Original Article

Post-exercise heart rate variability recovery after 800-m endurance run load among Cameroonian adolescent's males

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ABSTRACT

The 800-m (m) run is part of Physical Education classes in Cameroon, after which arrhythmias may occur during recovery. Hence, this study aimed at determining relationship between 800-m run loads on cardiac autonomic recovery among school adolescents.

Forty-two male adolescents (aged [17 ± 1] years) performed 800-m. Post-exercise heart rate variability (HRV) was recorded during 5-min (min) ($HRV_{5\text{-min}}$) and 15-min ($HRV_{15\text{-min}}$) in time: Standard deviation of normal to normal (SDNN); Root mean square of successive differences (RMSSD) and frequency domain (LH: Low frequency, HF: High frequency, TP: Total power). Rating of Perceived Exertion (RPE) and blood lactate concentration (BLa) were measured after exercise. In $HRV_{5\text{-min}}$, RPE was associated with SDNN ($r = -0.44$, $p < 0.01$) and RMSSD ($r = -0.38$, $p < 0.05$). BLa was correlated with SDNN ($r = -0.38$, $p < 0.05$) and RMSSD ($r = -0.56$, $p < 0.001$) in the time-domain, LF ($r = -0.64$, $p < 0.001$), HF ($r = -0.58$, $p < 0.001$) and TP ($r = -0.61$, $p < 0.001$) in frequency-domain. Moreover, RPE was correlated with LF ($r = -0.44$, $p < 0.01$), TP ($r = -0.49$, $p < 0.01$) while exercise duration with HF ($r = -0.38$, $p < 0.05$). In $HRV_{15\text{-min}}$, BLa was correlated with RMSSD ($r = -0.53$, $p < 0.001$) and SDNN ($r = -0.68$, $p < 0.001$). RPE was negatively correlated SDNN ($r = -0.53$, $p < 0.01$) and RMSSD ($r = -0.44$, $p < 0.01$). BLa was associated with HF ($r = -0.55$, $p < 0.001$), TP ($r = -0.50$, $p < 0.01$) and RPE with LF ($r = -0.51$, $p < 0.01$), HF ($r = -0.50$, $p < 0.01$), TP ($r = -0.49$, $p < 0.01$). In addition, exercise duration was negatively linked to HF ($r = -0.36$, $p < 0.05$). This study outlined that in untrained adolescents an increase of 800-m loads is associated with a slow vagal indexes of HRV during the recovery.

1. Introduction

Regular practice of dynamic exercise improves and maintains physical fitness, overall health and well-being of adolescents through strengthening muscles and the cardiovascular system, honing athletic skills, weight loss or maintenance, fighting against addictive practises as well as for enjoyment.[1] Dynamic exercise is regulated by the autonomic nervous system (ANS) which induces marked changes in heart rate (HR) via either inhibition of parasympathetic tone or stimulation of sympathetic tone, thereby slow downing or accelerating HR, respectively.[2,3]

During a sustained exercise, HR raises in response to sympathetic activation and cardiodeceleration deactivation, whereas after exercise HR recovery occurs in response to simultaneous progressive

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Abbreviations	
ANS	Autonomic nervous system
HR	Heart rate
HRV	Heart rate variability
PE	Physical Education class
BMI	Body mass index
BP	Blood pressure
RPE	Rating of Perceived Exertion
BLa	Blood lactate concentration
RR	Mean time between normal R waves of ECG
RMSSD	Root mean square of successive differences
SDNN	Standard deviation of normal to normal
LF	Low frequency
HF	High frequency
TP	Total power
HRV_{5-min}	minutes of heart rate variability recording
HRV_{15-min}	15 min of heart rate variability recording

cardioacceleration deactivation and a rapid parasympathetic reactivation., It is therefore reasonable to expect that these autonomic changes are dependent on the cardiac autonomic responsiveness, and that adaptive chronotropic changes to exercise-induced stress display this cardiac autonomic modulation and this depends on the intensity of exercise. During recovery after maximal exercise, HR decreases mainly because of parasympathetic reaction control while sympathetic control remains practically unchanged.[4,5]

Such interplay between sympathetic and vagal regulation of HR usually occurs during common autonomic challenges such as endurance exercises.[6,7] The continuous assessment of ANS activity is possible by studying heart rate variability (HRV) which is considered as a standard, reliable and non-invasive approach. Post-exercise HR or HRV recovery is positively correlated with the sympathetic responsiveness during stress and its slow reduction and overall autonomic modulation of HRV.[8]

High values of HRV are generally interpreted as good indicator of increased of parasympathetic branch of ANS.[9] It is well established that high cardiac vagal tone increases electrical stability of the heart[9–11] and various HRV reduction had been shown to be predictive of cardiac mortality and morbidity.[12,13] Physiological justification for this protective effect often invokes a key role for the ANS, in particular the parasympathetic branch.[9]

Physical Education class (PE) is an activity universally implemented in countries education systems all over the world. Its positive effects on health and school performances are well documented.[14] Physical Education consists in practicing different physical exercises comprised mainly of races (e.g., speed, endurance), which are very strenuous in energy and associated with cardiovascular adaptation.[15] Regarding the latter aspect, profound HR changes are commonly appear during endurance race related PE and physical training interventions.

In Cameroon, 800-m endurance races are included in the School-time PE program and national examinations. In practice, during evaluation and teaching session endurance races are perceived by schoolchildren as physically-exhausting and strenuous, and thus are generally performed at the end of PE session.[16] Occurrence of deleterious cardiovascular events, such as sudden cardiac death, in schoolchildren during PE related endurance races have been noticed these last years in the Cameroon. It is commonly known that cardiovascular events mostly arise during post-exercise recovery phase.[17–20] Likewise, a study previously reported the appearance of several life-threatening cardiac rhythm and conduction disorders among school adolescents during recovery phase after endurance run.[21]

Several authors outlined the clinical value of measuring autonomous function during post-exercise recovery phase for prognostic of cardiovascular disorders. It was showed that delayed cardiovascular autonomic recovery was associated with cardiovascular events in general population.[22–24] Therefore, parasympathetic recovery, after exercise test, is studied as an important indicator of prognosis and mortality.[25,26]

In adolescents, behavior of cardiovascular autonomic regulation during recovery is still elusive, especially in those performing 800-m endurance races at school. However, available data in adolescents pointed out that low HRV was strongly associated with a cluster of cardiovascular risk factors[27] while delayed of post-exercise parasympathetic reactivation was a powerful marker of arrhythmias.[28–31] Post-exercise HRV recovery depends on many parameters as the type of exercise,[32] training[33] modalities, and exercise intensity.[34,35] It is in this context of post-exercise arrhythmias and recovery disorders that, the present study was designed to analyze association between 800-m run load and post-exercise HRV recovery among Cameroonian male schoolchildren.

2. Materials and methods

2.1. Participants

This study took place at a local government high schools in the town of Douala, Cameroon. Forty-two male active adolescents practicing PE regularly non-trained in 800-m, took part in the study. Students with documented cardiovascular or respiratory disorders, and under medication were not included. Prior to field experimentations, parents/tutors of adolescents and school administration staff were informed about the aim, specific objectives and procedures of the study. Participants were asked to hydrate at least 4 h after the last meal, and avoid any strenuous exercises and consumption of coffee and alcohol beverages within 24 hours (h) before field experimentation.[36] Experimentations were carried out between 4.00 p.m. and 5.00 p.m. at ambient temperature of 20–23 °C to control the influence of circadian rhythms.

2.2. Ethical approval statement

Adolescents were carefully informed about the experiment procedures and an appropriate signed informed consent document was gave by their parents/legal tutors. The study was approved by the University of Douala Institutional Ethic Committee for Human Research (NO: 1177CEI-UDo/11/2017/T). The protocol was complied with the human and animal experimentation policy statement guidelines of the American College of Sport Medicine and in accordance with the Helsinki Declaration as amended in Seoul in October 2008.

2.3. Experimental procedures

The experimental protocol consisted of mimicking the processes of evaluation of school adolescents during PE session with 800-m. The protocol was performed on a closed track of 200 m by two investigators, one located at the starting block and the other one at the arrival. Participants were invited to perform the protocol starting with free warm up majority constitutes by stretching and low run then followed by 800-m endurance run. Participants were grouped (two participants in each group) and encouraged by investigators during endurance race to obtain best performances. Upon ending the race, each adolescent was asked to recover in supine position for 15 min without chattering or carrying out abrupt movements in order to make stable parasympathetic reactivation and HRV signal in accordance to the Task Force recommendations.[9]

2.4. Parameters measurement

2.4.1. Anthropometry and blood pressure

Weight, percentage of fatty mass were measured using an electronic impedancemeter scale (Tanita BC-532, Kyoto, Japan) and body mass index
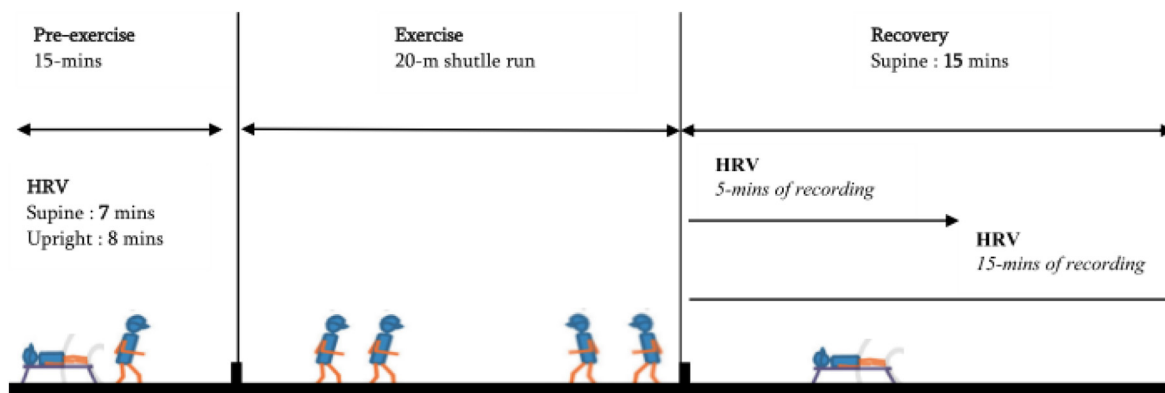
Fig. 1. Protocol of the study m: meter, min: minutes, HRV: Heart rate variability.

Table 1

Age, anthropometric and hemodynamic characterization and exercise characteristics of participants.

Parameters	Mean ± SD
Age (years)	17 ± 1
Height (cm)	169.5 ± 8.6
Weight (kg)	58.4 ± 8.1
Body fat (%)	8.32 ± 3.84
BMI (kg/m^2)	20.3 ± 2.3
SBP (mmHg)	118 ± 11
DBP (mmHg)	71 ± 8
HR$_0$ (bpm)	79 ± 3
Exercise characteristics	
Distance (m)	800
RPE	13 ± 1
Exercise duration (s)	205 ± 26
Speed (m·s^{-1})	3.96 ± 0.49
BLa (mmol·L^{-1})	10.8 ± 4.1
HR peak (bpm)	197 ± 10

SD: Standard deviation; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR$_0$: resting heart rate, RPE: Rating of Perceived Exertion; BLa: Blood lactate concentration.

Table 2

Correlation between exercise load and HRV$_{5\text{-min}}$.

	BLa (mmol·L^{-1})	RPE	Exercise duration (s)
Time-domain			
RR (ln ms)	−0.47**	−0.27	0.22
SDNN (ln ms)	−0.38*	−0.44**	−0.40**
RMSSD (ln ms)	−0.56***	−0.38*	0.16
Frequency-domain			
LF (ln ms^2)	−0.64***	−0.44**	−0.23
HF (ln ms^2)	−0.58***	−0.39*	−0.38*
TP (ln ms^2)	−0.61***	−0.49**	0.20

BLa: Blood lactate concentration; RPE: Rating of Perceived Exertion; RR: mean time between normal R waves of ECG; RMSSD: Root Mean Square of successive differences; SDNN: Standard Deviation of Normal to Normal; LF: Low Frequency, HF: High Frequency, TP: Total Power; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

2.4.3. Rating of Perceived Exertion (RPE), performance and blood lactate concentration (BLa)

Perceived exertion of the protocol was evaluated using the Borg's rating perceived exertion 6–20 scale.[39] A subjective verbal-anchored scale was shown to the participants after completion of the 800-m endurance run. Performance was recorded in seconds. BLa was measured between the third and the fifth minute after exercise in accordance of the recommendation[40] using a Lactate Scout (SensLab GMBH, Germany).

2.5. Statistical analysis

Statistical analyses were performed using StatView 5.0 software (SAS institute, Inc., USA). Values were expressed as mean ± standard deviation (*SD*). The natural logarithm transformation (ln) was applied for absolute HRV parameters and to meet the normality requirements of parametric statistical analysis. Pearson's correlation coefficient was used to study link between BLa, rating perceived exertion (RPE), exercise duration (performance), and post-exercise HRV parameters. The student *t*-paired test was performed to compare means of HR and HRV components at each study phase of recovery. Statistical significance was set at *p*-value < 0.05.

3. Results

Mean values of participants' anthropometric and hemodynamic parameters are presented in Table 1.

Correlations between BLa, RPE, performance and post-exercise HRV HRV5-minare presented in Table 2 outline a significant correlation between exercise load and post-exercise HRV parameters in time-domain. Thus in HRV5-minof time-domain, RPE, exercise duration and BLa were negatively correlated with RR and SDNN ($p < 0.05$).

(BMI) calculated. Blood pressure (BP) was measured before the race and after a resting period of 15 min using a BP monitor, Omron M6 (Kyoto, Japan).

2.4.2. Heart rate variability

HR (The R-R interval) series were recorded continuously using a valid and reliable heart rate monitor Polar RS800CX (Electro Oy, Kempele, Finland) with a sampling rate of 1 000 Hz.[37] Before exercise, HR was recorded according to the recommendations of the task force, i.e. 7 min on supine position and 8 min on standing without movement (Fig. 1). The R-R interval series recorded data were extracted from a computer using the processing program Polar Protrainer 5.1 (Polar Electro, Kempele, Finland) and occasional ectopic beats (irregularity of the heart rhythm involving extra or skipped heartbeats; extra systoles and consecutive compensatory pause) were visually identified and manually replaced with interpolated adjacent HR interval values. Following data transfer, HR curves were exported in text format to Kubios HRV v2.2 (Biosignal Analysis and Medical Imaging Group, Joensuu, Finland)[38] for the analysis of R-R intervals in time and frequency-domain. Recovery related to post-exercise HRV was studied during 5 min (HRV$_{5\text{-min}}$) and 15- min (HRV$_{15\text{-min}}$) according to recommendations of task force of 1996.[9] The kinetic of HR and HRV recovery was studied 5-min immediately after the run and 10-min (5-15-min) after the previous phase of recovery.

Table 3
Correlations between exercise load and post-exercise $HRV_{15\text{-min}}$.

	BLa (mmol·L^{-1})	RPE	Exercise duration (s)
Time-domain			
RR (ln ms)	−0.52**	−0.40*	0.22
SDNN (ln ms)	−0.68***	−0.53**	−0.11
RMSSD (ln ms)	−0.53**	−0.44**	0.16
Frequency-domain			
LF (ln ms^2)	−0.49**	−0.51***	−0.15
HF (ln ms^2)	−0.55***	−0.50**	−0.36*
TP (ln ms^2)	−0.50**	−0.49**	0.37

RPE: Rating of Perceived Exertion; BLa:Blood lactate concentration; RR mean: mean time between normal R waves of ECG; RMSSD: Root Mean Square of successive differences; SDNN: Standard Deviation of Normal to Normal; LF: Low Frequency, HF: High Frequency, TP: Total Power; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

A strong negative correlation was found between RMSSD and BLa ($p < 0.001$); exercise duration and SDNN ($p < 0.01$). Likewise, BLa was strongly associated with LF, HF and TP in frequency-domain ($p < 0.001$). In addition, RPE was negatively linked to LF and TP ($p < 0.01$) while exercise duration were negatively associated with HF ($p < 0.05$).

The correlations between BLa, RPE, performance and $HRV_{15\text{-mins}}$ post-exercise HRV recovery are summarized in Table 3. In time-domain, negative significant ($p < 0.01$) correlations were found between BLa and RR, and RMSSD. Moreover, BLa was strongly associated with SDNN ($p < 0.001$) while RPE and SDNN were correlated ($p < 0.01$). In frequency-domain, BLa and RPE were negatively associated ($p < 0.01$) to LF and HF and TP. In addition, exercise duration was slightly correlated with HF ($p < 0.05$).

The recovery kinetic of post-exercise HR and HRV in time-domain as illustrated in Fig. 2 shows a significant ($p < 0.001$) recovery of HR and HRV after exercise. HR at 5- and 5-15-min post-exercise significantly ($p < 0.001$) decreased than the one reported at after 800-m run. On the other hand, RR, SDNN and RMSSD at 5-min and 5–15 min increased ($p < 0.001$) compared to that observed immediately after exercise.

Fig. 3 depicts kinetic of post-exercise recovery HRV in frequency-domain. LF, HF and TP recorded at 5-min and 5–15 min of recovery were significantly ($p < 0.001$) high compared to that noticed immediately after exercise ($p < 0.001$). These parameters of HRV in time and frequency domain increased ($p < 0.05$) after 800-m run during the recovery without reaching pre-exercise values.

4. Discussion

We aimed to determine the effect of 800-m loads on post-exercise cardiac autonomic recovery and its kinetic among school adolescents in Douala, Cameroon.

Findings outline that BLa and RPE were negatively correlated with post-exercise HRV, and this is in accordance with previous authors.[41–46] Kaikkonen et al.[46] assessed the effects of training loads on post-exercise 3-min HRV among athletes, and reported strong and negative correlation between HRV, BLa and RPE. Likewise, we found a negative correlation
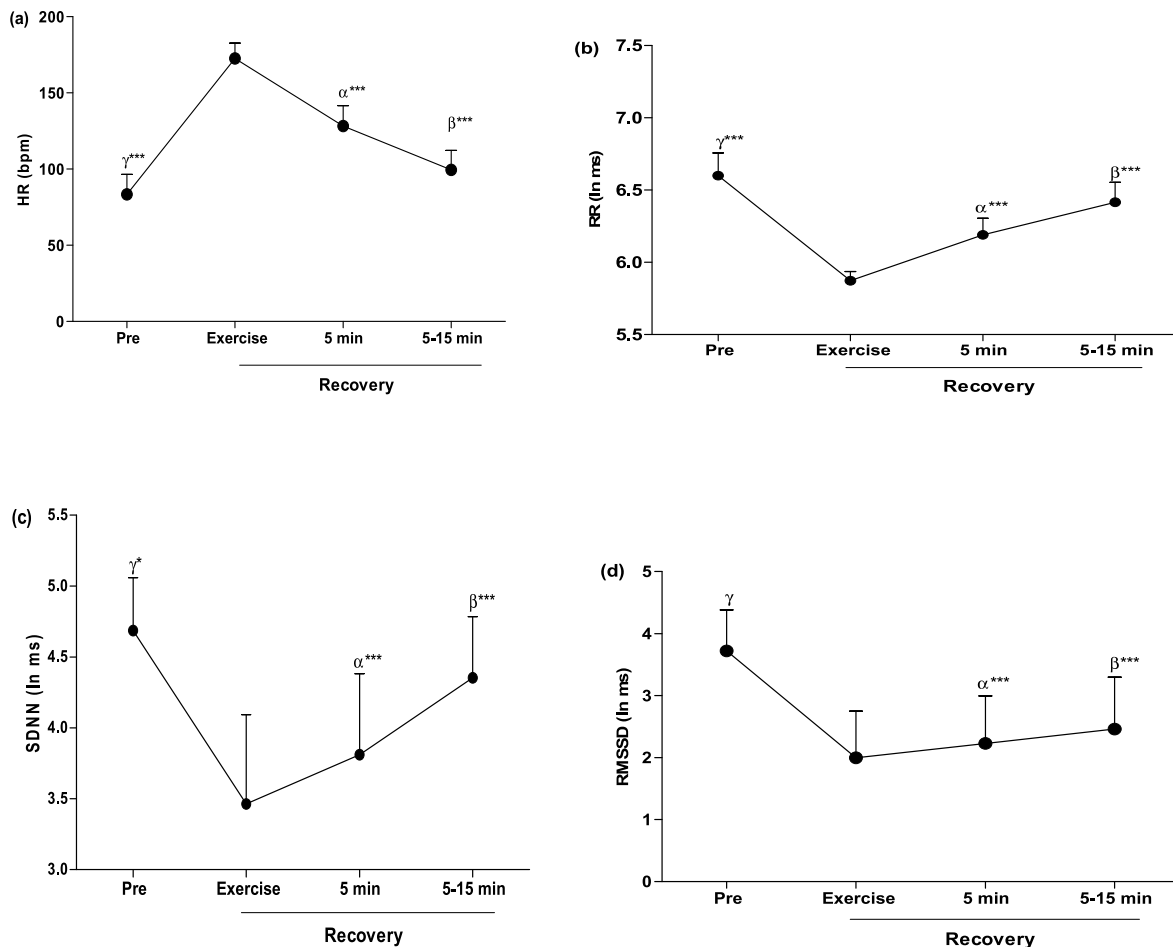

Fig. 2. The recovery kinetic of time-domain of HRV. (a): HR, (b): RR, (c): SDNN and (d): RMSSD. HR: heart rate, RR mean: mean time between normal R waves of ECG; RMSSD: Root Mean Square of successive differences; SDNN: Standard Deviation of Normal to Normal. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. α: comparison between end of exercise and 5-min post exercise, β; comparison between 5-min and 5-15-min post exercise, γ: comparison between pre exercise and 5-15-min post exercise.
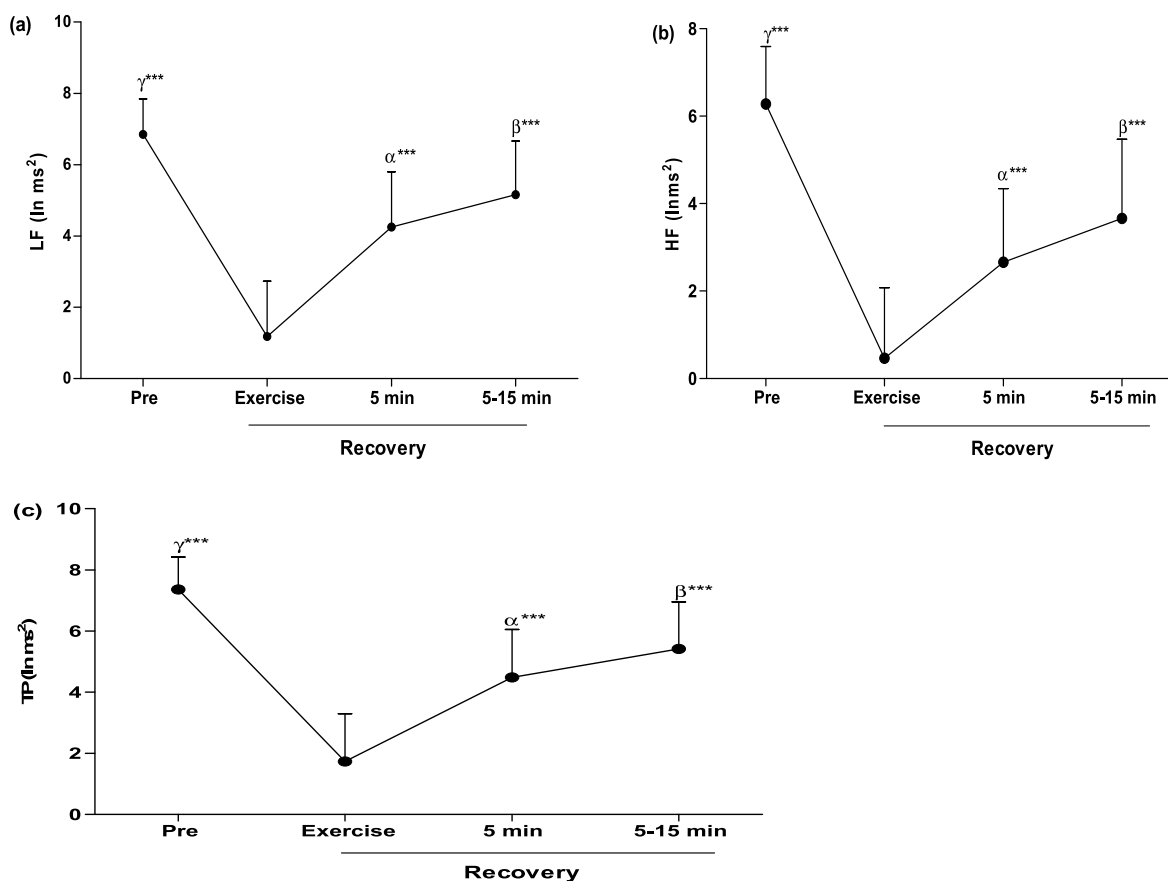
Fig. 3. The recovery kinetic of frequency-domain of HRV (a): LF, (b): HF, and (c): TP. LF: Low Frequency, HF: High Frequency, TP: Total Power, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, α: comparison between end of exercise and 5-min post exercise, β: comparison between 5-min and 5-15-min post exercise, γ: comparison between pre exercise and 5-15-min post exercise.

between BLa and 15-min of HRV as did Al Haddad et al.[47] on nocturnal HRV after a supramaximal intermittent exercise. These findings suggest that BLa could be an interesting physiological and metabolic marker that slow HRV during post-exercise recovery of 15-min.

Negative associations were found between exercise duration and post-exercise short- and long -term HRV in time-domain (SDNN) and frequency-domain (HF). Some authors stated that increase in duration of moderate to high intensity exercise could elicit slow recovery of parasympathetic reactivation-related short/long term of HRV recording.[44,48] However, it should be noted in the present study the absence of real competition between students during the protocol as observed during their evaluation process during PE would have highlighted important associations between physical performance and HRV following to acute cardiovascular adaptations constitutes a limitation to this study.

Most of statistically significant correlations between exercise characteristics and post-exercise HRV were seen in frequency domain. This confirms previous investigations that largely used frequency domain as proxy parameter for evaluating post-exercise cardiac autonomic recovery. Moreover, frequency-domain based HRV analysis is commonly used to appraise changing conditions and physiological tasks such as exercise test and recovery.[49]

RPE, BLa and exercise duration post-exercise were negatively associated to components of HRV (LF, HF and TP) which is probably related to increased sympathetic activity.

Physiologically, this result would be related to exercise load which is closely linked to the exponential elimination of metabolites resulting from the catabolism of energy substrates in the muscles associated with a slow decline in circulating cortisol and catecholamine concentration during post-exercise recovery. This is followed by a subsequent decrease in vagal indices. In addition, exercise intensity has been found to influence HRV both during and after immediate exercise[41,43] and HRV$_{15-mins}$ recovery.[42,49,50] Other mechanisms that may help explain the negative association between exercise intensity and HRV during the recovery phase in the present study is the recovery pattern of baroreflex sensitivity. Post-exercise recovery of set point and baroreceptor sensitivity is closely related to increased parasympathetic nervous system activity immediately after exercise cessation.[51,52] It is established that post-exercise baroreflex recovery is also influenced by exercise intensity.[52] It should be noted that the increase in intensity during exercise results in significant metabolite production which could delay baroreflex recovery by increasing the baroreflex set point with a detrimental effect on HRV recovery.[53]

Findings from the present study seem to indicate that exercise intensity can be a major factor shaping post-exercise HRV during immediate or HRV$_{15-mins}$ recovery in Cameroonian adolescents. Indeed, on time domain analysis, HRV vagal indices were significantly increased during 15-min recovery, and this is in line with results of Gladwell et al.[54] in young healthy non-trained females, and Buchheit et al.[55] in trained adolescents during 5-min recovery. Regarding frequency domain analysis, 5- and 15-min HRV values were significantly higher than that noted at the end of exercise. Similar results were reported in untrained individuals.[49,54] Whatever an aerobic exercise testing in children or adolescents can make acute adaptation on ANS. But it's important to see effect exercise intensity on parasympathetic recovery, because a slow parasympathetic reactivation after a sub-maximal/maximal can because of cardiac electric conduction troubles that can harm adolescent health.

Despite negatives association between marker of 800-m run intensity, significant parasympathetic reactivation was observed in both time and frequency domain HRV during recovery phase (Figs. 2 and 3). It is well known that physiological mechanisms, mainly loss of central command

and baroreflex activation, selecting for fast changes in cardiac autonomic modulation occur in cardiac pre-load and contractility immediately after physical exercise is completed.[55–59] Early increased vagal activation during recovery is associated with inhibition of sympathetic autonomic system which is predominant contributors to early HRV recovery,[2,60] associated to the fast decrease of plasma cortisol and catecholamine's which have been produced to make in place physiological and metabolic adaptations due to exercise. Besides, recovery position could also explain this finding. It was documented that supine position, used in the present study, can speed up parasympathetic reactivation.[61]

5. Conclusion

The practice of PE in order to preserve its beneficial effects on health in adolescence is crucial, especially the practice of endurance races. However, aerobic exercise in adolescents makes acute physiological adaptations on ANS which must quickly be restored a few minutes after the cessation of an effort. Therefore, from the perspective that endurance races do not have adverse effects on the health of adolescents, this study has shown that psychological (RPE) metabolic (BLa) parameters of 800-m and exercise duration were negatively associated with post-exercise cardiac autonomic recovery. An increase in these parameters shows a slow vagal indexes recovery. Thus, 800-m endurance race loads could be significant factors modulating post-exercise HRV recovery in adolescents.

6. Limitations

The present study did not take into account the gender, competitive, physical performance, and the training aspects of adolescents on post-exercise neurovegetative regulation. For future studies it would be important to look for eventual links between cardiac morpho-functional changes using ECG and the kinetics of HRV recovery for identifying factors likely to be causes of a slow parasympathetic reactivation and how HRV kinetic differ between the youth with different activity or fitness levels.

Submission statement

All authors have read and agree with manuscript content and their position. The manuscript has not been published and is not under consideration for publication elsewhere.

Ethical approval statement

Participants gave informed consent document signed by their parents/legal tutors. The study was approved by the University of Douala Institutional Ethic Committee for Human Research (N°: 1177CEI-UDo/11/2017/T). The protocol was complied in accordance with the Helsinki Declaration as amended in Seoul in October 2008.

Authors' contributions

MNJ: conceived the study, collected data, performed the data analysis, interpreted the results and drafted the manuscript. ET, LGG, WM: Collected datas, BLEC: performed the data analysis and drafted the manuscript, KFLP, CNO: performed data analysis, proofread English language, and revised manuscript for important intellectual content, GWR: drafted the manuscript; GLG, MMW: collected data; CAA, JG, BN, NOC: drafted the manuscript; ANPB, TA, supervised the study and draft the manuscript; BB, FR, MSH conceived et supervised the study.

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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