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Practical analysis of the metabolic response to a resistance training session in male and female sprinters

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Abstract
Introduction. In modern sport, training individualization and detailed analysis of specific patterns of biochemical indices under certain exercises and training sessions is become more and more crucial. Aim of Study. This study aimed to concurrently evaluate the lactate and blood ammonia response during resistance training in four elite sprinters (two men and two women). Material and Methods. Blood samples were taken from the fingertip before and after the warm-up, after each exercise (power cleans, squat jumps, quarter squats and lunges), and at the 10th and 20th min of the cool-down. Results. In male athletes, maximum lactate concentrations were achieved after the power clean exercise, while peak blood ammonia concentrations after squat jumps. In female athletes, peak blood ammonia and lactate concentrations were noted more individually. The course of changes in lactate concentrations was very diverse in each athlete. The ammonia concentration in response to the performed exercises was much more consistent, however still different between individual athletes. Conclusions. A practical analysis of the metabolic response to different exercises in a resistance training session, using lactate and ammonia concentrations, offers vital information that can help coaches better understand internal training load experienced by the athlete and to better adjust the prescribed loads and rest periods to the training targets in future training sessions.

KEYWORDS: ammonia, lactate, power, strength, elite athletes.

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Introduction

In modern sport, the biochemical monitoring of athletes is becoming more and more crucial in achieving the highest level of sports proficiency. With the use of wisely selected biochemical indices, coaches can, for example, receive detailed information about an athlete's metabolic response to different types of training and/or exercises. In a typical 100 m track sprint effort, the contribution of the anaerobic energy systems is about 90% concerning the lactate/phosphate creatine ratio, or 75-79% when calculated from the accumulated oxygen deficit [2, 18]. When, due to increased energy demand, ATP consumption exceeds its production and ADP concentration rises, adenylate kinase redirects the reaction towards the synthesis of ATP (2ADP = ATP + + AMP) and inosine monophosphate (IMP) to maintain the decreasing energy potential. This is why changes in adenosine monophosphate (AMP), and its direct metabolite – ammonia (NH_3), may reflect cellular energy metabolism more adequately than solely ATP or ADP concentration [5, 24]. In prolonged efforts, anaerobic glycolysis supports energy coverage, which is reflected by increased lactate concentration [4]. It was shown that the knowledge about actual levels of ATP breakdown and its restoration is based mainly on blood ammonia concentration, while the concentration of lactate – indicating the rate of anaerobic glycolysis – specifies the currently predominant ATP resynthesis pathway [11, 21]. Therefore, by concurrently measuring ammonia and lactate concentrations, which accumulate in blood in specific patterns [4, 8, 20, 23], coaches can precisely assess an athlete's response to different exercise types in terms of the magnitude of ATP degradation and the way it is restored [9, 20, 23].

The metabolic reaction to running exercise of different lengths (duration) and intensity, either in laboratory conditions [6, 9, 12, 14, 15, 16] or during real-time training [11, 21], was were earlier widely discussed. The shorter the distance (time) and the higher the intensity the more pronounced differences occur in the concentrations of blood ammonia and lactate [10, 15]. One hundred meters and longer distances cause a gradual and parallel increase in blood ammonia and lactate concentrations [5, 11]. Concerning the sex differences in metabolic response to exercise, it was previously shown that in most training tasks, irrespective of their character and intensity, blood ammonia and lactate concentrations are higher in men than in women [1, 3, 4, 7, 13, 22].

It is more difficult to anticipate the metabolic response to different resistance training exercises – an integral part of a sprinter's training plan. In each training session, there are exercise tasks of potentially opposing metabolic characteristics, one more strength-, power- and hypertrophy-oriented, others more focused on muscular endurance. Typically, higher blood lactate concentrations were observed after a session of moderate-intensity, a higher number of repetitions and decreased rest time between sets [14, 16]. It is of great importance to analyze in detail the patterns of blood ammonia and lactate changes to specific resistance exercises during real training sessions. Thus, this study aimed to concurrently evaluate the lactate and blood ammonia response in real-time resistance training of four elite sprinters.

Methods

Subjects

The study included two male and two female sprinters competing in the 100-m and 4 × 100-m relays at the national and international levels. The age and the competitive sports training background was 32 and 15 years, 23 and 5 years for males and 28 and 14 years, 25 and 11 years for female athletes. The study was approved by the Local Bioethical Committee at the Poznan University of Medical Sciences, Poland. The participants were informed of the procedures and gave their written consent prior to their inclusion in the study.

Procedures and measurements

The measurements were performed on the first day of a training camp. The training session started at 10 am and comprised of the exercises presented in Table 1. The warm-up before the strength training session consisted of jogging (10 min), dynamic stretching (15 min), and strength training preparation (15 min).

Table 1. Content of the main part of the strength training session

Exercise	Recovery time
Exercise 1 – Power cleans	5 min between exercises 1-4
Set 1: 6 × 60% 1RM	3 min between sets 1-2
Set 2: 5 × 80% 1RM	
Set 3: 2 × 90% 1RM	4 min between sets 2-3 and 3-4
Set 4: 2 × 95% 1RM	
Exercise 2 – Squat jumps	
Sets 1-3: 9 × 30% 1RM	4 min between sets 1-3
Exercise 3 – Quarter squats	
Set 1: 6 × 140 (75% 1RM)	4 min between sets 1-2 and 2-3
Set 2: 5 × 150 (80% 1RM)	
Set 3: 4 × 160 (85% 1RM)	5 min between sets 3-4 and 4-5
Set 4: 4 × 170 (90% 1RM)	
Set 5: 4 × 180 (95% 1RM)	
Exercise 4 – Lunges	
Sets 1-2: 10 × 35% 1RM (5 × right leg, 5 × left leg)	4 min between sets 1-2

Note: 1RM – one-repetition maximum in each athlete

Blood ammonia, lactate, and HR measurement

To analyze blood ammonia and lactate concentrations during the training session, blood samples were taken from the fingertip before and after the warm-up, 3 (or 2) min after each exercise set/repetition performed in the main part of the workout, and at the 10th and 20th min of the cool-down. To determine the blood ammonia concentration, 20 μl of whole blood was applied to a test strip and analyzed with a PocketChem BA (Arkray, Japan). To measure lactate accumulation, a Biosen C-line (EKF Diagnostics, Germany) was used. In brief, 20 μl of whole blood was drawn into a prefilled micro test-tube using a capillary. The L-lactate contained in the sample was enzymatically converted to pyruvate and hydrogen peroxide, which was detected by the electrode.

Results

The comparison of lactate and blood ammonia concentrations in both male and female sprinters during the training session is presented in Figure 1. Figures 2 and 3 separately show the individual courses of lactate and ammonia concentrations, respectively.

In male athletes, maximum lactate concentrations were achieved earlier than peak blood ammonia concentrations. After 20 min of recovery, blood ammonia concentrations

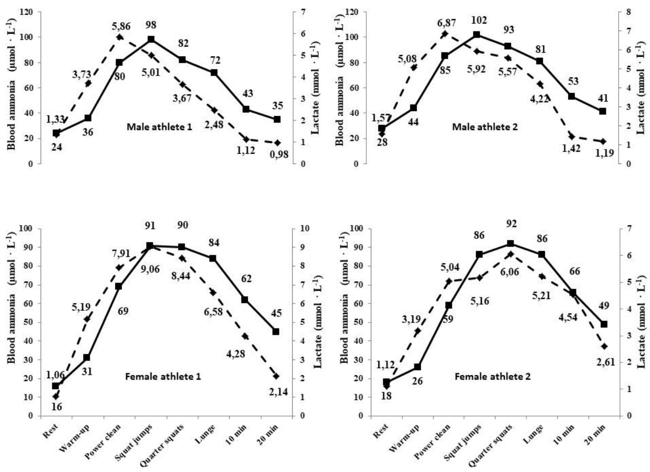

Figure 1. Blood ammonia (solid line) and lactate (dashed line) concentrations: comparison in each female and male athlete

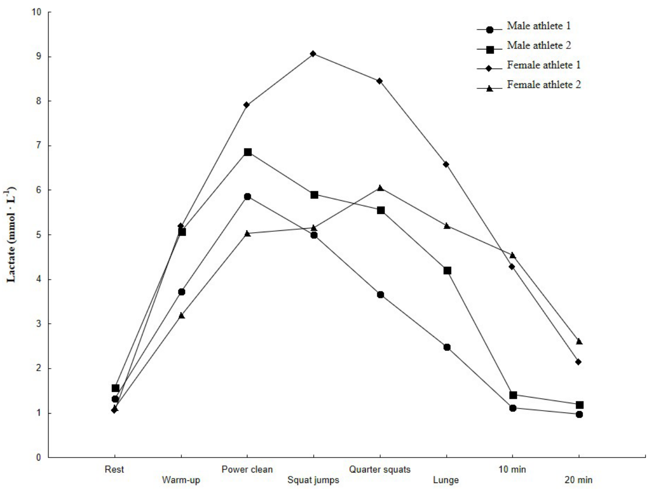

Figure 2. Lactate concentrations in all male and female sprinters during the strength training session

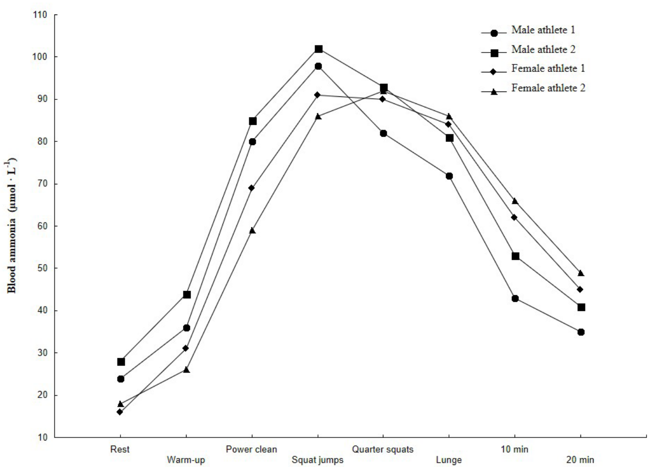

Figure 3. Blood ammonia concentrations in all male and female sprinters during the strength training session

but not lactate concentrations achieved resting values. In female athlete 1, peak blood ammonia and lactate concentrations were achieved at the same stage of the session 1 and the course of both biomarkers during the training workout was similar, too. In female athlete 2, the curve of lactate concentration was "irregular" and different from that of blood ammonia concentration. In both female athletes, after 20 min of recovery, blood ammonia and lactate concentrations did not achieve the resting values.

The values of lactate concentrations (Figure 2) were different in each sprinter. The highest concentrations were obtained by female athlete 2 and the lowest by male athlete 1. Also, peak concentrations were obtained in different phases of the training session. In the case of blood ammonia concentration, the differences between athletes were much less pronounced and the pattern of changes was similar. Male athletes were characterized by lower values at rest, higher peak concentrations, and lower values after 20 min of recovery compared to female sprinters.

Discussion

The aim of this study was to concurrently evaluate the lactate and blood ammonia levels during resistance training of four elite sprinters.

Blood ammonia concentration

Blood ammonia concentrations increased from rest until the squat jump and quarter squat exercise and then decreased up to 20 min after the workout. Blood ammonia concentrations were highest in both the squat jump exercise (highest) and quarter squat exercise (second highest) for all athletes (both male and female athletes). Since both squat jumps and quarter squats were performed for a higher number of repetitions, a high exertion (near muscular failure), and with a high level of intent (as fast as possible), this can explain the higher blood ammonia concentration. This is in line with Sánchez-Medina and González-Badillo [17] who measured blood ammonia concentration in resistance exercise leading to failure or not and concluded that sets taken closer to failure and with a larger number of repetitions lead to greater ammonia concentrations. Since blood ammonia concentration represents cellular energetic stress through AMP deamination [19], it is clear that higher levels of effort and exertion will lead to higher concentrations. Additionally, male sprinters achieved higher blood ammonia concentrations than female sprinters, possibly due to greater muscle mass, a greater percentage of fast-twitch muscle fibers (containing more AMP deaminase which leads to greater AMP deamination), and greater levels of strength leading to greater recruitment of muscle mass during resistance exercise (activating more fast-twitch muscle fibers during each repetition) [22]. The pattern of recovery also shows that male athletes achieved lower blood ammonia concentrations after quarter squats up until 20 min after the training session. After quarter squats, lunges were rather an accessory exercise and were not performed with maximum intent and exertion and therefore blood ammonia concentrations were lower. Although blood ammonia concentration courses were similar in all athletes, absolute values were different indicating that each athlete may have an individual metabolic response which is determined by an athlete's specific maximal exertion (to failure) or effort (highest intent) during exercise.

Blood lactate concentration

Blood lactate concentrations increased from rest until the power clean exercise and then varied depending on the athlete. For female athlete 1, lactate concentration increased greatly, while for female athlete 2, it increased slightly. For both male athletes, lactate concentration decreased with each subsequent exercise from the power clean. For the female athletes, concentrations varied in each exercise. Lactate concentration is an indicator of anaerobic glycolysis contribution during exercise [4]. Lactate concentration level, therefore, may indicate the level of anaerobic glycolysis utilization in each exercise, and individually for each athlete. The power clean is a complex movement and requires much coordination compared to the squat jump and quarter squat exercises, and therefore could trigger activation of more muscle groups causing greater lactate concentration. Interestingly, there were no visible patterns observed between male and female athletes regarding lactate concentration (male sprinters did not have higher lactate concentrations or vice versa).

If the goal of a strength training session is to increase maximal strength or power, then it would be of interest to avoid high lactate concentrations, which indirectly indicate neuromuscular fatigue [17]. Therefore, measuring lactate concentration in between sets can help coaches to monitor signs of muscle fatigue and optimally prescribe training parameters, like the number of repetitions or rest breaks, for each athlete individually to adequately target the training session goal (hypertrophy, strength, power). It is important to note, however, that lactate levels during a resistance training session are not comparable to ones achieved during a typical sprint training session. Blood lactate concentrations during a speed-endurance or special endurance session [5, 10, 11, 12] are much higher compared to those obtained in this study.

The limitation of this study is that we did not analyze ammonia and lactate concentrations in differently scheduled strength-oriented exercises. In the future, it would be interesting to compare the metabolic response of the same sprinters to differently scheduled resistance training sessions.

Practical applications

Measuring the metabolic response in sprinters using lactate and ammonia concentrations during a resistance training session offers vital information that can help coaches better understand the internal training load experienced by the athlete. Both lactate and ammonia concentrations can be used to monitor an athlete's response to resistance training exercises. Blood ammonia concentrations can be used to determine exertion and effort level after a set or after an exercise is completed. Blood lactate concentrations can help determine anaerobic glycolysis contribution after completion of a set or number of sets. Both ammonia and lactate can be used to determine individual athlete metabolic response, and help to determine if the resistance training session goal (hypertrophy, strength, power) is being targeted and if not, to individually adjust training parameters. In the future, it would be of interest to analyze more deeply the differences in metabolic response to strength training sessions of diverse training goals (hypertrophy, strength, power, endurance).

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