Effect of Active and Passive Recovery on Blood Lactate and Performance During Simulated Competition in High Level Gymnasts

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Catalogue Data

Key words: oxidation, removal, heart rate
Mots clés: oxydation, élimination, fréquence cardiaque

Abstract/Résumé
The purpose of this study was to investigate the effect of two recovery strategies between men’s gymnastics events on blood lactate removal (BL) and performance as rated by expert “blind” judges. Twelve male gymnasts (21.8 ± 2.4 years) participated. The sessions were composed of routine performances in the six Olympic events, which were separated by 10 min of recovery. All gymnasts performed two recovery protocols between events on separate days: Rest protocol, 10 min rest in a sitting position; Combined protocol, 5 min rest and 5 min self-selected active recovery. Three blood samples were taken at 2, 5, and 10 min following each event. Gymnasts produced moderate values of BL following each of the six events (2.2 to 11.6 mmol·L⁻¹). There was moderate variability in BL values between events that could not be accounted for by the athlete’s event performance. Gymnasts showed higher BL concentration (p > .05) and significantly (p < .05) higher scoring performances (as rated by a panel of certified judges) when they used a combined recovery between gymnastics events rather than a passive recovery (ΔBL = 40.51% vs. 28.76% of maximal BL, p < .05, and total score = 47.28 ± 6.82 vs. 38.39 ± 7.55, p < .05, respectively).

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Le but de cette étude est de déterminer l’effet de deux modes de récupération intercalées entre les agrès de gymnastique masculine sur l’élimination de l’acide lactique sanguin (BL) et la performance évaluée par des juges experts “neutres.” Douze gymnastes masculins (21.8 ± 2.4 ans) ont réalisé deux protocoles à des intervalles séparés: Protocole repos, 10 min de récupération passive; Protocole combiné, 5 min de repos suivies de 5 min de récupération active libre. La séance de gymnastique se compose de six épreuves (routines) Olympiques intercalées de 10 minutes de récupération. Trois prélèvements sanguins sont effectués 2, 5, et 10 minutes après l’arrêt de chaque exercice. Les gymnastes produisent des valeurs de lactatémie modérées (de 2.2 à 11.6 mmol·L⁻¹), mais avec une grande variabilité entre les agrès. La lactatémie était plus élevée (p > .05) mais la performance (appréciée par des juges experts) était significativement supérieure (p < .05) lors du protocole de récupération combiné que celle provoquée par le protocole de récupération passive (ΔBL = 40.51% vs. 28.76%, p < .05, de la lactatémie maximale, et les scores totales sont de 47.28 ± 6.82 vs. 38.39 ± 7.55, p < .05, respectivement).

Introduction

Many studies have shown a positive effect of active recovery on blood lactate concentration (BL) reduction during repeated standardized exercise (Gaesser and Brooks, 1979; Stamford et al., 1981; Weltman et al., 1979). Researchers have confirmed that the rate of BL disappearance is greater during continuous aerobic work than during passive or a combination of high and low intensity work (Ahmaïdi et al., 1996; Bogdanis et al., 1994; 1995; 1996; Bond et al., 1991; Bonen and Belcastro, 1976; 1977; Bonen et al., 1978; Cazorla et al., 1987; Davies et al., 1970; Dodd et al., 1984; Gisolfi et al., 1966; Graham et al., 1976; Hermansen and Stensvold, 1972, Hermansen et al., 1975; Hubbard, 1973; Karlsson et al., 1975; Signorile et al., 1993; Stamford et al., 1981; Tesch and Wright, 1983; Weltman et al., 1977a; 1977b; 1979). Researchers have suggested different work intensities during the recovery period as optimal for lactate removal (30 to 80% of VO₂max) (Ahmaïdi et al., 1996; Bogdanis et al., 1994; 1995; 1996; Bond et al., 1991; Bonen and Belcastro, 1976; Cazorla et al., 1987). All the cited investigations have used laboratory tests such as Wingate or treadmill tests. A limitation of laboratory tests is the fact that subjects had to perform movements which were different from sport-specific skills. Only a few investigations have shown similar results during sport-specific situations (Cazorla et al., 1987).

Long recovery periods (15 to 40 min) have been used during many earlier investigations, except those of Signorile et al. (1993), Bogdanis et al. (1994; 1995; 1996), and Ahmaïdi et al. (1996). During long recovery periods, phosphocreatine (PCr) resynthesis and pH equilibration can be fully accomplished. Lactate elimination can be largely completed during extended rest periods as well. Thus the relative contribution of active recovery is overwhelmed by natural recovery processes that can easily take place during extended rest periods. However, researchers have confirmed that active recovery is beneficial after highly intense anaerobic activities. One objective of this study was to investigate the effect of short active recovery on BL removal after brief gymnastics efforts. Therefore, this study attempted to provide more detailed information regarding short intense efforts and relatively short recovery periods.
Only two studies have explored the effect of active recovery on high intensity performances with relatively short recovery periods: Ahmaïdi et al. (1996) and Bogdanis et al. (1996). These authors used force-velocity and Wingate tests, respectively. In our study, the effect of two kinds of recovery was examined during gymnastics practice. Gymnastics performance can provide a useful model for such investigations due to the anaerobic nature of the performances, the natural and typical recovery periods between events, and the use of sport-specific skills.

Considerable work with gymnasts has been conducted in the morphological, behavioral, and biomechanical areas; however, there is a paucity of information on the physiology of gymnastics (Jemni et al., 2001). One ubiquitous aspect of gymnastics training and performance is the intermittent nature of the efforts. Because gymnastics involves competing on several events interspersed with rest periods, it is important to assess the optimal means of recovery so that the gymnast can begin each event without undue fatigue. Fatigue in gymnastics is more than a simple physiological problem. Fatigue-related falls in gymnastics often lead to injury (Kolt and Kirkby, 1999; Sands, 2000a; Tesch, 1980; Tesch et al., 1978).

Coaches pursue varying training objectives based on the particular period of training. Gymnasts, much like sprinters, perform in both an aerobic and an anaerobic condition (Jemni, 2000; Sands, 1998). During intense sessions, gymnasts must perform routines while fatigued. They are often expected to find the best compromise between technical effectiveness, safety, and high-intensity effort.

During the competitive phase of the season, gymnasts usually repeat their six events several times per practice session. Lechevalier et al. (1999) found high BL values in young high-level gymnasts performing their routines twice. These types of practices are similar to interval training, due to the intermittent and intense activities involved. It is generally observed that few gymnastics coaches use active recovery between routine repetitions.

The purpose of this study was to compare the effects of combined and passive recovery on BL concentration and performance in six men’s gymnastics competitive events: floor exercise, pommel horse, still rings, vault, parallel bars, and horizontal bar. By comparing the recovery methods during gymnastics sessions, we hoped to determine guidelines that could help gymnasts reduce their BL between competitive events.

**Methods**

**SUBJECTS**

Twelve male gymnast volunteers (21.8 ± 2.4 yrs) participated in the study. The gymnasts competed at the national (n = 9) or international level (French National Team members, n = 3). All subjects were informed of the nature and possible inconveniences associated with the experiment. All gave informed written consent prior to participation, and an ethical acceptability certificate was obtained from the research ethics committee (Comité Consultatif de Protection des Personnes dans la Recherche Biomédicale. Bicêtre, France).

Gymnasts were measured for body mass, height, and skinfolds (biceps, triceps, subscapular, suprailiac) using a Holtain LTD caliper (Crymych, Pembrokeshire, UK). Percentage of body fat was calculated according to Durnin and Rahaman (1967). Descriptive physical information is shown in Table 1. A tread-
mill test was used to measure the gymnasts’ VO₂ max in a secondary study (protocol published by Toraa and Friemel, 2000). Individual anaerobic thresholds (OBLA) (Sjödin and Jacobs, 1981) and corresponding heart rates (HR) were determined.

**PROTOCOL**

The tests involved simulations of gymnastics competitions as described in an earlier study (Jemni et al., 2000). Judges, timekeepers, physicians, coaches, and spectators attended the competitive sessions to simulate competitive conditions. Sessions began with 15 min of self-selected general warm-up followed by a specific warm-up of 30 min (Figure 1). A 10-min recovery period was also provided at the end of the initial warm-up. Each session was composed of six events/apparatuses. The gymnasts passed from one apparatus to another in accordance with Olympic competition rotation order (International Gymnastics Federation, 1997). The competition began with floor exercise, followed by pommel horse, rings, vaulting, parallel bars, and horizontal bar. A 3-min specific warm-up time was provided before each event as per International Gymnastics Federation rules. Two expert national judges judged each gymnast’s performance. These same judges were used for all evaluations and had no instruction about the benefit of the protocols. All gymnasts performed the same optional routines at each simulated competition. They were instructed to consider the competitions real and to perform at their best. The gymnasts were not informed about the potential benefits of passive or active recovery.

![Figure 1](https://via.placeholder.com/150)

**Figure 1.** Protocol session.
Each of the six event performances (routines) was separated by 10 min of recovery. Recovery time in official international competition is similar. Three blood samples (25 µl) were taken from a hyperaemic earlobe 2, 5, and 10 min after each event and added to buffer-diluting solution (pH 7.2) manufactured especially for the Microzym L-analyzer (Biotrade Laboratories, Toulouse, France). Tubes could be stored at room temperature for no longer than 2 weeks.

The determination of BL was performed by a micro-enzymatic method with a Microzym L-analyzer (Setric Genie Industriel, Neuberg, Germany) one day after the drawing of blood.

Each gymnast was controlled by a timekeeper who monitored and recorded effort time at each event and told the attending physicians when to sample blood from the gymnast. The heart rates of the gymnasts were continuously monitored by a Bauman and Haldi Sport-tester BHL 6000 which calculated minimal, maximal, and average HR for the duration of each event routine or recovery activity. Gymnasts were required to warm up for the next event just after having their blood samples taken at the 10th recovery minute (3 min specific warm-up).

Each gymnast undertook two recovery protocols. Protocols were randomized so that during a given session the gymnasts performed passive or combined recovery as follows:

- Rest protocol: During each 10-min recovery period of the competition session, gymnasts rested in a sitting position.
- Combined protocol: Gymnasts rested during the first 5 min of the recovery period and then undertook 5 min of self-selected active recovery immediately following the 5th min blood sample.

The gymnasts typically did light running separated by handstands, single somersault movements, and swings to handstand on the parallel bars. Heart rate was used to monitor and control activity during recovery periods. Gymnasts were instructed to maintain a modestly high HR value (~145 b·min⁻¹), but not to exceed their individual anaerobic threshold values (170 ± 8 b·min⁻¹) that had been determined earlier (Stamford et al., 1981; Weltman et al., 1979).

Testing was conducted in a gymnasium over a 5-week period. The simulated competitions were separated by 2 weeks for each gymnast. Four gymnasts were tested at each session. National level gymnasts were instructed not to train the day before the test. International level gymnasts were instructed not to train during the preceding half-day before the test. No gymnast was accustomed to using active recovery between performances.

STATISTICAL ANALYSES

Means and standard deviations were calculated for all data. Comparisons between event HR values as well as BL data were made using one-way analysis of variance (ANOVA) with repeated measures on the second dimension. When significant main effects were found (p < .05), a post hoc Newman-Keuls multiple comparison test was applied to determine the cell-to-cell differences. Statistical analyses were performed using Statistica software (StatSoft, Maison-Alfort, France).
Results

Activity times measured at each event are shown in Figure 1. The shortest event was vaulting (5.57 ± 0.77 sec) and the longest event was floor exercise (57.96 ± 2.99 sec). Performance on the pommel horse, rings, parallel bars, and horizontal bar lasted approximately 35 seconds on average.

BLOOD LACTATE

Blood lactate information is shown in Figures 2 and 3. Maximal BL values were found after 2 min at each event. Maximal event values across both protocols were between 2.67 ± 0.43 and 6.37 ± 1.65 mmol·L⁻¹. Considerable variability was also observed among individual BL<sub>max</sub> values (from 2.21 mmol·L⁻¹ in the vault event to 11.64 mmol·L⁻¹ in the floor exercise event).

Mean BL<sub>max</sub> accumulation across all six events during the combined recovery protocol was higher, but not statistically different (p > .05), than that of the rest protocol (5.48 ± 1.91 vs. 3.79 ± 1.09 mmol·L⁻¹ respectively). Warm-up BL<sub>max</sub> value of the combined recovery protocol was significantly higher than that of the rest protocol. This may explain the high value obtained from the floor exercise and the following events. Meanwhile, the increases in BL from the end of the warm-up to the end of the first event (floor exercise) were not significantly different (p > .05). The same results were found by comparing the other increases in BL between events.

The highest mean BL<sub>max</sub> value obtained across both simulated competitions was observed during the floor exercise (5.57 ± 2.35 mmol·L⁻¹). The lowest mean

![Figure 2](image-url)

**Figure 2.** Blood lactate evolution during the rest-recovery protocol. ▼ (ΔBL) Represents the difference in BL values between peak value and that obtained after 10-min recovery; □ = Significantly different vs. the other event averages, p < .05.
value was obtained on the vaulting event (3.28 ± 1.28 mmol·L⁻¹). Between these two values were, in decreasing order, those of still rings, pommel horse, horizontal bar, and parallel bars (5.33 ± 1.85; 5.18 ± 1.83; 4.28 ± 1.79; 4.22 ± 1.55 mmol·L⁻¹, respectively).

BLₘₐₓ values varied between events during the same protocol. The highest event value of the rest recovery protocol was floor exercise (Figure 2), which was significantly higher than the other event averages (p < .05). The highest BLₘₐₓ event value observed during the combined recovery protocol was for the still rings (Figure 3). The BLₘₐₓ value for vaulting was significantly lower than it was for the other events during both protocols (p < .05).

At the end of the 10-min recovery periods, BL values were usually higher than the corresponding rest values before each protocol. Thus the recovery between events was generally not complete. The 10-min recovery BL values were considered the starting values for the next apparatus.

As can be seen in Figures 2 and 3, ΔBL indicates the difference in BL values between the peak value and the value obtained after the 10-min recovery period. These differences give an indication of the metabolic recovery after each event.

The combined recovery protocol percentages of ΔBL across all events were significantly greater (p < .05) than that of the rest protocol (40.51% vs. 22.02%). Gymnastics events varied with regard to ΔBL as well. BL concentration during the combined protocol was significantly less (p < .05) than that of the rest protocol during four events: pommel, rings, parallel bars, and horizontal bar (Figure 3).

Figure 3. Blood lactate evolution during the combined-recovery protocol. ▼(ΔBL) Represents the difference in BL values between peak value and that obtained after 10-min recovery; □ = Significantly different vs. the other event averages of the session, p < .05. S = Significantly different vs. Δ of the passive recovery protocol, p < .05.
Mean performance values of each event and protocol performances are shown in Table 2. Combined-recovery protocol performances were significantly improved \((p < .05)\) compared to those of the rest protocol. Total scores were 42.80 ± 6.82 vs. 38.39 ± 7.55, respectively. A statistically significant difference was observed only between floor exercise performances (Table 2). Gymnast performance was significantly correlated with maximal BL only during the combined protocol \((R^2 = 0.68; p < .05)\) (Figure 4). This means that as performance increases, so does BL concentration.

In order to examine the effects of the recovery protocols on performance, we calculated the difference between start value and real score attributed at each event \((\Delta \text{score})\). Gymnastics uses the “start value” as an overall assessment of the difficulty of the skills and combinations in the routine. For example, a gymnast with a higher start value has the potential for a higher score. Of course this assumes that the gymnast with the higher start value performs the more difficult skills as well as, or better than, the gymnast with a lower start value. A gymnast with a higher start value should defeat a gymnast with a lower start value if both perform their skills with the same number and magnitude of performance errors/deductions. The gymnast’s performance, regardless of difficulty, can be separated from skill difficulty by performing the same routine each time and noting the difference in scores (Sands, 2000b).

No statistically significant difference between protocol \(\Delta \text{scores}\) was found. A significant correlation was found only between \(\Delta \text{BL}\) and \(\Delta \text{score}\) of the combined recovery protocol \((r = -0.75; p < .05)\) (Figure 5). This means that the greater the BL disappearance, the closer the gymnast came to reaching the maximum possible score.

**HEART RATE**

Means and standard deviations of heart rates are shown in Table 3. Performances in gymnastics events resulted in high HR values. No statistically significant differ-

<table>
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<tr>
<th>Protocol</th>
<th>Floor</th>
<th>Pommel</th>
<th>Rings</th>
<th>Vault</th>
<th>Parallel</th>
<th>Horiz.</th>
<th>Tot. Score</th>
<th>(\Delta \text{score})</th>
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<tbody>
<tr>
<td>Rest</td>
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<td>5.99</td>
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<td>SD</td>
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<td>1.44</td>
<td>1.03</td>
<td>1.32</td>
<td>1.85</td>
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<tr>
<td>Combined</td>
<td>Mean</td>
<td>7.25*</td>
<td>6.56</td>
<td>6.95</td>
<td>8.39</td>
<td>6.81</td>
<td>6.64</td>
<td>42.80*</td>
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<td></td>
<td>SD</td>
<td>1.15</td>
<td>1.77</td>
<td>1.57</td>
<td>0.61</td>
<td>1.23</td>
<td>1.43</td>
<td>6.82</td>
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* Significantly different, \(p < .05\), between protocols.

**GYMNASTICS PERFORMANCE**

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<td>6.82</td>
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* Significantly different, \(p < .05\), between protocols.
Figure 4. Relationship between score (performance) and maximal blood lactate concentration.

Combined recovery protocol

Rest recovery protocol
Figure 5. Relationship between $\Delta_{\text{score}}$ (performance) and $\Delta_{\text{BL}}$ (BL disappearance).
ence between protocol HR were found except at the 10th minute, which showed a higher HR value during the combined protocol.

Mean vault HR values were significantly less than those of all other events during both protocols. Differences were found between apparatuses, as performance on the horizontal bar resulted in the highest peak HR values during both protocols. Mean HR values during both protocols were $175.78 \pm 6.28 \text{ b} \cdot \text{min}^{-1}$.

After a 10-min recovery period, HR values were usually greater than their resting values.

**Discussion**

The improvement in total performance score of the combined recovery protocol is considerable, as all gymnasts performed the same routines in both protocols. The significant difference between protocol scores, and the significant correlation between $\Delta_{\text{BL}}$ and $\Delta_{\text{score}}$, facilitates the interpretation of the relationship between BL reduction and gymnastics performance. Indeed, $\Delta_{\text{BL}}$ increased while $\Delta_{\text{score}}$ decreased (difference between maximal possible score [i.e., start value] and real score). This means that decreased BL concentrations are linked to better performance. Numerous investigations have reported that lactate removal from the blood (i.e., lower concentration) following exercise is of great importance in improving the subsequent performance, particularly when the exercise is repeated at high intensity (Ahmaïdi et al., 1996; Bogdanis et al., 1994; 1996).

This study revealed an increase in $\text{BL}_{\text{max}}$ concentration accompanied by an increase in performance during the combined protocol (Figure 4).

This finding contrasts with several earlier investigations which suggested that work performance is adversely affected by the elevated lactate (Karlsson et al., 1974; 1975; Klausen et al., 1972). The earlier studies involved one-dimensional consideration of lactate concentrations and assumed that lactate may reduce the rate of muscular glycolysis by inhibiting the activity of glycolytic enzymes. Since these earlier studies, the role of lactate in performance has been modified to indicate that higher levels of lactate may be indicative of higher energy output and

**Table 3** Mean Heart Rate Values in b·min$^{-1}$ at Each Event per Protocol

<table>
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<tr>
<th>Protocol</th>
<th>Peak</th>
<th>Mean</th>
<th>10-min Recovery</th>
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<tbody>
<tr>
<td>Rest</td>
<td>172.81</td>
<td>162.06</td>
<td>98.74</td>
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<tr>
<td></td>
<td>12.69</td>
<td>7.30</td>
<td>2.48</td>
</tr>
<tr>
<td>Combined</td>
<td>175.96</td>
<td>160.80</td>
<td>135.53*</td>
</tr>
<tr>
<td></td>
<td>9.24</td>
<td>6.82</td>
<td>5.86</td>
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</table>

* Significantly different, $p < .05$, compared with the other protocol.
increased intensity of performance, not simply an increased fatigue stimulus (Bar-Or et al., 1980; Olbrecht, 2000). High performance is correlated to high blood and muscle lactate value during intense anaerobic exercise. Indeed, lactate production depends on age, diet, training characteristics, intensity of activities, and level of fitness (Gaesser and Poole, 1988; Gaul et al., 1995; Tolfrey and Armstrong, 1995; Yoshida, 1986). The fact that better performances result in higher BL concentrations may also mean that the athletes are simply using more of their anaerobic fitness and thus producing higher forces, as reflected in their higher BL concentrations.

Blood lactate reflects the combination of anaerobic metabolism in energy production and the rate and amount of lactate clearance (Brooks et al., 1991; Donavan and Brooks, 1983; Duvallet et al., 1987; Foster et al., 1995; Jacobs, 1981; Parra et al., 2000; Stainsby and Brooks, 1990; Stanley et al., 1986; 1988; Yki-Jarvinen et al., 1990). Muscle lactate values are usually higher than blood lactate values, especially when lactates are measured after intense exercise. While it is desirable to determine direct muscle lactate values, Rusko et al. (1986) demonstrated that BL and muscle lactate values are linearly related during progressive exercise until the anaerobic threshold is reached. When efforts exceed this crucial intensity, the relationship between muscle and blood lactate concentrations is no longer linear. While acknowledging this limitation, field studies such as this must strike a balance between sport-specificity, measurement accuracy, and practicality of the measurements. In our study, blood lactate was the parameter that best met these requirements.

Parallel augmentation in BL concentration changes was also detected during the combined recovery protocol (Figure 4). This same phenomenon was observed in sprint swimmers (Cazorla et al., 1987). Carzola and colleagues suggested that high-level swimmers could engage in optimal recovery intensity that allows for optimal lactate removal between sprint swimming bouts. Their finding is supported by our own study.

Diet and nutrition were not controlled during our study, due to logistical problems with subject recruitment. However, BL_max values of the different events were comparable to those found in the recent literature (Goswami and Gupta, 1998; Lechevalier et al., 1999; Montpetit, 1976). Rodríguez et al. (1999) found similar results in women’s routines (2.5, 7.4, 4.3, and 7.9 mmol·L^{-1} in vaulting, uneven bars, balance beam, and floor exercise, respectively). However, the BL_max values were higher than those found by Montgomery and Beaudin (1982) in lower level female gymnasts. Maximal lactate values for gymnasts appear to be higher than those for ice-dancers, whose competitive routines last 4 minutes (Roi et al., 1989).

We conclude that moderate activity during the recovery period maintains an adequate blood flow and may improve lactate oxidation and clearance. Lactate can be converted to glucose and protein. However, lactate oxidation in skeletal muscle is the mechanism most responsible for lactate clearance during exercise (Brooks, 1986; Gaesser and Brooks, 1979; Hermansen et al., 1975; Hermansen and Stensvold, 1972; Hubbard, 1973). The use of isotopic tracers in active and inactive skeletal muscles has demonstrated that lactate is used as a substrate and ultimately is converted to CO_{2} and H_{2}O (Corsi et al., 1972; Graham, 1978; Granata et al., 1976; Jorfeldt, 1970; Stanley et al., 1986; Yoshida and Watari, 1993). Lac-
Lactate, which is produced primarily as a result of Type IIb fiber recruitment, is transported to Type I or IIa fibers where it is oxidized. Indeed, there is a relationship between lactate removal and the percentage of slow twitch (ST) fiber, which in turn is related to the metabolic features of these fibers (Wasserman et al., 1987; 1989). Lactate delivery, uptake, and oxidation are facilitated by the ST fibers. These fibers have a large capillary density and are rich with H-LDH isozyme (LDH-1 + LDH-2) (Karlsson et al., 1975). Lactate can be used as a substrate for ST fibers during low intensity activity because the ST fibers are more dominant in such activities (Andersen, 1975; Bonen and Belcastro, 1976; Bonen et al., 1978; Brooks, 1986).

Almost all investigations agree that optimal lactate clearance occurs by engaging in a moderate activity during recovery. However, not all researchers agree on the optimal exercise intensity that should be used. Belcastro and Bonen (1975) suggested that the optimal intensity for lactate clearance is 30 to 45% of VO$_2$ max in inactive persons and 50 to 65% of VO$_2$ max in athletes. Accordingly, previous studies revealed that exercise recovery at workloads below the anaerobic threshold is more effective, with respect to lactate reduction, than exercise recovery above the anaerobic threshold (Stamford et al., 1981; Weltman et al., 1979). The use of light workloads for recovery is based on the notion that higher workloads will lead to an increased imbalance between the rate of lactate production and lactate clearance. In our study, gymnasts engaged in 5 min of free active recovery during the combined protocol. Exercise intensity was below anaerobic threshold (controlled by heart rate).

The heart rate values measured during gymnastics routines in this study were high, as shown in Table 3. These values should not be used as a direct indication of effort intensity. It is difficult to interpret HR energetic significance, given the lack of a steady-state condition in the performance as well as the short duration of the routines. An increase in HR just before the beginning of each event has been noticed. This HR increase may be partly explained by an increase in catecholamines due to the gymnasts’ anticipatory responses. However, given the upper body involvement in gymnastics activities, it is possible the high HR is partially due to the interthoracic pressures associated with maximal upper body efforts and breath-holding (Boileau et al., 1984).

**Conclusion**

During intense gymnastics sessions, gymnasts produce moderately high lactate values. This study shows that a combined recovery between repetitions may be of great importance to the gymnast. Lactate clearance was higher when gymnasts used 5 min rest and 5 min self-selected active recovery at an intensity below the lactate threshold. With this kind of recovery, gymnasts improved their performance. This recovery may be used during the competitive period when gymnasts usually have to repeat their six events more than twice in one session, which is common during training and simulated competitions during training. Because there is a relatively high injury rate in gymnastics, and fatigue is often related to injury, this may help gymnasts reduce the likelihood of injury.
Acknowledgment
We gratefully acknowledge all gymnasts who participated to this study, especially from the “INSEP French pole,” “Champigny sur Marne Red Star team, gymnastics section,” and “Morsang Sur Orge team,” as well as their coaches. We also thank all the medical staff and judges who participated in the study.

References


