Plasma ammonia response to sprint swimming

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**Background.** To study the plasma ammonia response after sprint crawl swimming.
**Methods.** Nine sprinters (S) and ten non-sprinters (NS) completed a 15-, a 25- and a 50-m crawl at maximal intensity with a 10-min and a 15-min resting period in between. Capillary blood samples were collected before and at regular intervals after each effort for plasma ammonia determination.

**Results.** Ammonia kinetics differed among distances, but not between groups, with peak values (observed 2-8 min postexercise) being higher after 50 m as compared to shorter distances. Significant differences between S and NS were found in peak ammonia after 50 m (124.5±58.2 vs 98.7±63 μmol L⁻¹) and in the change of ammonia relative to swim time (ΔNH₃/Δt) after 25 m (2.66±1.87 vs 1.49±0.84 μmol L⁻¹ s⁻¹) and 50 m (1.87±1.33 vs 1.01±0.49 μmol L⁻¹ s⁻¹). ΔNH₃/Δt was highest after 15 m (3.33±2.53 in S, 3.92±1.67 μmol L⁻¹ s⁻¹ in NS).

**Conclusions.** These differences in the plasma ammonia response to sprint swimming according to duration and athlete seem to be connected to distinctions in muscle fiber profile and energy providing processes.

**Key words:** Ammonia - Exercise physiology - Adenylate metabolism - Swimming.

Plasma ammonia concentration has been known to increase after physical work since 1927.¹² Deamination of adenosine monophosphate (AMP) and branched-chain amino acids have been identified as possible sources of this increased ammonia production.³⁴ The former is generally thought to be the prime contributor to ammonia production during short intense exercise through activation of adenylate deaminase whose activity has been found to be higher in fast-twitch as compared to slow-twitch muscle fibers of rat and human.⁵⁸

The 50-m crawl became an official event in international competition in 1986.⁹ The best male competitors complete the race in 22-23 s. Since muscle biopsies of crawl sprinters have revealed a higher percentage of fast-twitch fibers as compared to middle- or long-distance swimmers,¹⁰⁻¹² it can be presumed that higher plasma ammonia concentrations would be found in sprinters than in non-sprinters.

There are no published data on plasma ammonia changes after sprint swimming. It was the purpose of this study to measure changes in the plasma ammonia concentration after intense short-term crawl bouts and to investigate differences between sprinters and non-sprinters.

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TABLE I.—Characteristics of the subjects (mean±SD).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sprinters (n=9)</th>
<th>Non-sprinters (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>22.6±4.0</td>
<td>21.3±3.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>191.0±8.0</td>
<td>183.5±6.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>85.7±8.6</td>
<td>78.9±7.3</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>12.7±1.4</td>
<td>12.2±1.3</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>75.4±7.4</td>
<td>68.2±6.0</td>
</tr>
</tbody>
</table>

*1: Significantly different from sprinters (p<0.05).

TABLE II.—Swim time and velocity of sprinters and non-sprinters at each crawl bout (mean ±SD).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sprinters (n=9)</th>
<th>Non-sprinters (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 m</td>
<td>6.06±0.22</td>
<td>6.47±0.30</td>
</tr>
<tr>
<td>25 m</td>
<td>11.48±0.32</td>
<td>12.31±0.46*</td>
</tr>
<tr>
<td>50 m</td>
<td>25.43±0.92</td>
<td>27.4±1.14*</td>
</tr>
<tr>
<td>Velocity (ms⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 m</td>
<td>2.48±0.09</td>
<td>2.33±0.12*</td>
</tr>
<tr>
<td>25 m</td>
<td>2.18±0.06</td>
<td>2.04±0.08*</td>
</tr>
<tr>
<td>50 m</td>
<td>1.97±0.07</td>
<td>1.83±0.07*</td>
</tr>
</tbody>
</table>

*1: Significantly different from sprinters (p<0.001).

Materials and methods

Subjects

Nineteen club swimmers were included in this study. Nine participated regularly in 50- and 100-m events and were characterised as sprinters (S), whereas ten participated in 200-m or longer lasting events and were characterised as non-sprinters (NS). Their characteristics are listed in Table I. Body fat was estimated from skinfold measurements. Prior to testing every subject was informed about the test procedure and gave written consent.

Test procedure

Each participant completed a 15-m, a 25-m and a 50-m maximal crawl bout by starting from the block. There was a 10-min rest period between the 15-m and 25-m bouts and a 15-min rest period between the 25-m and 50-m bout. Total swim time of each bout and split times at 10, 15, 20 and 25 m (where applicable) were measured by video recording. The split times were determined in order to examine whether internal meters were swum at the same velocity in all three bouts. The same set of crawl bouts was repeated one week later and the fastest of the two sets was analysed for each participant.

Ammonia determination

Blood samples (150 µL) were collected from a hyperhaemised earlobe into a lithium heparin containing monoject samplette (Sherwood, St. Louis, MO) immediately before the beginning and immediately after the end of each crawl bout, as well as 2, 4, 6 and 8 min after the 15-m bout, 2, 4, 6, 8 and 12 min after the 25-m bout and 2, 4, 6, 8, 12, 15 and 20 min after the 50-m bout. The samples were immediately cooled in ice water and centrifuged at 11000×g within 30 min. Plasma was removed and frozen at -20°C within five hours from the time when blood was obtained. On the following day ammonia was measured in a COBAS BIO Analyzer (Roche, Nutley, NJ) based on the enzymatic method of Da Fonseca-Wollheim, as adapted to capillary blood by Fischer et al. A test kit from Boehringer Mannheim (cat. no. 125857) was used.

Statistical analysis

Significant differences between means were estimated with Mann-Whitney “U”-test and with Newman-Keuls test after initial analysis of variance.

Results

Significant differences in swim times and velocities were detected between S and NS with the exception of the swim time at 15 m (Table II). No differences were found among the 10-m split times of each bout, among the time of the first bout and the 15-m split times of the second and third bouts or between the 20-m split times of the second and third bouts. The plasma ammonia kinetics after each swim bout are presented in Figure 1. Peak values occurred within 2-8 min. Because of big standard deviations in S no significant differences were found between the groups, but the kinetics differed significantly (p<0.01) between the 15- and 50-m bouts as well as between the 25- and 50-m bouts.

The peak ammonia concentration increased with distance (Fig. 2) and differed significantly between 15 and 25 m (p<0.05), between 15 and 50 m (p<0.01) as well as between 25 and 50 m (p<0.01). The differ-
ence between the groups was significant (p<0.01) only after the 50-m bout. Values of S and NS were, respectively, 74.3±17.1 and 75.2±20.1 μmol L⁻¹ after the 15-m bout, 90.4±12.7 and 83.2±10.6 μmol L⁻¹ after the 25-m bout, and 124.5±58.2 and 98.7±6.3 μmol L⁻¹ after the 50-m bout.

Figure 3 presents the change in ammonia concentration, from pre-exercise to peak value, relative to swim time (ΔNH₃/Δt) for each bout. With increasing distance, ΔNH₃/Δt decreased significantly (p<0.001). The difference between the groups was not significant at 15 m (3.33±2.53 in S; 3.92±1.67 μmol L⁻¹ s⁻¹ in NS), but was significant at 25 m (2.66±1.87 in S vs 1.49±0.84 μmol L⁻¹ s⁻¹ in NS; p<0.01) and at 50 m (1.87±1.33 in S vs 1.01±0.49 μmol L⁻¹ s⁻¹ in NS; p<0.01). ΔNH₃/Δt at 25 and 50 m was nearly twice as high in S as in NS.

**Discussion and conclusions**

This study examined the plasma ammonia response after swimming bouts of 6-30 s. Mean peak values
ranging from 74 to 125 μmol L⁻¹, found between the 2nd and 8th minute postexercise, are similar to those reported by Schneider et al.,16 Hageloch et al. 17 and Snow et al. 18 who measured concentrations of 70-120 μmol L⁻¹ between the 3rd and 10th minute after a track or bicycle test.

It is well accepted that the increase in ammonia after short-term intense exercise derives from the first branch of the purine nucleotide cycle catalyzed by adenylate deaminase.19 Factors known to activate the enzyme include ADP and AMP,20 as well as the hydrogen ion.21 Differences in adenylate deaminase between fiber types were presumed by Parnas and Mozolowski,1 who reported a higher ammonia production in fast white muscle of pigeons, and were demonstrated by Meyer and Terjung 6 in rat and by Dudley et al. 8 in human.

It has been shown that sprint swimmers possess a higher percentage of type II muscle fibers.10 11 12 24 These reports can explain our own findings of significantly higher swimming velocities over all distances, peak ammonia concentration after 50 m and ΔNH₄/Δt at 25 and 50 m exhibited by S as compared to NS.

Energy during the first seconds of intense exercise is provided mainly by creatine phosphate degradation accompanied by ammonia accumulation.25 The increase in ADP and AMP due to the high ATP turnover activates adenylate deaminase.6 8 19 27 28 Application of the metabolism simulation model of Mader et al. 29 on a 15-m, 25-m and 50-m crawl sprint of male sprinters and non-sprinters with characteristics similar to the subjects of the present study confirmed that ATP turnover dropped with distance in both groups because of the great decrease in creatine phosphate at the very beginning of exercise and the inability of glycolysis to maintain such a high ATP turnover.31 This state of energy provision at the very beginning of intense exercise may be responsible for the significantly higher ΔNH₄/Δt after 6 s of a (15-m) crawl sprint as compared to 11-12 s (25 m) or 25-27 s (50 m).

Assuming that changes in plasma ammonia concentration reflect ammonia production in muscle, the above finding indicates that the rate of ammonia production is higher with shorter all-out bouts. The fast increase in ammonia may be due to maintain the ATP-regenerating process via the reaction catalyzed by adenylate kinase 20 27 32 during the first seconds of intense exercise.

In conclusion, we have found higher peak plasma ammonia concentrations (i) after 50 m of sprint swimming as compared to shorter distances and (ii) in sprinters as compared to non-sprinters. Additionally, ΔNH₄/Δt was highest after 15 m and lowest after 50 m of sprint swimming and higher in sprinters than in non-sprinters after 25 and 30 m. Our data indicate that differences in the plasma ammonia response to sprint swimming according to athlete and distance can be explained by distinctions in muscle fiber profile and energy providing processes.

References