Effects of Cardiovascular Endurance Training Periodization on Aerobic performance and Stress Modulation in Rugby Athletes

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Abstract: Background: Rugby is an intense sport that demands athletes to compete in frequent short bouts of high intensity exercise, consisted of both defensive and offensive play. Athletes must be periodized basic and specific fitness conditioning to improve their performance. **Aim:** To verify biological and psychological stress markers during strenuous cardiovascular endurance training (CET) periodization, using Profile of Mood States (POMS) questionnaires, heart rate variability (HRV) and blood urine nitrogen (BUN) as the criteria measurements, and determine the association of training intensity distribution in rugby training. **Methods:** Twenty-four male national level rugby athletes completed 8 weeks CET. Subjects were evaluated POMS, HRV and BUN five times during CET: at the beginning (week 0, date 0, T1), in the middle (week 1, date 5, T2; week 4, date 26, T3; week 6, date 40, T4) and at the end (week 8, date 52, T5) of the training programs. Peak oxygen uptake ($\dot{V}O_{2peak}$) and works of lactate threshold at 4 mmole/L (W_{LH}) were tested before and after CET. **Results:** There were significantly increasing in the absolute $\dot{V}O_{2peak}$ (20.7(16.5) %), relative $\dot{V}O_{2peak}$ (23.6(16.6) %) and W_{LH} (40.5(39.1) %) after the totally CET. Training increased BUN levels, LF/HF ratio and POMS total mood disturbance scores. The BUN and LF/HF were significantly correlated with POMS subscales before and during different CET stages. However, there was only significant association between HF distributions based on TMD (before: r= 0.795, P=.001; at the end of CET: r = 0.739, P=.001). **Conclusion:** 8 weeks periodized CET would increase aerobic performance and strengthen cardiovascular regulation in rugby athletes. A noninvasive monitoring method could be developed by POMS highly correlated HRV and BUN for physiological controlling in periodization.

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1. Introduction

Rugby is a forceful sport in which the maximal performance relies on the various technical, tactical, physical and psychological developments. Rugby is a intense sport that demands athletes to compete in frequent short bouts of high intensity exercise, consisted of both running play and contact play. During these high-intensity bouts of activity, athletes are involved in defensive and offensive sprinting activities that power, strength, agility, and speed are needed. We believe that athletes must arrange basic and specific fitness conditioning to improve their performance.

The planned classification or structure of training loads (technical, tactical and physical) in periods or stages has been recommended to as periodization[1]. Periodization goals to strengthen the athletes' performance. Traditionally, periodization is separated into four phases: off-season (building of the athletic shape), pre-season (acquirement of the athletic shape), in-season competition (maintenance of the athletic shape) and transition (temporal loss of the athletic shape)[2].

Although, most elite athletes consecrate themselves to training programs that force them to the extreme of their exercise performance, thereby usually entering a condition typically recommended as "overreached" (OR). Optimal performance is only reachable if athletes can recover after optimally balance training stress and energetic recovery. Coaches should organize modifications in training load and compensation in regularly practice that include a transient short-term fatigue and effort followed by recovery leading to a long-term performance refinement. However, when the athlete is not well improved, mild hurts could develop into tissues damages. Athletes often train an extended period of severe training called "overtraining syndrome" (OTS) and are characterized by reducing performance in spite of an expanded rest period, associated by physiological, biochemical, and psychological stress symptoms.

The assessment and monitoring of stress markers during training programs would assign the remodeling and individualization of an athlete's training workload[3]. Therefore, the best management to evaluate the training adaptation and to avoid overreaching and overtraining during training programs is the regular monitoring of selected biochemical, physiological and psychological markers.

Cardiovascular endurance training (CET) is a key component in periodization, because it is strongly combined with specific conditioning and beneficial metabolic, physiological and psychological effects. Intense or prolonged exercise during the training period may have caused skeletal muscle trauma, protein catabolism, and degradation of body tissue proteins. The byproduct serum blood urine nitrogen (BUN) concentrations should increase after training. Analyzing heart rate variability (HRV), which indirectly quantifies the influence of autonomic controlling on cardiac, could also be an important tool to analyze of cardiovascular stress in athletes [4]. Psychological adaptations have also been used to record the state during different training periods. These changes have been measured through the Profile of Mood States (POMS) questionnaire[5]. It has been shown that mood flutters increase similarly to training volume and/or intensity, and that individual POMS scores may get used to qualify training.

However, different metabolic stress indices might have various time courses in response to the periodization of intense training and following effective recovery. This suggests that training monitoring in athletes should be effected not only in a multi-level approach using estimations of performance but various biological and psychological indices as well. The present study analyzed psychological and physiological recovery in rugby athletes by comparing BUN to examine metabolic effect. HRV parameters and POMS scores were to verify the responses of adaptations during 8-week CET separately. In addition, any correlations between elements of physical and mental modifications were assessed with reference to the periodization. It was hypothesized that physiological and psychological markers during strenuous training section should be significantly modified sufficiently physical conditioning, maintained to provide adequate stimuli and altered the neural mechanisms of cardiovascular regulation.

2. Methods

2.1. Subjects

Twenty-four male national level rugby athletes were recruited in this study. The study protocol and purpose were explained and informed consent was obtained from all subjects before the study. Approval for the study was obtained from the Human Ethics Committee of the Cheng Shiu University. In a pre-study interview, information on routine use of vitamins and other nutritional supplements was obtained from each subject. Volunteers found to be taking regular medication that might interfere with cardiac autonomic function were used as exclusion criteria from the study. Two weeks prior to the tests, subjects were required to cease vitamin and supplement intake. Subjects were instructed to avoid exercise or strenuous physical activity for 3 days before and after CET aerobic tests. In the twenty-four hour period preceding the study, subjects recorded all food and drink intake and this dietary pattern was duplicated in other parts of monitoring. Peak oxygen uptake ($\dot{V}O_{2peak}$) and works of 4mM (4 mmole/L) lactate threshold (W_{LH}) of each subject were determined before and after the CET period.

2.2. Experimental design and procedures

This study was 8 weeks in duration including a total of 206 hours of rugby training. The first 4 weeks of endurance training (ET1, ET2) involved LT speed training (32 h). The 5^{th} to 8^{th} weeks of endurance training (SIT1, SIT2) involved interval speed training (28 h). The rugby training program included of rugby related basic physical, tactical and technical training, and recreational training (Table 1). CET included field exercises, interval training and circuit training. The SIT1 and SIT2 program consisted of mainly endurance type of sport activities such as high intensity interval training could improve endurance performance, resulting in enough time for the enhancement of other limiting skills such as rugby technique, starts and turns as well as sprint and strength endurance.

Subjects were evaluated five times in the study: at the beginning (week 0, date 0, T1), in the middle (week 1, date 5, T2; week 4, date 26, T3; week 6, date 40, T4) and at the end (week 8, date 52, T5) of the training programs. Diets or lifestyles were not controlled during the course of the season (table 1).

The tests were always performed in the same order in the testing session. On the day of the experimental test, measurements were executed at 6:20 am- 7:20 am before breakfast on Friday morning. Athletes did not perform strenuous physical activities in the 12 hours before recordings. No subject was taking drugs at the time of the recording sessions. The experiments were performed in a comfortable room at ambient temperature (22°C to 24°C) and relative humidity (55-60%). Subjects reported to the laboratory following a 10-h overnight fast. Subjects were instructed to consume 240 mL of water to increase hydration when they arrived at the laboratory. The athletes lay supine for 15 minutes before experiments to relax in the room made noiseless. Firstly, subjects were tested HRV and then asked to complete the POMS questionnaires. Blood samples were collected in a rest position from the earlobe in order to analyze hemoglobin (HB) and serum BUN (Table 1).

Table 1. The monitoring stages during the cardiovascular endurance training programs of the study

Training period	Before-training		CET				After-training
		Base line	$ET1_k$	ET2	SIT1	SIT2	
Test	before	T1	T2	T3	T4	T5	after
Testing Date	-7^{th}- -3^{rd}	0	5^{th}	26^{th}	40^{th}	52^{th}	56^{th} - 58^{th}
Testing parameters	$\dot{V}O_{2peak}$, LH	HB, BUN, HRV, POMS					$\dot{V}O_{2peak}$, LH

2.3. Training program

The training program was designed by researcher and the team's coach. There were 37 sessions with a mean volume of 24.8 h per week between ET1-ET2. During SIT1-SIT2, the rugby athletes performed 37 sessions with a mean volume of 26.2 h per week extending entire rugby-training program (Table 2).

Table 2. Training characteristics between ET1-ET2 and SIT1-SIT2

Type of Training	Duration of a session (min)	Weekly frequency	
		ET1–ET2	SIT1–SIT2
Recovery	30	5	6
Endurance	60	6	7
Specific rugby	30	6	4
Specific speed	40	3	4
Tactical	30	3	4
Technical	40	6	6
Simulated match	60	5	5
Recreational	60	1	1

The training program consisted of recovery training (continuous running/swimming/dancing at 45–55% of maximal heart rate), endurance training (continuous running at 65–80% and 80–90% of maximal heart rate between ET1-ET2 and SIT1-SIT2, respectively), specific rugby training (rugby activities according to playing position), specific speed training (sprints between 10–30m), tactical training (rugby activities up to tactical objective), technical training (attack against defense in the fields), simulated match (a simulated match including of two halves, each of 30 min) and recreational training (like a simulated match with the athletes playing in different sports like badminton).

Table 3. Summarizes the training characteristics between ET1-ET2 and SIT1-SIT2.

Variable (n=24)	**ET 1**	**ET2**	**SIT 1**	**SIT2**
Protocol	40–60 min running	30 min running× 2–4 repeats, 20 min rest	30 s × 8–12 repeats, 2.5 min rest	30 s × 10–15 repeats, 1.5 min rest
Training intensity	(5 × per week)	(5 × per week)	(5 × per week)	(5 × per week)
Training intensity	45% $\dot{V}O_{2peak}$	~ 65-75%$\dot{V}O_{2peak}$ (~ 4mM LT)	''All out'' maximal effort	''All out'' supra-maximal effort
Weekly training	~8 h	~4-8 h	~7 h	~7 h
Training session	7days	21days	14day	14days

2.4. Psychological parameters assessment

A validate Chinese version of the POMS questionnaire [5] was used to evaluate exercise related mood using the subscales tension (Ten), depression (Dep), anger (Ang), vigor (Vig), fatigue (Fat), confusion (Con) and esteem (Est). POMS total mood disturbance (TMD) obtained by adding all other measures and subtracting vigor (TMD=Ten+Dep+Ang+Fat+Con+Est+100-Vig).

2.5. Blood Collection and Analysis

Earlobe blood samples were collected from each subject for determination of HB and blood urine nitrogen (BUN). The serum BUN levels were measured immediately with an Ektachem DT60 II chemistry analyzer (Johnson and Johnson, Rochester, NY, USA). The hemoglobin was measured with Analyzer (HemoCue® Hb 201+, Ängelholm, Sweden).

2.6. Aerobic Performance.

Peak oxygen uptake ($\dot{V}O_{2peak}$) was measured using a bicycle ergometer (cyclus2 record trainer, h/p/COSMOS, Nussdorf-Traunstein, Germany). The initial workload of the test was 100 W (70-80 rpm), and it was increased by 50 W every third minute until exhaustion. Oxygen uptake ($\dot{V}O_2$) was measured continuously using a gas analyzer (ML870B80 & MLS240 Metabolic Module, PowerLab, ADInstruments, Australia). The blood samples (20 μL) were taken from the earlobe every third minute to measure blood lactate concentrations by using the Biosen_C_line Clinic (analyzer for glucose and lactate, EKF Diagnostics, Barleben, Magdeburg, Germany) and defined works of 4mM (4 mmole/L) lactate threshold (W_{LH}) by para-analysis program (Para-analysis, h/p/COSMOS, Nussdorf- Traunstein, Germany). The heart rate was recorded continuously using heart rate monitor (Polar Electro, Kempele, Finland). Volitional exhaustion was the main criterion indicating that the $\dot{V}O_{2peak}$ was achieved, and the highest mean $\dot{V}O_2$ over 1 minute was set as $\dot{V}O_{2peak}$. The subject's exhaustion was ensured of at least two of the four following criteria: (a) no longer maintaining the required speed; (b) heart rate within 10 beats of age-predicted maximum; (c) a respiratory exchange ratio above 1.05 and (d) rating of perceived exertion (RPE) >18.

2.7. Power Spectral Analysis

The athletes were instructed to avoid physical activity and to maintain their usual food intake, but not to drink alcohol or caffeine for 48 h before the testing. Heart rate (HR) recordings for HRV spectral analysis were performed between 6:20 and 7:20. During the first 15min, the athletes were in a supine position. Electrocardiograms (SSIC, Enjoy Research Inc., Taipei, Taiwan) [6] were used to record the athletes' HR in supine position, and the respiratory rate was set at 12-15 cycles/min. Spectral analysis was performed using the autoregressive model [7]. This procedure allows for the automatic quantification of the central frequency and the influence of each relevant oscillatory component present in the interval series. Components in the frequency band from 0.03 to 0.15 Hz were considered low frequency (LF), and those in the range of 0.15 to 0.4 Hz, which is synchronous with respiration, were considered high frequency (HF). LF/HF components of RR interval are considered to be an expression of cardiac and vascular efferent sympathetic regulation, respectively, whereas the HF component of RR interval variability is considered to be an expression of cardiac vagal modulation [8].

2.8.Statistical analysis

Standard statistical methods were used to calculate the mean and standard deviations (SD). The haemocrit level was used to adjust the other parameters for different dehydration. The differences between the before and after training programs values were statistically examined by paired *t* test. ANOVA with repeated measures was used to determine the differences between tests. When a significant *F* value was achieved, appropriate LSD *post hoc* tests procedures were used to locate the difference between means. Pearson product-moment correlation coefficients (r) were used to determine association between POMS, HRV and BUN variables. The $P<0.05$ criterion was used to establish statistical significance.

3. Results

3.1. Anthropometric characteristics and metabolic values

Table 4 shows the variables concerning the anthropometric and metabolic characteristics of the athletes examined before and after the CET period. There were significantly increasing in the metabolic variables of $\dot{V}O_{2peak}$ and LH after CET.

Table 4. Anthropometric characteristics and metabolic values of the rugby athletes before and after CET

Characteristics	unit	Before training	After training	Change (%)
Age	y	22.7(2.3)	22.7(2.3)	
Height	cm	175.4(5.7)	175.4(5.7)	
Weight	kg	76.5(6.3)	77.2(6.8)	0.92(.67)
Absolute $\dot{V}O_{2peak}$	L/min	3.5(0.6)	4.2(0.7)*	20.7(16.5)
Relative $\dot{V}O_{2peak}$	mL/kg/min	47.8(7.2)	58.6(9.5) *	23.6(16.6)
Works of lactate threshold(4mM)	watts	119.9(49.7)	162.1(54.2)*	40.5(39.1)

Values are expressed as mean (SD). *: P<0.05, vs. before training programs.

3.2. Monitoring parameters responses

Table 5 shows the monitoring parameters during CET. We observed significant reduction in HB and elevation in BUN from T1 to T5, especially during SIT1 and SIT2 periods. Training increased BUN levels (T1, 15.0(2.6) mg/dL vs. T5, 27.9 (2.6) mg/dL, p<.05), LF/HF (T1, 1.44 (0.18) vs. T5, 1.62 (0.19), p<.05) and POMS total mood disturbance (T1, 100.6 (4.5) scores vs. T5, 136.3(12.3) scores, p<.05). There were similarly increasing significantly in HF and LF/HF at T5 (SIT2). POMS levels at T5 were significant differences compared with T1-T3.

Table 5. Responses of physiological and psychological stress markers in the rugby athletes during CET

Parameters	unit	T1	T2	T3	T4	T5
Hb	g/dL	14.1(0.5)	13.9(0.9)	13.6(0.7)	13.1(2.3) [AB]	12.3(1.8) [AB]
Bun	mg/dL	15.0(2.6)	16.3(4.8)	17.6(4.6)	23.8 (5.2) [AB]	27.9 (2.6) [ABC]
HF	ln(ms^2)	5.01 (0.44)	4.81 (0.54)	4.94 (0.61)	5.67 (0.74) [B]	6.48 (0.43) [ABC]
LF	ln(ms^2)	6.62 (0.34)	6.27 (0.62)	6.43 (0.57)	6.63 (0.56)	6.81 (0.36) [B]
LF/HF	ln(ratio)	1.44 (0.18)	1.38 (0.55)	1.46 (0.67)	1.52 (0.72)	1.62 (0.19) [ABC]
Tension	scores	5.0(1.9)	4.7 (2.8)	4.9 (2.7)	6.7 (3.6) [B]	8.7(2.2) [ABC]
Anger	scores	3.0 (1.9)	3.3 (2.5)	3.8 (3.1)	4.3 (2.7) [A]	5.3(2.9) [ABC]
Fatigue	scores	6.0 (2.8)	5.7 (2.9)	6.1(3.5)	7.5 (5.5) [B]	9.1 (4.8) [ABC]
Depression	scores	4.0(1.9)	4.2 (1.5)	4.4 (2.3)	6. 9 (3.9) [ABC]	7.8 (2.8) [ABC]
Vigor	scores	12.5 (3.3)	14.4 (2.1)	14.9 (2.6)	12.7 (4.8) [C]	9.0 (3.2) [ABCD]
Confusion	scores	3.5 (1.5)	3.1 (1.3)	3.7 (1.9)	4.9 (1.9) [B]	6.1 (1.8) [ABC]
Esteem	scores	8.5 (2.3)	8.1 (1.8)	8.4 (2.5)	8.4 (3.1)	8.2 (2.5)
TMD	scores	100.6 (4.5)	98.5 (5.7)	99.5 (6.9)	109.2 (14.8)	136.3(12.3) [ABCD]

Values are expressed as mean (SD). [A]: P<0.05, vs.T1; [B]: P<0.05, vs.T2; [C]: P<0.05, vs.T3; [D]: P<0.05, vs.T4.

3.3. Correlations analysis between physiological and psychological stress monitoring

The BUN and LF/HF were significantly correlated with POMS subscales before and during different CET stages (T1, Table6; T5, Table 7). However, there was only significant association between HF distributions based on TMD.

Table 6. Correlational analysis between physiological parameters and POMS scores before CET (T1).

	Tension	Anger	Fatigue	Depression	Vigor	Confusion	Esteem	TMD
BUN	R=.685 P=.001 *	R=.570 P=.002 *	R=.615 P=.008 *	R=.632 P=.005 *	R=.743 P=.001 *	R=.657 P=.003 *	R=.751 P=.001 *	R=.785 P=.001 *
HF	R=.079 P=.698	R=.276 P=.171	R=.165 P=.420	R=.176 P=.387	R=.123 P=.546	R=.126 P=.539	R=.089 P=.663	R=.795 P=.001 *
LF	R=.519 P=.065	R=.276 P=.171	R=.432 P=.027 *	R=.433 P=.027 *	R=.667 P=.002 *	R=.469 P=.015 *	R=.653 P=.003 *	R=.991 P=.001 *
LF/HF	R=.736 P=.001 *	R=.695 P=.001 *	R=.660 P=.002 *	R=.671 P=.002 *	R=.822 P=.001 *	R=.695 P=.001 *	R=.824 P=.001 *	R=.910 P=.001 *

*: P<0.05

Table 7 Correlational analysis between physiological parameters and POMS scores at the end of CET (T5).

	Tension	Anger	Fatigue	Depression	Vigor	Confusion	Esteem	TMD
BUN	R=.720 P=.001 *	R=.442 P=.031 *	R=.471 P=.015 *	R=.553 P=.003 *	R=.586 P=.001 *	R=.627 P=.006 *	R=.610 P=.009 *	R=.943 P=.001 *
HF	R=.297 P=.140	R=.066 P=.746	R=.088 P=.667	R=.132 P=.518	R=.088 P=.666	R=.237 P=.243	R=.189 P=.355	R=.739 P=.001 *
LF	R=.683 P=.001 *	R=.376 P=.057	R=.375 P=.058	R=.487 P=.011 *	R=.512 P=.007 *	R=.582 P=.001 *	R=.588 P=.001 *	R=.965 P=.001 *
LF/HF	R=.769 P=.001 *	R=.607 P=.001 *	R=.541 P=.004 *	R=.717 P=.001 *	R=.697 P=.001 *	R=.763 P=.001 *	R=.770 P=.001 *	R=.969 P=.001 *

*: P<0.05

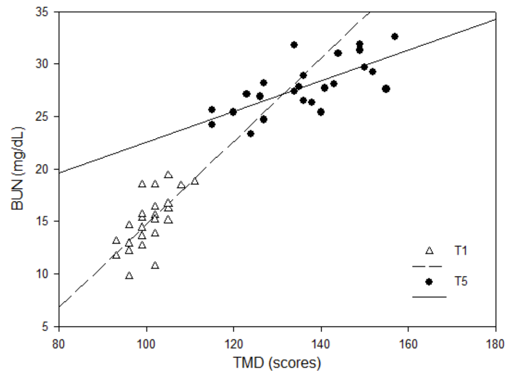

Figure 1. Relationship between the BUN and TMD changes in POMS before (T1) and during (T5) CET.

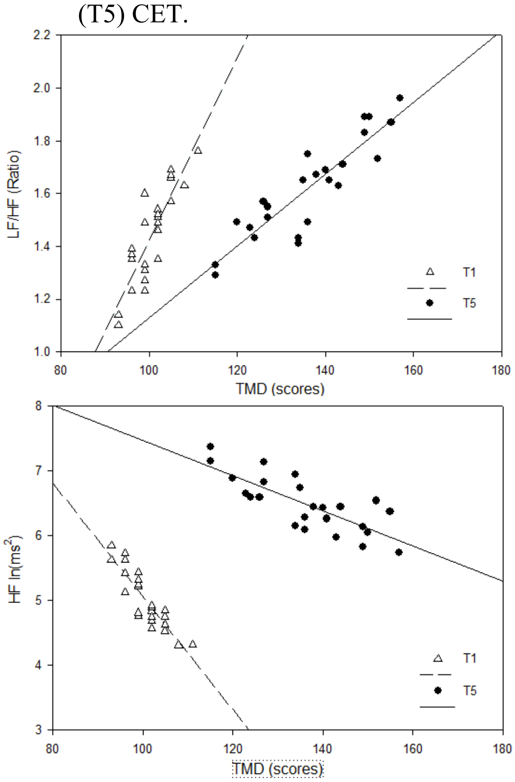

Figure 2. Relationship between the LF/HF ratio, HF and TMD changes in POMS before (T1) and during (T5) CET.

Discussion

The amount of red blood cells (erythrocytes) in the blood of an athlete can have a great impact on performance during both training and competition, particularly for an endurance athlete. Red blood cell content in the blood can be described as the balance between red cell production (erythropoiesis) and red cell destruction (hemolysis). The higher the red cell count in the blood, the better the oxygen-carrying capacity to the exercising muscles. Although endurance training is most often associated with improved oxygen-carrying capacity, intensive training can also induce a substantial hemolysis. This, along with iron stores that are often compromised because of excessive training or poor nutritional habits, may endanger the hematological status of endurance athletes. In this section, the potential benefits of a taper in terms of enhancing an athlete's hematological status and iron stores are discussed. Hematological changes strongly suggest that the training reductions usually applied during the taper facilitate a positive balance between erythropoiesis (i.e., red cell production) and hemolysis (i.e., red cell destruction), which contributes to taper-induced performance improvements. However, increased red cell production could compromise the iron status of athlete because erythropoiesis requires significant iron.

Serum BUN levels increase significantly after intermittent exercise. It means that intermittent exercise may induce renal dysfunction during vigorous exercise. In the present study, serum BUN elevated clearly during SIT1-SIT2, In spite of signals of muscle injury and degradation of somatic tissue proteins. It is possible that the reduced water intake caused concentrated BUN level in blood in the subjects due to increased urination.

When high-intensity exercise is performed, there may be an imbalance between the energy supply and the demand for ATP, eventually leading to the formation of BUN. BUN is also produced when muscle protein reserves are broken down and oxidized during exercise, especially when carbohydrate availability is limited. Blood BUN concentration could be used as a stress marker of the muscles' ability to produce ATP from ADP and also as evidence of increased protein degradation during times of increased training stress.

Many studies have reported that highly intensive exercise causes protein catabolism in blood or tissues. The current result showed that protein catabolism were greater in the SIT than in the ET2 (lactate threshold). One of the objectives of this study was to clarify the relationship between physiological stress (blood biochemical/physiological parameters) and mental fatigue (POMS) caused by physical activity during a series CET. Therefore, our results show that the ET2-CET built up athletes' experiences of physiological stress, mental fatigue and more effective protein catabolism than baseline. These latter results may due to the different styles of training modes of high intensity intermittent training.

However in the stages of SIT1-SIT2, mental fatigue is likely to be influenced by protein catabolism, energy metabolism, degeneration, and injury to muscle tissue. The athletes tolerated intense muscular impact at a high frequency. These results suggest that (a) playing in W_{LH} ET2-CET caused athletes both physical/mental fatigue and new balance adaptation,

(b) the training modes related difference activity were responsible for differences degrees in physical/mental fatigue during CET sessions and (c) health management during a rugby CET periodization is very important for the athletes and should be tailored to each athlete's performance. In the ET2-CET, where metabolism and energy consumption are associated with mental fatigue, ingestion of some quickly acting energy source is thought to be important to adjust recovery from fatigue. In SIT1-SIT2, protein catabolism, degeneration of muscle tissue, and injury are associated with long-term higher metabolic rate and mental fatigue as well as energy metabolism and consumption. We might supply proteins with the energy source and suggest as an effective modes to accelerate recovery from training-evented fatigue.

Psychological condition was modulated during CET. Psychological stress in rugby CET is not only the intensity of the exercise, but also to the athletes' satisfaction with their own performances probably. Therefore in this study the athletes' psychological states may have been affected by the training loads. Thus future studies should apply these results to the series training from pre-season to in-season. However, a decreased POMS tension scores were significant in only the subjects whose rest incorporated low intensity exercise. This result is in accordance with previous findings, that moderate exercise enhances relaxation an decreases psychological stress. Therefore incorporating low intensity exercise into the rest period after CET may achieve better psychological recovery in the athletes. With regard to the psychological responses, POMS questionnaire has been widely applied to investigate the relationship between mood state and athletic performance. Experimental studies with athletes have shown that physical activity can both improve and decrease the POMS scores. Morgan [9] defined the typical athlete profile of the POMS as the "iceberg profile". In the "iceberg profile", the athletes score below the 50th T score on tension, depression, anger, fatigue and confusion and above the 50th T score on vigor in comparison with other subjects. In our study, as noted by other authors, the athletes presented a typical "iceberg profile" over the training program. We also verified a reducing of the fatigue score from T1 to T2, which coincided with the best team performance.

Therefore, we believe that the athletes presented positive adaptations in response to the training program developed between T1, T2 and T3. The vigor scores decreased in T4 and T5 compared to T1 and T2. It response corresponded exactly to the worst physiological conditioning. The descent in the vigor scores may be explained either by the increase in intensity of training and protein catabolism. Higher BUN concentrations and correlation could prove. We find the decrement in the team performance affected the athletes' mood. In respect to the serum BUN response to the CET program, our athletes presented a rise in T4 compared to T1. Kumae et al. [10] did not observe alterations in the serum BUN concentrations in response to an increment in training volume during four weeks in experienced middle and long distance runners. Kumae et al. did not verify changes in the serum BUN of experienced sessions of distance runners (one with increase in the training volume and one with increase in the training intensity) during four weeks either. Besides the difference between the sports modalities used by us and by Kumae et al.'s studies, during training stages in which our subjects presented a rise in the serum BUN concentrations, there was an increment in both volume and intensity (i.e. SIT1-SIT2) of CET (Table 3). In our study, the serum BUN concentrations did not demonstrate any changes in response to the training program.

It is likely that the parasympathetic nervous system is altered in OTS, but specific biomarkers remain to be identified. Changes in heart rate at rest, reduced maximal heart rate during exercise, and changes in HRV, that is, the beat-to-beat changes of the heart, have all been noted as signs of OTS. An increase in resting heart rate has been reported in athletes' OTS, but these findings are not consistent and have not been confirmed in prospective studies. Likewise, we observed HF and LF/HF elevations reflecting higher sympathetic nervous system activity from CET. Studies examining the effects of CET on HRV in athletes are confusing because studies had shown no significant change in parasympathetic modulation until T5. Investigations of HRV in OR or in OTS has been limited[2], but if methodologies are standardized, HRV may be a potential, noninvasive tool for forecasting OR and the development/progress of OTS.

In the highly selected athletes of this study, we observed an effect associated with marked increases in the HF and LF/HF ratio; and decreases in the LF component of HRV. These findings of the studies would confirm that athletes enhances vagal and sympathetic cardiac modulation after CET. Sympathetic vasomotor control also did change from baseline, as indicated by significant variations in the LF component. However, when the training load approached the SIT2 period, neural cardiovascular regulation showed a clear increasing shift from vagal to sympathetic predominance, with concordant changes in hemodynamic variables and in cardiac and vascular indices of autonomic modulation.

The possibility that the increased markers of sympathetic activation would represent an trend of the daily intermittent exercise, because athletes did train vigorously from at least 15 hours before the recording sessions and signs of enhanced sympathetic activation were detected in the recordings sessions performed with the same experimental schedule at supra-maximal training load. Finally, short-term overtraining in athletes did not alter frequency domain indices of HRV. Our results suggested that enhanced sympathetic activation and attenuated vagal inhibition could represent the neuro-vegetative adaptation for increasing athletic performance. Increasing the inhibitory influences of vagal mechanisms while coexistent enhancing sympathetic activity might serve to prepare the cardiovascular system to the rapid and wide, even anticipatory, variations in heart rate, cardiac output, blood flow redistribution, and muscle microvesscular perfusion of highly performing. Power spectral analysis of short-term HRV might represent a valuable tool to assess the time course of neurovegetative cardiovascular adaptations to CET.

Meeusen, *et al* [11] concluded three factors predominate the prevention of OT. There are (a) that the structure of the training programs must allow adequate regeneration and recovery; (b) the training programs must incorporate monitoring of OT symptoms; and (c) that the normal fatigue associated with training is not confused with that associated with OT. Periodization of training is important in order to allow for performance monitoring, training modification and to avoid training monotony[9]. Intensive training in short bursts with frequent intermittent modes, and sudden increases in training load should be avoided. But team sport training generally involves a diverse range of training activities, often under quite variable environmental conditions, as well as interindividual variability in the responses and adaptations to training. These issues complicate the integration of training variables into quantifiable units.

The main limitation of this study is the lack of a control group. However, this would be more a theoretical than an actual methodological limitation within the framework of our investigation. The ideal protocol of CET with a crossover design is virtually impossible in all levels athletes. A final potential limitation of this study includes the indirect testing autonomic function by HRV.

CET elevated biological stress increasing BUN, POMS scores and HRV modulation. According to training loads periodization, there are strong correlations among training load and physiological/psychological stress. CET should be significantly modified sufficiently physical conditioning, maintained to provide adequate stimuli and altered the neural mechanisms of cardiovascular regulation shifted the cardiovascular autonomic modulation from a parasympathetic toward a sympathetic predominance with enhanced sympathetic activation and reduced vagal inhibition.

In conclusion, the results of this study indicate that 8 weeks periodized CET would increase aerobic performance and strengthen cardiovascular regulation in rugby athletes. A noninvasive monitoring method could be developed by POMS highly correlated HRV and BUN for physiological controlling in periodization.

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