HEART RATE AND BLOOD LACTATE CONCENTRATION AS TRAINING INDICES FOR HIGH LEVEL MEN'S GYMNASTS

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Introduction

Considerable work has been performed on gymnasts 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 is performed by competing on several events interspersed with recovery periods, gymnasts practice for long period sessions. I have observed that coaches seldom ask themselves about the effectiveness of the repetitions or the quality of recovery. Coaches pursue varying training objectives based on the particular period of training. Gymnasts, much like sprinters, perform in both aerobic and anaerobic conditions (Jemni, 2000a; Sands, 1998). During intense sessions, gymnasts are asked to perform routines while fatigued. They are often asked to find the best compromise among technical effectiveness, safety, and high intensity effort.

The aim of this study was to analyse HR and BL from one apparatus to another during the six events of men's gymnastics competition. A secondary purpose was to examine the physiological effects of performing a series of gymnastics events.

Methods

Subjects

Table 1 Physiologic characteristics of the gymnasts

	Age year	B. mass kg	Height cm	B. fat (%) 4 skinfolds	Risser level	ςO$_2$ max ml.kg^{-1}.min^{-1}
mean	18.43	66.11	171.57	8.85	4.25	52.62
SD	1.13	3.82	6.21	1.29	0.42	3.02

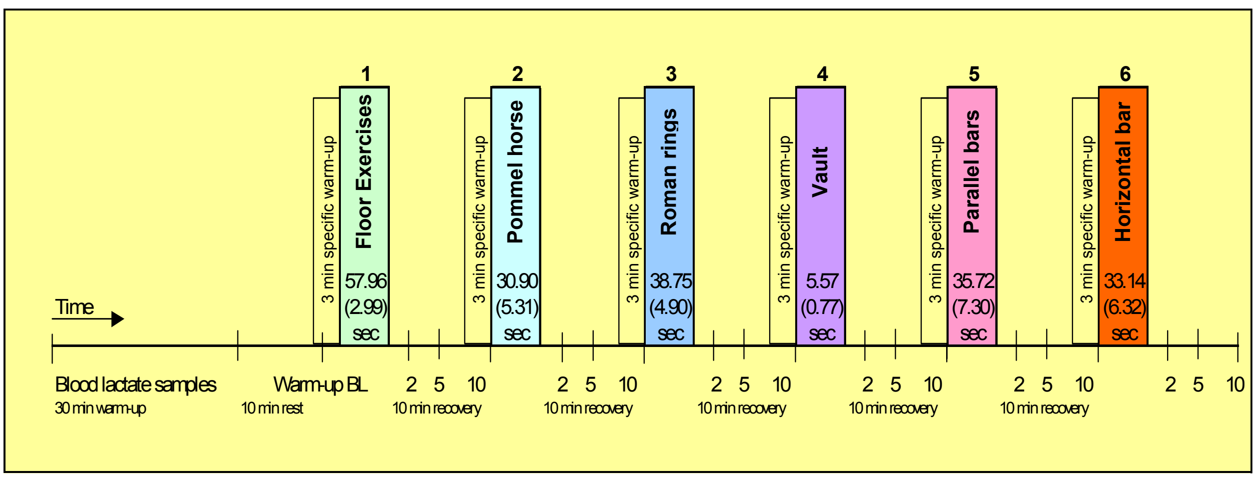
B = body ; Risser level: radiological exam of the pelvis

Seven male volunteer gymnasts of the French international gymnastic team, aged 18.43 ± 1.13 years old participated in the study. They trained two hour long sessions per day, 6 days per week. Their physiologic characteristics are shown in table 1. Their ςO_2 max was measured using a standard maximal treadmill test. Their skinfold thickness were measured according to Durnin and Rahaman (1967). Skeletal ages were determined according to Risser method using a radiological exam of the pelvis (Risser 1948). This test was used to assess skeletal maturity (table 1).

Protocol

The tests involved simulations of gymnastics competitions as described in an earlier study (Jemni et al., 2000b) (Figure 1). Each of the six event performances (routines) was separated by 10 min of recovery. Two physiological parameters were evaluated: heart rate (HR) and blood lactate concentration (BL). Three blood samples (25 μl) were taken from a hyperaemic earlobe: 2, 5 and 10 min after each event. The determination of BL was performed by a micro-enzymatic method with a Microzym L-analyzer. The HRs of the gymnasts were continuously monitored by a Bauman and Haldi Sport-tester BHL 6000. Gymnasts were required to warm-up for the next event just after having their blood samples taken at the tenth recovery-minute (3 min specific warm up).

Figure 1: protocol session



Results and Discussion

Heart rate

Gymnastics competition events induced very high HR values during a short time (Table 2 and 3). Only 16.31 % of these values were between 180 and 190 b.min^{-1} (table 3). Most recorded values were between 158 and 170 b.min^{-1}. Nevertheless, there were differences between apparatus requirements. Table 3 shows that the most required HR range in floor exercises was that between 171 and 179 b.min^{-1}. Gymnasts used this range about 34.44 % of the performance time. The same range was required approximately 26 % of the time in horizontal bar. HR never exceeded 179 b.min^{-1} in vaulting event. Mean vault values were significantly less than those of the other exercises ($p < 0.05$) (table 2). After a 10-minute recovery period, HRs were usually greater than their rest values (table 3).

Table 2 Mean values (± SD) of maximal, average, and after 10 recovery minute heart rate

	Heart rate (b.min^{-1})		
	Mean	maximal	10 recovery min
Floor	173.29 ± 7.34	186.00 ± 11.33	105.71 ± 10.83
Pommel	166.43 ± 11.53	184.57 ± 10.63	110.43 ± 4.43
Rings	.	.	103.00 ± 10.03
Vaulting	148.86 ± 15.56 ^{s}	161.71 ± 14.21^{s}	101.57 ± 9.03
Parallel bars	170.00 ± 9.86	180.17 ± 10.63	102.00 ± 5.92
Horizontal bar	172.86 ± 10.61	185.00 ± 9.06	101.57 ± 9.48
Mean	*166.29*	*179.49*	*104.05*
SD	*10.12*	*10.19*	*3.49*

^{s}: significantly different ($p < 0.05$)

Remark. rings heart rates were not studied because of artefacts found in the records

We noted also that HR values were not high in pommel horse. This result seems to be remarkable, because this event used especially the arms; they must carry the body-weight from one part of the apparatus to another while performing continuously movements and combinations; HR would be higher than during an exercise done with the legs at the same power (Bevegard, and Shepherd, 1967). However, given the upper body involvement in gymnastics activities, it is possible the high HRs are partially due to the interthoracic pressures associated with maximal upper body efforts and breath holding (Boileau et al., 1984).

Some authors have tried to explain the high heart rate by physiological mechanisms: Vander et al., (1970) concluded that this phenomenon concern not only central blood circulation but also the peripheral nervous system. It seems that information from the central nervous system stimulates the vaso-dilator sympathic' axis which induces a vaso-dilatation of the muscular arteries and modifications on heart behaviour: increment of the general and local blood flow as well as heart rate. Otherwise, the high HRs noticed just before the beginning of each event were supported by the increment of the adrenal hormones.

As we did not observe a steady state of HR during relatively short gymnastic exercises, it is difficult to interpret their energetic significance. We cannot estimate the energetic cost from the relation of HR to oxygen uptake as measured during a treadmill test. Training evaluation through heart rate should consider this fact to avoid any misinterpretation, especially if we cannot eliminate the psychological stress effect. Otherwise, mean HR may give a better idea about the event intensity.

Table 3 Required heart rate ranges by apparatus and the time during they have been recorded.

	% HR between 100 - 131 b.min^{-1}	time min	% HR between 132 - 157 b.min^{-1}	time min	% HR between 158 - 170 b.min^{-1}	time min	% HR between 171 - 179 b.min^{-1}	time min	% HR between 180 - 190 b.min^{-1}	time min
Floor	0.00	0.00	7.26	0.06	30.93	0.25	34.44	0.28	20.17	0.14
Pommel	7.37	0.07	16.16	0.12	32.44	0.17	15.03	0.12	20.10	0.14
Vaulting	19.17	0.07	44.97	0.18	22.54	0.04	13.31	0.03	0.00	0.00
Parallel bar	0.00	0.00	15.56	0.09	26.63	0.22	18.56	0.09	19.19	0.07
Horizontal b	0.00	0.00	12.69	0.12	29.89	0.33	26.00	0.19	22.10	0.09
Mean	5.31	0.03	19.33	0.11	28.49	0.20	21.47	0.14	16.31	0.09
SD	8.38	0.04	14.76	0.04	3.95	0.11	8.74	0.10	9.18	0.06

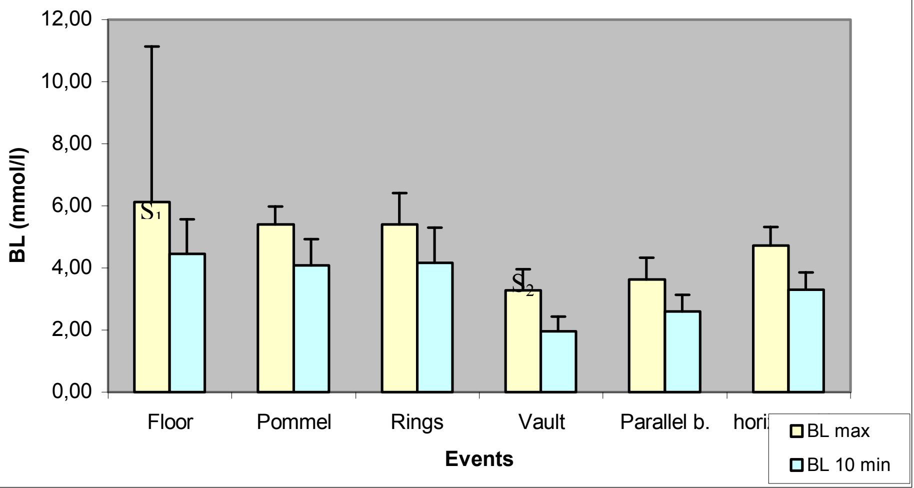
HR = Heart rate

Blood lactate

The mean maximum BL of all six apparatuses was 4.77 $\pm$ 1.11 mmol.1^{-1}. Peak level BL appeared at the second minute after each event, except after the pommel horse, where it was slightly higher at the fifth minute but not statistically significant ($p < 0.05$). BL varied from one apparatus to another (fig 2). The highest value was observed during the floor exercise (6.13 $\pm$ 1.00 mmol.1^{-1}). The lowest value was at the vaulting event (3.27 $\pm$ 0.68 mmol.1^{-1}). Between these two values were - in decreasing order - those of pommel horse, rings, horizontal bar and parallel bars. Statistical comparisons showed that vaulting values were significantly less than those of the other exercises. On the other hand, floor exercises values were significantly higher than those of vaulting, parallel bars and the horizontal bar. At the end of the recovery period, BL was usually higher than its rest value. The 10-minute recovery's BL value was considered the starting value for the next apparatus (Fig 2). Maximal BL decreased progressively until the vaulting event, then increased during parallel bars and horizontal bar series.

Montpetit (1967) supposed that lactate production during gymnastic routines was negligible. Our results don't confirm this, seeing that BL mean values were between 3.27 $\pm$ 0.68 and 6.13 $\pm$ 1.00 mmol.1^{-1}. So the average BL value of all cumulated events was over the Kindermann threshold (4.77 $\pm$ 1.11 mmol.1^{-1}, or 5.07 mmol.1^{-1} excluding vault) in spite of the late maturity observed in this group of gymnasts. [Kindermann threshold is an index (4 mmol.1^{-1}) describing that the rate of lactate appearance is more important than its removal. It indicates the moment when anaerobic metabolism is more required than the aerobic one] (Kindermann et al. 1979).

Figure 2: Blood lactate evolution during each competition event



S_1: Significantly higher than vaulting, parallel bars and horizontal bar.
S_2: Significantly less than the other events.

Diet and nutrition were not controlled during this study due to logistical problems with subject recruitment. However, BL values of the different events were comparable with those found in the recent literature (Jemni et al., 2001; 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 in vaulting, uneven bars, balance beam and floor exercise, respectively). However, the BL values were higher than those found in lower level female gymnasts by Montgomery and Beaudin (1982). Gymnasts' maximal lactate values appear to be higher than ice-dancing athletes whose competitive routines last four minutes (Roi et al., 1989) and lower than rhythmic gymnasts measured by Alexander et al. (1987) performing 1.30 min competitive routines.

High performance is correlated to high blood and muscular lactate value during intense anaerobic exercises, not simply an increased fatigue stimulus (Bar-Or et al., 1980; Olbrecht, 2000). 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 six months late maturity might be the reason for the low average lactate value; less Phosphofructokinase activity reduces the glycolysis possibilities. The fact that better performances result in higher BL concentrations may mean also 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 in blood, especially when lactates are measured after intense exercise. While direct muscle lactate values are desirable to determine, Rusko et al. (1986) demonstrated that BL and muscular values are linearly related during progressive exercise until reaching the anaerobic threshold. 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 among sport-specificity, measurement accuracy, and practicality of the measurements.

Conclusion

The data here elucidate the metabolic requirement through the course of a gymnastics competition and show the differences between events. The anaerobic requirement is very important in four events contrary to what it used to be considered. Blood lactate concentration remained not negligible seeing mean overage above lactate threshold. The lactate concentration differed between apparatuses. Vaulting lactate value, as well as its heart rate, were significantly smaller than those of the other exercises. Floor routines induced the highest lactate production, followed in decreasing order by 1) rings and pommel horse, 2) horizontal bar and 3) parallel bars.

Heart rate response was strong during gymnastic exercises. These values should not be used as a direct indication of effort intensity.

By knowing such indices, coaches could prescribe individual training programs at each phase of the season such as the competitive one in which gymnasts usually have to repeat their six events two to five times in one session. The effect of one exercise on another and the short recovery duration between events may cause coaches to think also about using active recovery. This has been done in many other sports. Our next study will examine a variety of recovery models during gymnastics' session.

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