data obtained previously cannot be applied directly to competitive athletes at elite levels. The first part of the present study is therefore to elucidate effect of various

exercise protocols on blood ammonia level in elite athletes. It is hoped that data obtained will allow the establishment of normative values for monitoring training of elite athletes.

Method

Blood ammonia level of elite athletes in various sports during selected training sessions was measured.

Summary of the subjects and training program is listed as follows:

Subjects	**Training Program**
5 windsurfers	Isokinetic trunk extension/flexion exercise on Cybex machine
4 or 8 middle distance runners	10K time trial *Time trial was repeated with (8 subjects) and without (4 subjects) carbohydrate supplement*
3 road cyclists	8 repeats of hill training, each hill repeats lasted for about 30 minutes
6 road cyclists	Continuous cycling at 70% MVO_2 for 2 hours

Results and Discussion

A. Effect of isokinetic trunk extension/flexion exercise on blood ammonia

Set	Speed (deg/sec)	Rep	Rest (sec)	Blood ammonia (μg/dl)
Rest				68.0 ±24.6 (5)
1	60	5	40	
2	60	5	40	
3	120	10	90	
4	180	20	90	99.4±9.1 (5)*
5	90	5	120	
6	60	5	40	
7	60	5	40	105.6±33.6 (5)
8	120	10	40	
9	180	20	120	
10	60	5	/	
Post-exercise (1 min)				117.2±26.1 (5)*
Post-exercise (3 min)				89.3±27.6 (5)**

* Values significantly different to the resting value ($p<0.05$).

** Value has tendency to be different from the post-exercise (1 min) value ($p=0.066$).

Post-exercise blood ammonia level was significantly higher than the resting value. This is in according to previous literature (Wilkerson et al, 1977; Dudley, 1983; Buono et al, 1984; Graham et al, 1987; Broberg & Sahlin, 1989; MacLean et al, 1991; Snow et al, 1991).

The only exception was the reading obtained after the 7th set of exercise. Eventhough, there is a high tendency for the exercise ammonia level to be higher than the resting

values. The insignificance is mainly caused by the higher variance among the data obtained. The large variance in exercise ammonia level is likely to be resulted from the difference in the pattern of fatigue among the subjects. At a lower speed (60 deg/sec) of muscular contraction the previously fatigue slow twitch fibres can be replaced by fast twitch fibres which has a higher capacity to produce ammonia during exercise (Fishbein et al, 1990). Subjects who produced higher ammonia level at the 7th set of the training program may have fatigued their slow twitch fibre earlier.

Blood ammonia level after exercise returned slowly to the resting level. According to the data obtained in this study, it takes more than 3 minutes to return back to the resting value. The post-exercise ammonia level at 3 minutes was still significantly higher than the resting value.

B. Effect of continuous running on blood ammonia level

Exercise blood ammonia level before and after 10K time trial with or without carbohydrate supplement before training.

	No CHO supplement	With CHO supplement
Rest	76.8±13.0 (4)#	100.9±21.4 (8)#
Warm up	113.3±36.9 (4)	114.6±25.7 (8)
Post-exercise (peak value)	235.3±110.4 (4)*	180.5±29.0 (8)*

*Significant difference found between post-exercise blood ammonia and corresponding resting blood ammonia.

#Significant difference in blood ammonia level was only found between resting values of the two groups. However, there is high tendency for the post-exercise peak ammonia level in the no supplement group to be higher than that in the CHO supplemented group.

Post-exercise ammonia level is significantly higher than the resting value which is consistence with previously findings. The lack of significant difference in ammonia level between resting value and post-warm-up value is caused by the large variance. There was no strict control in the warm-up among subjects which will likely to result in high variance in the warm-up ammonia level.

Although significant difference was not found in the post-exercise ammonia level among the CHO supplemented and not supplemented trial, there is a high tendency for the post-exercise peak ammonia level in the no supplement trial (235.3±110.4 μg/dl) to be higher than that in the CHO supplemented trial (180.5±29.0 μg/dl). This is consistent with Broberg and Sahlin's (1988) finding which confirmed that ammonia production increases in response to low glycogen level in the exercising subjects. The trial conducted without carbohydrate supplement is more likely to have the subjects under glycogen depleted state.

C. Effect of road cycling on blood ammonia

Three road cyclists completed a training composed of 8 repeats of hill training. Each of these hill repeats lasted for about 30 min. The corresponding blood ammonia level is recorded as below:

	Blood ammonia (μg/dl)
Rest	71.0±6.6 (3)
Post-exercise	148.7±31.3 (3)*

*Significantly different from the rest value ($p<0.05$)

In addition to isokinetic exercise and running, cycling can also increase blood ammonia level significantly.

D. Effect of 2 hours continuous cycling on blood ammonia

Six road cyclists worked at 70% MVO_2 on their own bike with cycle-simulator for 2 hours. The corresponding blood ammonia levels were recorded as follows:

	Blood ammonia (μg/dl)
Rest	80.7±17.5 (6)
20 min	145.7±47.2 (6)*
40 min	163.3±48.4 (6)*
80 min	200.3±70.5 (6)*
100 min	205.0±34.3 (6)*
120 min	202.2±72.6 (6)*
Post-exercise (20 min)	149.5±42.8 (6)*

* All exercise ammonia and post-exercise ammonia levels were significantly different from the resting value ($p<0.05$).

Working at 70% of the MVO_2 increased the blood ammonia level significantly from the resting value. When each of the exercise blood ammonia level was compared to the level at the previous time point, no significant difference was found. This means that the rise in ammonia level is significant only at the start of the exercise (or the first 20 min). From 20 minutes onwards, there is no further significant increase in ammonia. This finding is not consistent with previous studies (Borberg and Sahlin, 1989) in which ammonia level continuously increase during exercise. At the present stage, it is not possible to explain whether the difference is related to the training level of the subjects or not.

Conclusion

The exercise ammonia level obtained in this study will act as the normative data for elite athletes during corresponding training. This is the first piece of information on exercise ammonia level of local elite athletes. Although most of the findings in this study are consistent with previous studies on average subjects, the increase in blood ammonia during prolonged submaximal exercise seems to be different among the trained and untrained. Ammonia level continuously increases in the untrained subjects during exercise. On contrast, the ammonia level of elite athletes increase significantly during the first 20 minutes and then remains relatively constant in the rest of the submaximal exercise.

Part 2 - Dissociation of ammonia threshold from lactate threshold

Background

During standard graded exercise protocol with each step lasts for 1-3 minutes, blood lactate and blood ammonia levels increase in parallel (Buono et al, 1984). During submaximal prolonged exercise, blood lactate elevates from the rest level and remains at the same level or even decreases after reaching the steady state. Blood ammonia level continues to increase until end of exercise (Urhausen and Kindermann, 1992). By increasing the duration of each stage of a graded exercise, it is possible to dissociate ammonia threshold from lactate threshold.

This study aims at identifying a graded exercise protocol to dissociate ammonia threshold from lactate threshold. Ammonia threshold can be a new parameter to be applied in sport science. At present, prolonged submaximal training is prescribed at a certain percentage of the lactate threshold. As the intensity was not identified directly from physiological findings, errors are more likely to occur. According to the characteristics of exercise ammonia, it is speculated that ammonia threshold will be a better reference for prescribing prolonged submaximal training.

Method

Five testing protocols were used in the study. They were 6 x 5 min (3 min rest between sets), 5 x 10 min (5 min rest between sets), 4 x 15 min (8 min between sets), 10 x 4 min (continuous) and 6 x 8 min (continuous). Six active and healthy subjects were asked to exercise on Monark 829 cycle ergometer. Blood lactate (YSI Sports 1500, USA) and blood ammonia (Ammonia Checker II, Japan) were measured at the end of each stage. Heart rate (Polar Sports Tester, Finland) is continuously monitored during the exercise. Onset of blood lactate accumulation and onset of blood ammonia accumulation were used to define lactate threshold and ammonia threshold respectively.

Results

Testing Protocol	**Lactate threshold (% VO2max)**	**Ammonia threshold (% VO2max)**
5min x 6	47.0±8.2	53.7±11.2
10min x 5	43.2±7.4	46.5±8.8
15min x 4	43.0±8.7	50.0±7.2
20min x 4	36.1	---
4min x 10	59.7±1.2*	66.5±4.6*
8min x 6	52.2±7.3	52.5±8.9

* Significant difference between ammonia threshold and lactate threshold was found when 4 min x 10 (continuous) testing protocol was used.

Conclusion

The testing protocol of 4 min x 10 (continuous) was identified to be able to dissociate ammonia threshold from lactate threshold. It is speculated that ammonia threshold will be a better reference for prescribing prolonged submaximal training than lactate threshold.

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