Exercise-related parameters of horses competing in show jumping events ranging from a regional to an international level

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Summary — The present study investigated cardiovascular, metabolic and hematological responses in 14 horses participating in show jumping competitions. In order to compare physiological responses in relation to the level of the event, the jumping horses were ranked in 4 groups from international to regional level. During all exercise activities (warm-up, jumping course, recovery) the horses were equipped with a heart rate recorder and the heart rates were averaged for each phase. Blood samples were collected at rest and 1 min after the last jump to measure the packed cell volume, red blood cell and blood lactate concentration. The jumping performance of the horses was quantified by the earnings index computed annually and the level of training was estimated from the number of starts/year in competition. The heart rate during the jumping course, the packed cell volume at the finish, the performance index and the number of starts were significantly different between the groups ($P < 0.05$). Heart rate during the jumping course rose to peak values ranging from 182.8–205.5 beats/min and the packed cell volume reached extreme values ranging from 42.0–60.1%. The great differences in show jumping performances were poorly correlated to the variations observed for the cardiac, hematological and lactate parameters. This study shows that jumping represents intense muscular exertion. However, the exercise fitness of horses should be considered as a secondary factor for success in show jumping though it cannot be ignored in the case of high performance animals.

horse / jumping / exercise / heart rate / lactate

Résumé — Paramètres de l'exercice physique chez des chevaux participant à des épreuves de concours hippiques de niveau régional à international. *L'objet de cette étude est d'explorer les paramètres cardiovasculaires, hématologiques et métaboliques de 14 chevaux prenant part à des épreuves de concours hippiques. Afin de comparer leur réponse physiologique à cet exercice en fonction du niveau de l'épreuve, les chevaux testés ont été regroupés en 4 groupes s'échelonnant du niveau régional à international. Les chevaux étaient équipés d'un cardio-fréquencemètre dès le début de l'échauffement jusqu'à la récupération après le parcours, afin de calculer les fréquences cardiaques moyennes correspondantes à chaque phase de l'exercise. Des prises de sang étaient effectuées au repos avant l'épreuve et une minute après le dernier saut pour mesurer l'hématocrite, la concentration en globules rouges et la lactatémie. Pour quantifier la valeur sportive des chevaux, l'indice de performance annuel a été utilisé. Leur état d'entraînement était estimé d'après*

le nombre de sorties en compétition enregistrées au cours de cette même année. La fréquence cardiaque pendant le parcours, l'hématocrite après le parcours, l'indice de performance et le nombre de sorties en compétitions sont significativement différents entre les groupes (P < 0,05). La fréquence cardiaque pendant le parcours atteint de 182,8 (± 10,4) à 205,5 (± 0,5) battements/min et l'hématocrite augmente jusqu'à des valeurs comprises entre 42,0 (± 1,8) et 60,1 (± 3,8%). D'après les lactatémies comprises entre 3,25 (± 0,30) et 5,30 (± 2,35) mmol/l, les groupes 2 (national, grand prix) et 4 (régional, jeunes chevaux) dépassent légèrement le seuil anaérobie des 4 mmol/l. Les grandes différences observées entre les performances des différents chevaux sont mal corrélées aux variations des paramètres cardiaques, hématologiques et lactiques mesurés. Ces résultats montrent que l'effort de saut représente pour le cheval un travail musculaire intense. La capacité physique des chevaux semble être un facteur secondaire pour obtenir des performances en concours hippique, toutefois elle ne devra pas être négligée pour les chevaux de haut niveau.

cheval / saut d'obstacles / exercice / fréquence cardiaque / lactate

INTRODUCTION

In France show jumping is the main equestrian sport and has stimulated considerable genetic progress in jumping ability (Tavernier, 1990) though surprisingly little progress has been achieved in the training technique. A conventional training program includes dressage, coordination and strength training, but improvement of the aerobic capacity and anaerobic power are not taken into account. Some interesting studies have been conducted to investigate the jumping technique used by horses. These works have described the linear and temporal characteristics of the approach, jumping and move-off strides (Leach and Ormrod, 1984; Leach *et al,* 1984; Clayton and Barlow, 1989, 1990; Deuel and Park, 1990) and the trajectories of the body segments (Dufosset and Langlois, 1984; Preuschoft and Hüllen-Kluge, 1989). Few scientific data are available on the exercise physiology of jumping horses (Art *et al,* 1990). The aerobic and anaerobic demands during a show jumping competition could be estimated using physiological models (Barrey, 1990) but more experimental data are necessary to improve the training schedules on a scientific basis.

The present study investigated cardiovascular and metabolic responses of horses participating in show jumping events ranging from a regional to an international level.

MATERIALS AND METHODS

Horses

Fourteen horses of different breeds, ages, sexes and levels were investigated during show jumping competitions (table I). All of them were clinically sound and had been normally trained to compete. Two hours before the competition, all horses were submitted to a short clinical examination to avoid orthopaedic or medical problems which could have affected the measurements during and after exercise. Rectal temperature and heart rate were measured at rest and a venous blood sample was collected. Each horse tested was then observed successively during the warm-up, jumping course and recovery phases. When the horse was saddled, the heart rate recording and a tape recorder were started simultaneously by an observer. Once the rider began to exercise his horse, an observer commented on all the exercise activities during the 3 phases.

The jumping performance of each horse was quantified by its performance index (PI) obtained in 1989 and published by the French Steeple-Chase Society (Compétitions Équestres, 1989). This criterion is computed annually for each French jumping horse by taking into ac-

Table I. Characteristics of horses.

Horse	*Age (yr)*	*Sex* [a]	*Breed* [b]	*Group*
1	14	G	TF x PS = SF	1
2	7	M	SF	1
3	11	G	SF	2
4	9	M	PS x SF = SF	2
5	6	G	SF	2
6	10	G	SF	3
7	9	G	SF	3
8	7	G	SF	3
9	11	G	PS x SF = SF	3
10	7	G	SF	3
11	6	G	SF	3
12	9	M	SF	4
13	9	M	SF	4
14	5	G	SF	4

a G = gelding; M = mare; b SF = Selle Français (French Saddle Horse); TF = Trotteur Français (French Trotter); PS = Pur-Sang (Thoroughbred).

count the total annual earnings (Langlois, 1975, 1980). The total number of starts in competitions during 1989 was also considered as a variable (STA) to estimate the state of training.

Show jumping events

We selected horse–rider couples at all competitive levels from regional to international levels. Jappeloup de Luze (Olympic gold medal champion in Seoul, 1988) was considered to be the highest performing horse, and horse 14 the lowest performer. In order to compare the physiological responses of horses in relation to the level of the event, horse–rider couples were ranked in 4 groups: group 1: international level; group 2: national Grand Prix level; group 3: national middle level; group 4: regional level.

The height, width, number of fences and length of each event has been described in table II (Fédération Française d'Equitation, 1989). The measurements were undertaken at 2 official show jumping competitions. Horses 1 and 2 competed in an international show jumping event on a turf track (CSI; Franconville, 1989). Horses 3–14 participated in a national show jumping event on a sand track (CSO national 1 open; St-Sauveur-en-Puisaye, 1989). These 2 competitions took place outdoors in the summer when the weather was sunny and dry.

Heart rate measurements

At the beginning of the clinical examination, the heart rate at rest (HRo) was measured with a stethoscope. During exercise, the horses were equipped with a heart rate recorder (Horse Tester PEH 200, Polar Electro, Helsinski, Finland) which averaged values every 5 s. After the recovery phase, the data were displayed and listed with a portable micro-computer to calculate 4 parameters: maximum heart rate during warm-up phase (HRw); mean heart rate at the in-gate of the course field (HRg); mean heart rate during the course (HRc); heart rate after 5 min of walking recovery (HRr). The heart rate recording of each horse was plotted relative to time and each event such as jump, gait transition, waiting at the in-gate, course and recovery was designated on the records.

Blood analysis

Blood samples were collected at rest and 1 min after the last jump on the course using vacuum collecting tubes. Packed cell volumes (PCVo and PCVc) were measured in heparin tubes while red blood cells (RBCo and RBCc) were measured in EDTA tubes using a hematological analyzer (Coulter Counter Inc). A 0.50-ml blood sample was immediately deproteinized with 1 ml 0.6 N perchloric acid solution and cooled for subsequent quantification of lactate concentration (LAo and LAc) with an LM2 Analyzer (Analox Instruments).

Statistical analysis

In addition to the ordinary statistical procedures employed to calculate means (± SD) and correlation coefficients, a 1-way analysis of variance was used to test the significance of the differ-

Table II. Characteristics of the show jumping competitions.

	Group 1	*Group 2*	*Group 3*	*Group 4*
No of fences	15	15	10–15	10–14
Vertical fence height (m)	1.45–1.50	1.25–1.60	1.25–1.3	1.05–1.25
Oxer fence				
Height (m)	1.40–1.45	1.20–1.50	1.20–1.35	1.00–1.25
Width (m)	1.60–1.70	1.40–1.80	1.30–1.70	1.20–1.60
Course length (m)	450–750	450–500	450–500	400–450
Velocity (m/min)	350–450	350	350–450	350

ence between the groups. A paried Student's *t*-test was used to compare the means of variables which were significantly different between groups.

RESULTS

Competition results

All tested horses completed the jumping event. Horses 1 and 12 had a faultless round. All the other horses knocked down one or more fences or refused once or twice. Velocity during the course ranged from 330–450 m/min.

Heart rate recordings

Figures 1, 2 and 3 display heart rate recordings from horses 1, 4 and 13 respectively. There was a large variety of warm-up techniques in terms of duration, intensity and progressivity. During the warm-up phase, each heart rate peak > 120 beats-min indicated a jump. The heart rate increased more when the horse cleared an oxer fence than in the case of a vertical fence of the same height. At the arena ingate, some horses were in a state of passive recovery with a decreasing heart rate (*eg* figs 2, 3) while others showed a high frequency which rose 80–100 beats/min (fig 1). When horses went into the arena and started to gallop, the heart rate reached an initial level of 100–140 beats/min. After clearing the first fence, the heart rate increased dramatically to > 180 beats/min without reaching a steady state. The heart rate recovery phase occurred immediately after completion of the course.

Exercise-related parameters

The physiological parameters (HR, PCVo and RBCo) measured at rest were normal (table III).

The heart rate during the jumping course (HRc) and the packed cell volume at the finish (PCVc) were significantly different between groups ($P < 0.05$) (table IV). The heart rate during the jumping course rose to peak values ranging from 182.8 (± 10.4) to 205.5 (± 0.5) beats/min and the packed cell volume reached ex-

Table III. Means (± SD) of heart rate, blood lactate, packed cell volume and red blood cell measured at rest.

Group	HR_o (beats/min)	LA_o (mmol/l)	PCV_o (%)	RBC_o (10^6)
1	37.0	1.08	37.9	5.79
(N = 2)	(0.0)	(0.00)	(0.0)	(0.00)
2	34.7	1.12	38.4	5.69
(N = 3)	(1.9)	(0.09)	(1.3)	(1.13)
3	34.7	1.06	37.5	5.56
(N = 6)	(4.5)	(0.17)	(1.11)	(0.76)
4	37.3	1.07	38.2	6.36
(N = 3)	(0.5)	(0.26)	(1.27)	(0.02)
Mean (SD)	35.6	1.08	38.0	5.79
(N = 14)	(3.33)	(0.17)	(1.2)	(0.78)

treme values ranging from 42.0 (± 1.8) to 60.1 (± 3.8)% (table IV). According to blood lactate values ranging from 3.25 (± 0.30) to 5.30 (± 2.35) mmol/l, the concentrations of the groups 2 and 4 slightly exceeded the reference value of 4 mmol/l.

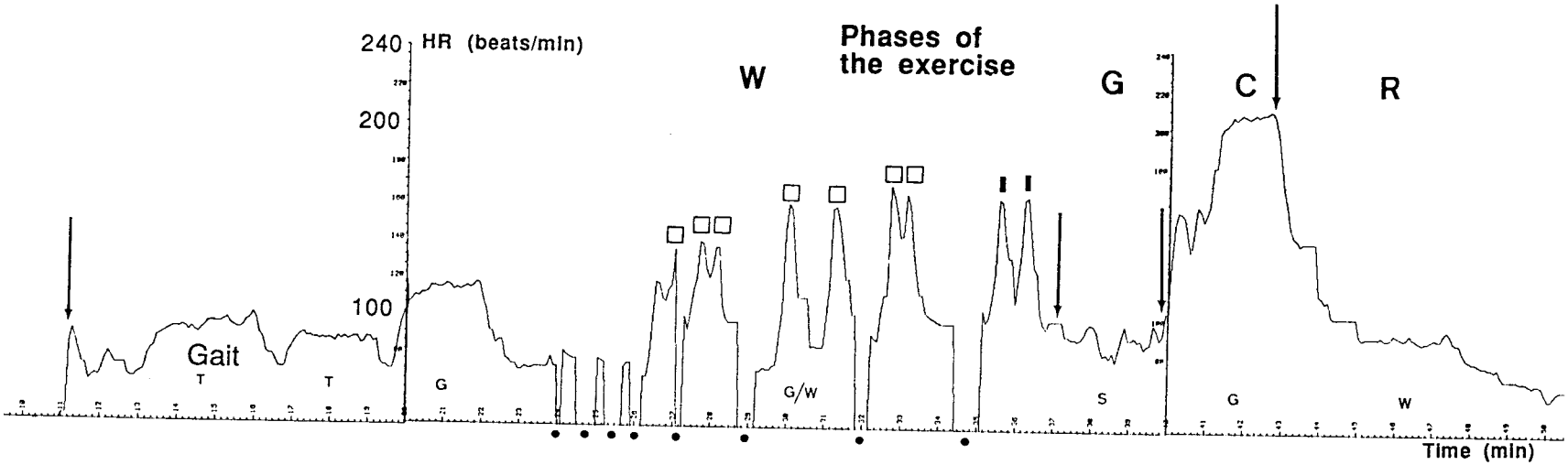
The packed cell volume at the end of the jumping course was negatively correlated to the performance index (–0.62; $P < 0.05$). The mean heart rates during the warm-up (HRw), jumping course (HRc) and recovery (HRr) phases were not significantly correlated with the number of starts (–0.43, –0.41, –0.18, respectively).

The performance index (PI) was significantly different between groups of horses ($P < 0.05$) (table IV). A performance index value > 110 indicated a good jumping horse. The number of starts (STA) was also significantly different between groups and was greater for national Grand Prix and middle levels.

Table IV. Means (± SD) of exercise related parameters, performance index (PI) and total number of starts (STA) in each group.

Group	HR_w (beats/min)	HT_g (beats/min)	HR_c* (beats/min)	HR_r (beats/min)	LAc (mmol/l)	PCV_c* (%)	RBC_c (10^6)	PI* (in 1989)	STA* (in 1989)
1	172.0	79.5	205.5^a	69.0	3.25	42.0^a	8.51	166.0^a	12.0^a
(N = 2)	(3.0)	(9.5)	(0.5)	(2.0)	(0.30)	(1.8)	(1.11)	(15.0)	(1.0)
2	160.0	93.0	188.1^{ab}	77.1	4.57	59.5^b	7.21	128.7^b	34.0^b
(N = 3)	(8.6)	(9.4)	(5.9)	(4.5)	(1.93)	(2.9)	(1.91)	(17.6)	(8.8)
3	163.5	78.5	182.8^b	77.2	3.65	60.1^b	9.49	108.8^{bc}	25.0^{ab}
(N = 6)	(3.9)	(15.1)	(10.4)	(15.9)	(1.10)	(3.8)	(0.83)	(9.9)	(8.3)
4	173.3	71.3	196.7^a	78.7	5.30	58.1^b	8.77	91.7^c	9.3^a
(N = 3)	(10.1)	(14.0)	(0.5)	(5.3)	(2.35)	(1.6)	(0.44)	(7.5)	(5.2)
Mean(SD)	166.1	80.2	190.2	76.3	4.14	57.0	8.71	117.6	21.7
(N = 14)	(8.5)	(15.0)	(11.0)	(11.3)	(1.75)	(6.8)	(1.43)	(26.3)	(12.1)

* Values are significantly different from one group to another at $P < 0.05$. ^{a,b,c}: means followed by the same superscript are not significantly different at $P < 0.05$.



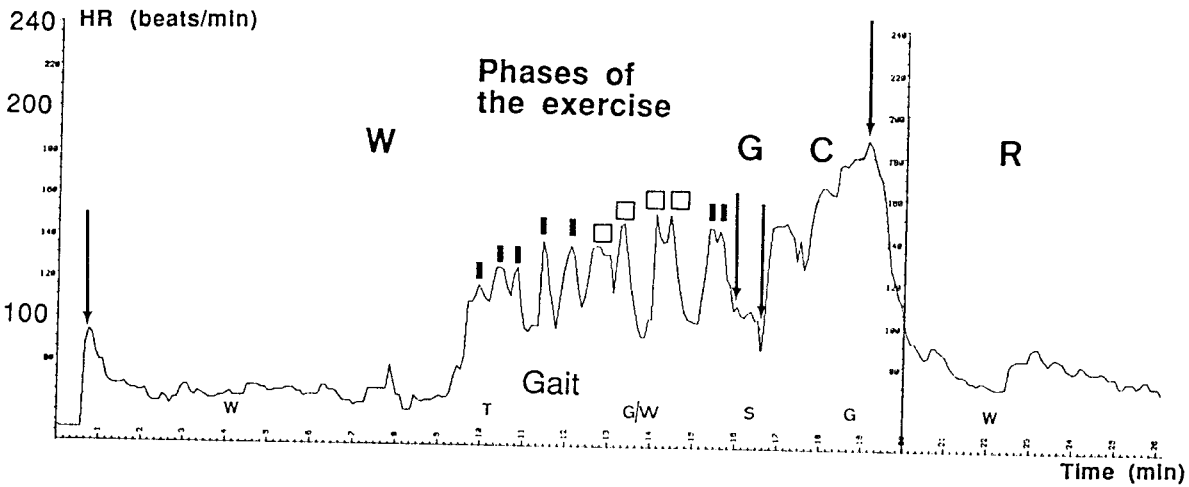


Fig 1. Heart rate recording of horse 1. Gait: W = walk, T = trot, G = gallop. Exercise phases are separated by vertical arrows. W = warm-up, G = at the field gate of the course, C = course, R = recovery at walk. Fences : ▮ = vertical fence, ı = oxer fence; • indicates loss of the heart rate recording.

Fig 2. Heart rate recording of horse 4. Gait : W = walk, T = trot, G = gallop. Exercise phases are separated by vertical arrows. W = warm-up, G = at the field gate of the course, C = course, R = recovery at walk. Fences : ▮ : vertical fence, ı = oxer fence.

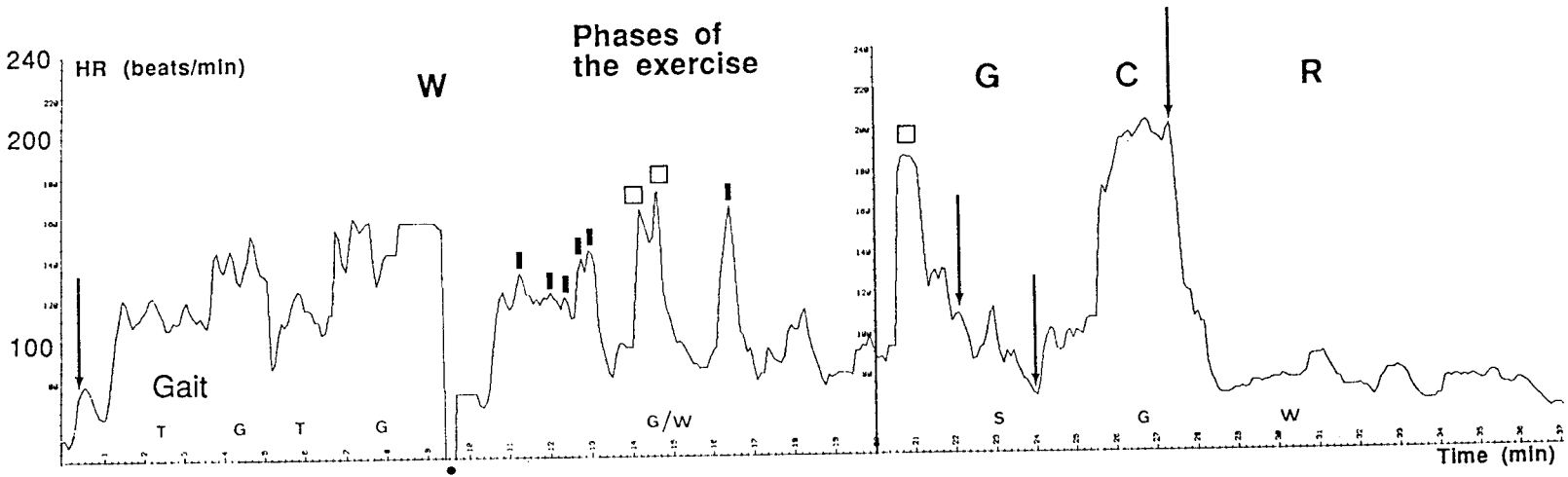


Fig 3. Heart rate recording of horse 13. Gait : W = walk, T = trot, G = gallop. Exercise phases are separated by vertical arrows. W = warm-up, G = at the field gate of the course, C = course, R = recovery at walk. Fences : ▮ = vertical fence, ı = oxer fence; • indicates loss of the heart rate recording.

DISCUSSION

Horse–rider combinations were selected in a large range of competition levels in order to determine differences in physiological response to jumping exercise. This field study did not compare the horses under the same conditions of exercise because each event was different. Consequently, the technical difficulties (fences, velocity) of each event was one of the factors which influenced the results of the exercise-related parameters between groups and within a group. The great differences in show jumping performances (see PI) were poorly correlated to the variations observed for the cardiac, hematological and lactate parameters. Exercise fitness should also be considered as a secondary factor for success in show jumping, but cannot be ignored in the case of high performance horses.

Recording the heart rate throughout a jumping competition provides interesting information on exercise ability and on the temperament of horses. During the warm-up phase, the heart rate rose to a peak at each practice jump. The larger the height and width of the fence, the higher the heart rate. This could be explained by the fact that the rider increases the velocity of his/her horse to clear higher and/or larger fences. The increase in heart rate prior to the jumping exercise could be considered as an anticipatory phenomenon already observed in jumping horses (Art *et al,* 1990), race horses (Krzywaneck *et al,* 1970) and human runners (McArdle *et al,* 1967).

The results demonstrate that the heart rate (HRc) and packed cell volume (PCVc) during the jumping course were influenced by the level of the show jumping event. The packed cell volume could reach a value of 60% and the mean heart rate during the course rose to 180–200 beats/min, indicating a large aerobic demand.

Blood lactate increased significantly during the exercise in all groups but there was no significant difference between groups. The large individual variation connected with the low repeatability of this biochemical analysis may explain the lack of significance of blood lactate results (Seeherman and Morris, 1990). However, the lactate concentration (LAc) at the finish seemed to be higher in group 4 which was less trained than the other groups according to the number of starts (table IV). As the blood lactate level reached a mean value of 4.14 mmol/l (± 1.81), the anaerobic demand was significant during a jumping competition. The onset of blood lactate accumulation, traditionally set at 4 mmol/l (Persson, 1983), was reached in the groups 2 and 4, but the blood lactate concentrations were below the values measured in racehorses (Saibene *et al,* 1985). This observation was consistent with the fact that the jumping horse should canter aerobically at slow speed (350–450 m/min) and the major anaerobic demand should be related to the bursts of power required at each take-off. The duration of the course was short and did not permit the aerobic system to reach a steady-state condition which is generally reached after 3 min in the human athlete (Di Prampero, 1981).

In practice, the training technique of jumpers should include the improvement of both the anaerobic and aerobic capacities. The aerobic capacity could be developed by using conventional or interval training. The recruitment of the fast contracting fibers during short acceleration sprints and strength training might develop the anaerobic power (Clayton, 1990). The blood lactate concentrations observed at the end of the jumping course justified a few minutes of active trotting recovery to increase the blood lactate clearance in the muscles (McLellan and Skinner, 1982; Marlin *et al,* 1987; Auvinet, 1990) and avoid muscular soreness.

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