Effects of light-emitting diodes phototherapy on autonomic modulation of footballers

http://dx.doi.org/10.11606/1807-5509201700010015

Ricardo Santos OLIVEIRA*
Solange de Paula RAMOS**
Ivan Frederico Lupiano DIAS**
Dari OLIVEIRA FILHO**
Fábio Yuzo NAKAMURA**

*College of Life and Environmental Sciences, University of Exeter, Exeter, United Kingdom of Great Britain and Northern Ireland.
**Centro de Educação Física e Esporte, Universidade Estadual de Londrina, Londrina, PR, Brasil.

Abstract

The aim of the study was to analyze the effects of LED therapy during a training week on parasympathetic modulation and perceived stress in soccer players. Eighteen soccer players participated in this study (age: 21.2 ± 2.6 years; body mass: 73 ± 7.2 Kg; height: 178.0 ± 6.2 cm). Pre and Post one training week, the rested heart rate and subjective perceived stress through daily analysis of life demands for athletes (DALDA) questionnaire were assessed. During this week, athletes were randomized into two groups: LED phototherapy (LED) and placebo (PLA). The treatment with LED phototherapy was applied daily on four points in lower limbs quadriceps and hamstring muscles after the last training session. The treatment was performed in a double-blind fashion. ANCOVA with repeated measures was applied to analyze the effects of treatment on autonomic modulation. The training performed by both groups was similar regarding intensity and duration. Likewise, there was no difference between groups for the internal load. We observed a time effect for the RR intervals (Mean RR - LED: Pre=1033.4 ± 150.7ms Post=1056.7 ± 114.8ms; PLA: Pre=962 ± 150.8ms Post=1016.8 ± 173.5ms), standard deviation of the mean RR intervals (SDNN - LED: Pre=101 ± 37.3ms Post=92.3 ± 27.5ms; PLA: Pre=97.5 ± 34.9ms Post=108.7 ± 16.4ms), and low and high frequency ratio (LF/HF- LED: Pre=1.7 ± 0.7 Post=1.4 ± 0.6; PLA: Pre=3.7 ± 3.4 Post=3.4 ± 2.1) for both groups. Furthermore, there were small changes in stress sources (Pre=1 ± 1; Post= 0 ± 1) and symptoms ('better than normal' Pre=5 ± 1; Post=4 ± 4; 'normal' Pre=19 ± 7; Post=21 ± 3) on DALDA for the LED group. The LED phototherapy did not affect the autonomic modulation, but induced small changes in perceived stress.

KEYWORDS: Recovery; Stress; Internal Load.

Introduction

Optimal performance during sports competition is the result of adequate application of training load[1] and optimal recovering periods[2]. Inadequate application of training loads can lead to a non-functional overreaching state and might evolve to overtraining[3]. In addition, inadequate recovery could prevent the necessary physiological adaptations to increase performance[2]. Thus, besides correct prescription of training loads, effective recovering methods might have positive effects in athletes performance and reduce overtraining risk.

Improved recovery time can be achieved by methods assisting a consistent reduction of physiological stress markers[2] arose from application of internal and external training loads[4]. Physiological changes from training overload, which is required at some training stages[5], are markedly related to autonomic nervous system changes. During periods of high training loads, there is a decrease in the rested parasympathetic autonomic modulation[6-8]. Similarly, there are negative changes in subjective stress and recovery markers during these periods. Studies have shown that load and recovery quality and quantity[9] influence changes in stress sources and symptoms, analyzed by DALDA, which can be related to the overtraining syndrome development[10-11].

However, the application of recovery methods might allow decreases in acute changes of autonomic nervous system measured by hearth rate variability (HRV)[12]. As an example, Buchheit et al.[13] showed that cold water immersion, a widely used recovery method[14], resulted in greater parasympathetic modulation following supramaximal exercise compared with a control situation, without any post-exercise recovery method. Additionally, Al Haddad et al.[15] observed increased parasympathetic markers during one week of cold water immersion compared with a control situation. Those studies indicate that recovery influences autonomic activity. It is worth highlighting, that increases in vagal modulation are relate to improved performance in team sports[16].

Therefore, strategies that provide increases, or at least avoid sharped decreases in parasympathetic modulation, may benefit elite athletes performance. Nevertheless, the application of recovery methods still presents controversial results[17-18]. Barnett[17] showed that common used recovery methods, such as massage, active recovery, cold water immersion and contrast, are controversial, not depicting clear efficacy both in markers change or increase in performance.

Phototherapy has been investigated as a potential method to optimize recovery. The mechanism involved in phototherapy is related to increased intracellular metabolic activity[19] combined with a decrease in pro-inflammatory substances[19-23] and muscle damage markers[23], which in turn can lead to systemic effects translated to increased parasympathetic activity[24-25] and decreased perceived stress[26-27].

Although inconclusive, mainly by the metabolite choice (e.g., creatine kinase and blood lactate), exercise model and the use of cross-sectional experimental designs, studies indicate a positive effect of phototherapy. For example, the use of phototherapy resulted in increased performance in resistance exercise up to exhaustion[28], diminished increase in creatine kinase 24h after exercise[29], as well as decreased inflammation[30] and increased rested autonomic modulation when daily used in animal model[31]. Overall, studies demonstrate that the acute use of phototherapy results in decreases in stress markers and increased performance[23,29-36].

However, the influence of the method on markers decrease during a training microcycle, as well as the mechanisms related to it, are less understood.

Therefore, the aim of the present study was to analyze the influence of light-emitting diode (LED) phototherapy use on autonomic modulation and subjective markers of stress/recovery, during one week of training in soccer athletes.

Methods

Subjects

The sample included 18 professional soccer athletes (age: 21.2 ± 2.6 years; body mass: 73.0 ± 7.2 Kg; height: 178.0 ± 6.2 cm) from Londrina, PR, Brazil. Goalkeepers were excluded from study procedures. As inclusionary criteria all subjects should be between 18 - 35 years, had had professional experience for more than a year, do not smoke and correctly follow the training routine for the experimental week. None of the 18 athletes was excluded from the study due to missing training sessions or anti-inflammatory drug use. Subjects were informed on the risks and benefits of the present study and signed an informed consent form. The study was approved by the Ethics and Research Committee Involving Human Beings of the State University of Londrina (CEP: 248/2011).

Experimental Design

During training, the athletes were randomized into two groups: LED group (n = 9), who received treatment; and a placebo group (PLA, n = 9), which did not receive irradiation. To ensure the double-blind design, the team's physical trainer was responsible for treatment application supervised by an evaluator during the application. The evaluator instructed the physical trainer on the correct position of the equipment key. The latter did not know the position that turned on or off the circuit. On the PLA group, the equipment key was placed in the 'turned off' position and maintained over the region to be irradiated. Randomization was performed using Excel software (Microsoft Windows®) by a researcher who was not involved in the treatment appliance.

The study was conducted in the last week of the team's pre-season. The treatment was applied on LED and

PLA groups every day after the last training session of the day. DALDA questionnaire was applied together with the rested heart rate assessments. Pre (Monday) and Post (Saturday) experimental week, rested heart rate was assessed during 10-min at a sitting position. Internal training load during the week was accompanied by the rate of perceived exertion (RPE) of the session). External training load was defined by the average of the duration of the training stimulus.

Treatment (LED-PLA)

During evaluation week, the athletes trained two times a day. One training session was performed in the morning and the next in the afternoon. Treatment was applied every day after the last training session. For doing so, the protocol proposed by Leal Junior et al.[36] was followed. Equipment was positioned in contact with the skin on both legs on the quadriceps and femoral biceps. Each muscle was irradiated in two points (proximal and distal) during 4-min. TABLE 1 presents treatment specifications. Application was performed during 10 to 45-min after the end of the last training session. For the PLA group, the equipment had the same characteristics than the LED group, but it was turned off with no lights (invisibles to human eye).

TABLE 1 - LED application parameters.

Parameters	Specifications
Diode number	56
Wavelength	940 nm
Frequency	Continuous
Exit power	3.3 mW per diode
LED spot size	0.007 cm^2
Power density	0.013 W/cm^2
Energy	44.35 J (per point)
Energy density	3.16 J/cm^2
Treatment time	4 min per muscle region
Number of irradiation points per muscle	Quadriceps: 2 points; Femoral Biceps: 2 points
Total energy per athlete	354.8 J.
Mode of application	Stationary in contact with the skin

Training load control

Quantification of internal training load was performed using the RPE[37]. It was calculated the product between the duration of the training session in minutes and the value reported by the athlete in the Brazilian version of the Borg-10 RPE scale[38]. The scale was presented to the athletes 30-min after the end of each training session[39].

All athletes were familiar with the scale in their training routines. Parameters analyzed were the total accumulated session RPE considering the whole week, calculated by summing the RPE of all training sessions (total RPE), the daily average of training impulse (mean RPE), the weekly monotony (session RPE divided by its standard deviation) and the strain (monotony multiplied by total session RPE). The method followed procedures proposed by Nakamura et al.[40].

External training load was assessed by the team's physical trainer, who provided the kind and duration of each training session during the experimental week, representing the quantity and the quality of the external load applied. During the week, the athletes performed the training regime described in TABLE 2.

TABLE 2 - Training performed by athletes in the experimental week.

JCR: Reduced space matches.

	Monday		Tuesday		Wednesday		Thursday		Friday	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
PLA	JCR	Sprints/ Technical	Technical/ Tactical	Power	Rest	Simulated match	Power	Sprints/ Tactical	Rest	Friendly match
LED	JCR	Sprints/ Technical	Technical/ Tactical	Power	Rest	Simulated match	Power	Sprints/ Tactical	Rest	Friendly match

DALDA questionnaire

The questionnaire was applied on Monday and on Saturday previously to training starts. The questionnaire is divided in two sections (Section A: 9 questions; Section B: 25 questions), which represent stress sources and symptoms, respectively. The athletes answered the questions from both sections signaling one of the following responses: 'worse than normal'; 'normal' or 'better than normal'. For filling, athletes were oriented to choose the response that precisely reflected their thoughts and activities indicating how each affirmation fitted their current state[41]. For data analysis, it were quantified the number of each response 'worse than normal'; 'normal' or 'better than normal' from each questionnaire section. DALDA questionnaire was validated and adapted to Portuguese language[41].

Heart rate monitoring

During 10-min rested and before the beginning of the training session on Monday and Saturday, the volunteer's heart rate (HR) was assessed in RR intervals (ms) with a heart frequency monitor model POLAR TEAM2 (POLAR®, Kempele, Finland). This equipment register and save heart R waves signals at each beat through a transmitter positioned on the athletes thorax. The equipment have a receptor that received the signals simultaneously from each athlete and stored for future analysis.

Heart rate variability

Data was collected with a sampling frequency of 1,000 Hz and the RR intervals records were filtered to eliminate possible noises from ectopic beats or reading errors of the apparatus on the order of 20 bpm[42], with the percent of RR intervals correction less than 2%. This procedure was performed using the Polar Pro Trainer software version 5.35 (Polar Electro®, Kempele, Finland). If any error point persisted, it was visually identified and interpolated to the adjacent values.

Following filtering, data was analyzed in Kubios HRV software version 1.1 (Biosignal Analysys and Medial Image Group, Kuopio, Finland). Time domain parameters were calculated from the RMSSD indices (square root of the mean of successive differences squared, between adjacent RR intervals) and the standard deviation of normal RR intervals (SDNN). The RMSSD is considered as a parasympathetic indicator and the SDNN as global autonomic indicator by HRV[12]. Data were interpolated in a cubic frequency of 2 Hz in corrected series of normal intervals, using the fast Fourier transform through Welch window to estimate the Spectral density. Low frequency components (LF: 0.04 - 0.15 Hz) were estimated as sympathetic and parasympathetic indicators and high frequency (HF: > 0.15 - 0.4 Hz) as parasympathetic indicator. Both LF and HF were expressed in normalized units (un). Sympathovagal balance was expressed by the ratio LF/HF[12,43].

Statistical analysis

Data are present as means and standard deviations. To compare treatment influence (LED or PLA) on rested HRV Pre and Post experimental week, a two-way repeated-measures ANCOVA was applied (2 groups [LED; PLA] x 2 moments [Pre; Post]) using the Pre values as covariate. Before the ANCOVA, the Mauchly test was applied to analyze sphericity. When sphericity was violated, the Greenhouse-Geisser correction was applied. To compare parameters of internal load (total RPE, mean RPE and monotony) independent measures Student t-test were applied. To compare strain, the Mann-Whitney test was applied, since this variable did not present a normal distribution. To compare responses 'worse than normal' and 'better than normal' from 'A' and 'B' sections of DALDA the Wilcoxon test was applied to verify changes within groups. Since HRV did not present normal distribution, the Spearman correlation coefficient was used to verify associations between HRV and internal load. Effect sizes of the differences was analyzed and interpreted following Hopkins procedures[44]: < 0.2: trivial; >0.2 - 0.6: small; >0.6 - 1.2: moderate; > 1.2: large.

Results

External and Internal loads

During the week, athletes performed eight training sessions. Both groups performed the same training sessions. There were no differences between groups for total RPE, mean RPE, monotony and strain. However, there was a moderate effect for monotony and strain (TABLE 3).

TABLE 3 - Mean (standard deviation) of session RPE parameters during the experimental week.

	Group		p	Effect size [IC = 95%]	Interpretation
	LED (n = 9)	PLA (n = 9)			
Total session RPE (AU)	1974.8 (316.5)	1944.6 (265)	0.82	-0.10 [-0.86 – 0.66]	Trivial
Mean RPE (AU)	388.9 (53.0)	387.4 (62.1)	0.82	-0.02 [-0.76 – 0.81]	Trivial
Monotony (AU)	2.1 (0.63)	1.71 (0.42)	0.14	0.69 [-0.10 – 1.48]	Moderate
Strain (AU)	3893. 9 (33)	3187.8 (25.5)	0.82	0.74 [-0.05 – 1.52]	Moderate

DALDA

Following training week, there were changes in 'worse than normal' response from section 'A' from DALDA for the LED group (Median ± interquartile range: Monday = 1 ± 1; Saturday = 0 ± 1; P = 0.05). Similarly, there were significant changes for this groups in 'better than normal' response from section 'B' of the questionnaire (Monday = 5 ± 1; Saturday = 4 ± 4; P = 0.05) and in 'normal' responses from section 'B' (Monday = 19 ± 7; Saturday = 21 ± 3; P = 0.04).

There was no change for the PLA group in any of the questionnaire responses: 'worse than normal' from section 'A' (Monday = 0 ± 2; Saturday = 0 ± 1; P = 0.41), 'normal' from section 'A' (Monday = 7 ± 2; Saturday = 8 ± 1; P = 0.29), 'better than normal' from section 'A' (Monday = 1 ± 2; Saturday = 1 ± 2; P = 0.51), 'worse than normal' from section 'B' (Monday = 2 ± 5; Saturday = 1 ± 2; P = 0.58), 'normal' from section 'B' (Monday = 20 ± 8; Saturday = 22 ± 6; P = 0.44), 'better than normal' from section 'B' (Monday = 1 ± 5; Saturday = 1 ± 4; P = 0.68).

Heart rate variability

Due to problems in data acquisition and analysis, two athletes from PLA group were excluded from final analysis. The repeated-measures ANCOVA did not demonstrate significant time, group or group-time interaction effects (P > 0.05) for the RRMSSD, HF and LF indices in normalized units. Nevertheless, it was observed significant time effect for mean RR (P = 0.044), SDNN (P = 0.001) and LF/HF (P < 0.001). None of the indices presented significant group or group-time interaction effects (TABLE 4).

TABELA 4 - Changes in cardiac autonomic modulation Pre and Post training week for the LED and PLA groups.

Data are mean ± standard deviation.
*Pre moment added in ANCOVA as covariate.
a) group effect;
b) time effect;
c) group-time interaction.

	LED (n = 9)		PLA (n = 9)		Effects
	Monday	Saturday	Monday	Saturday	
Mean RR (ms)	1033.4 ± 150.7	1056.7 ± 114.8	962 ± 150.8	1016.8 ± 173.5	a = 0.949 **b = 0.043** c = 0.949
SDNN (ms)	101 ± 37.3	92.3 ± 27.5	97.5 ± 34.9	108.7 ± 16.4	a = 0.112 **b = 0.001** c = 0.112
RMSSD (ms)	60.8 ± 21.1	68 ± 24.1	53.7 ± 21.6	76.2 ± 30.9	a = 0.303 b = 0.326 c = 0.303
HF (nu)	38.9 ± 10.1	44.9 ± 15.5	31.5 ± 21.4	30.4 ± 19.8	a = 0.221 b = 0.070 c = 0.221
LF (nu)	61 ± 10.2	55.1 ± 15.5	68.5 ± 21.3	69.5 ± 19.8	a = 0.221 b = 0.070 c = 0.221
LF/HF	1.7 ± 0.7	1.4 ± 0.6	3.7 ± 3.4	3.4 ± 2.1	a = 0.082 b <**0.001** c = 0.082

Discussion

The main objective of the present study was to verify if LED phototherapy utilization with the aim of recovery optimization would induce any positive effect on autonomic modulation and subjective perceived stress during one week of training in soccer athletes. We did not observe effects of LED phototherapy on HRV parameters compared with PLA group. For mean RR, SDNN and LF/HF, we observed an increase after the training week compared with Pre. In addition, the LED group did present changes in stress sources and symptoms Pre and Post the training week of one or two responses from sections 'A' and 'B', respectively.

Regarding LED phototherapy application to improve recovery, Camargo et al.[45] demonstrated that after training, LED phototherapy reduced muscle damage markers and leucocyte infiltration in animals compared with cryotherapy, which is a common method used by athletes[16]. In accordance, Leal-Junior et al.[36] showed decreases in lactate and CK concentrations for participants that received LED phototherapy compared with participants who received cryotherapy following anaerobic exercise. It is worth mentioning that lactate decrease after exercise do not necessarily reflect an improvement in muscle recovery, but a lower utilization of the anaerobic metabolism or a greater lactate clearance from blood stream.

Similarly, the physiological meaning of CK change in blood stream as a recovery marker have been questioned[46]; therefore, positive results reported in the literature, interpreted as an improve in recovery could better reflect the ergogenic effect of LED phototherapy. Apart from limitations from the markers, those results and other[29-36] indicate a potential effect of LED phototherapy as a recovery method for elite athletes.

Finally, the inflammatory responses post-exercise are part of the essential mechanisms for cellular adaptation; thus, daily application of recovery strategies that impinges inflammation after exercise could lead to impinged training adaptation. Nevertheless, LED phototherapy, besides reducing inflammation (what can be interpreted as deleterious from the training adaptation point-of-view) also stimulates intracellular protein synthesis pathways and metabolism, which are related to resistance and aerobic trainings adaptations. In fact, greater autonomic adaptations and muscle metabolism were recently observed in groups of animals that received phototherapy as a daily recovery method after resistance training[31]. These points deserve to be further investigated in future studies using athletes.

At exercise starts, there is a withdrawal on parasympathetic modulation concomitant with an up regulation on heart sympathetic modulation[47]. Studies show that rested vagal modulation remains dimmed up to 72h following exercise depending on intensity, duration and exercise type[48-50]. These changes in cardiac autonomic modulation after exercise are used to quantify recovery pattern[51].

As an example, Al Haddad et al.[15] showed that daily recovery sessions using cryotherapy during one training week (session-RPE ~650 AU) induced benefic changes, i.e., increases in RMSSD index compared with an control situation. We hypothesize that LED phototherapy would increase autonomic modulation possibly due to decreases in systemic inflammatory markers, markedly in pro-inflammatory cytokines[21], which lead to diminished autonomic activity, mainly vagal[24-25]. Nevertheless, we did not observe effects of LED phototherapy in the present study compared with the placebo situation.

It is important to highlight that training loads in the present study (~390 AU) were lower than a recent study (~650 AU)[15], in which increases in autonomic modulation were observed with the use of daily cold water immersion. Although the mechanisms related to different recovery methods are distinct limiting direct comparisons, several studies suggest that changes in autonomic activity are dependent on not only the recovery method but also on the weekly training load[52].

The training load observed in the present study was not high enough to induce decreases in vagal activity indexes. In fact, HRV changes during the application of training loads present an inverted 'U' dose-response pattern[53], i.e., increases in internal load promoted positive effects on HRV parasympathetic parameters; however, exacerbated loads are related to decreases in those indexes. In the present study, we observed significant increases in HRV indexes after the experimental week, confirming our hypothesis that low training loads to which the athletes were submitted, were not enough to cause disturbances in the autonomic nervous system; thus the effect of recovery methods on this system occurs during high-load training periods[15]. On the other hand, these results can also indicate that LED phototherapy as a recovery method cannot induce changes in the athletes' autonomic nervous system. Future studies investigating the effects of weekly loading on the effectiveness of different recovery methods are required.

Changes in stress sources and symptoms demonstrated that there were decreases in 'worse than normal' responses from section 'A' and a decrease in 'better than normal' responses from section 'B' for the group receiving treatment. Moreira et al.[54] showed that changes in internal training load were related with changes in 'worse than normal' responses from DALDA. In this study, the athletes who had mean weekly load greater than 400 AU demonstrated increase in 'worse than normal' responses from both sections. However, the athletes that had mean weekly load lower than 400 AU did not demonstrate changes in the responses. In the present study, the mean accumulated internal load were lower than 400 AU, which might explain the lack of changes in the responses. For example, a decrease in 'worse than normal' from section 'A' for the LED group went from 1 to 0; on the contrary a decrease in responses 'better than normal' (5 to 4) was observed. Those results might not reflect important practical differences during training.

Regarding the characteristics of the therapy applied to the LED group, we followed similar irradiation parameters used by Leal Junior et al.[36], who used doses of 41.7 and 30 J per muscle region, respectively.

In that study, the authors found increases in performance and reduced CK accumulation when LED phototherapy was used prior to exercise. We applied a wavelength of 940 nm due to the fact that longer wavelengths penetrate deeper into muscle tissue[55]. Previous studies showed that this wavelength after intense exercise in animal models was capable of reducing muscle damage and the inflammatory processes that occur following intense exercise[45,56].

The limitations of the present study were the small sample size, which may have limited the statistical analysis power; the lack of direct measures of external load, as for example, the distance in high-intensity during simulated match and the friendly match (TABLE 2); and the lack of performance measures at the end of the training week. The investigation of sport teams competing in first division of the state championship had limited us to a small number of participants, who were available by the team. Such limitation was counterbalanced by the high ecological validity of the present study. However, the limitations prevented further inferences of LED phototherapy utilization in sport training context. Future studies are required to clarify the possible effects of the treatment on external load and performance during microcycles with high - or low - training loads.

Analyzing the present study results, we conclude that the daily use of LED phototherapy as a recovery method did not promote changes in vagal modulation and perceived stress in elite soccer athletes.

Resumo

Efeito da fototerapia com diodos emissores de luz sobre a modulação autonômica em atletas de futebol

O objetivo do estudo foi verificar o efeito da fototerapia com diodos emissores de luz (LED fototerapia) durante uma semana de treinamento sobre a modulação parassimpática e estresse percebido em atletas de futebol. Fizeram parte da amostra 18 atletas (Idade: 21,2 ± 2,6 anos; Peso: 73 ± 7,2 Kg; Estatura: 178,0 ± 6,2 cm.). Pré e após uma semana de pré-temporada foram realizadas coletas da frequência cardíaca de repouso e a avaliação subjetiva de estresse e recuperação foi obtida por meio do daily analysis of life demands for athletes (DALDA). Os atletas foram aleatorizados em dois grupos, com nove atletas cada, grupo LED fototerapia (LED) e grupo placebo (PLA). O tratamento foi aplicado nos membros inferiores nos músculos do quadríceps e bíceps femoral todos os dias após a última sessão de treinamento. A aplicação foi realizada de maneira "duplo cego". ANCOVA de medidas repetidas foi utilizada para verificar o efeito do tratamento sobre modulação autonômica. O treinamento realizado por ambos os grupos foi o mesmo tanto em duração quanto intensidade. Da mesma forma, não houve diferença entre os grupos nos parâmetros de carga interna. Foi observado efeito da semana nos parâmetros média dos intervalos RR (Rrmédio - LED: pré=1033,4 ± 150,7ms pós=1056,7 ± 114,8ms; PLA: pré=962 ± 150,8ms pós=1016,8 ± 173,5ms), desvio padrão dos intervalos RR normais (SDNN - LED: pré=101 ± 37,3ms pós=92,3 ± 27,5ms; PLA: pré=97,5 ± 34,9ms pós=108,7 ± 16,4ms), e razão baixa e alta frequência (LF/HF - LED: pré=1,7 ± 0,7 pós=1,4 ± 0,6; PLA: pré=3,7 ± 3,4 pós=3,4 ± 2,1) para ambos os grupos. Além disso, houve pequenas alterações nas fontes (pré=1 ± 1; pós= 0 ± 1) e sintomas ('melhor que normal' pré=5 ± 1; pós=4 ± 4; 'normal' pré=19 ± 7; pós=21 ± 3) do DALDA para o grupo LED. A LED fototerapia não apresentou efeito sobre a modulação autonômica, mas proporcionou pequenas alterações nas fontes e sintomas de estresse.

Palavras-chave: Recuperação; Estresse; Carga interna.

References

1. Kentta G, Hassmen, P. Overtraining and recovery: a conceptual model. Sports Med. 1998;26:1-16.
2. Kellmann M. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. Scand J Med Sci Sports. 2010;20:95-102.
3. Armstrong LE, Vanheest JL. The unknown mechanism of the overtraining syndrome: clues from depression and psycho-neuroimmunology. Sports Med. 2002;32:185-209.
4. Impellizzeri FM, Rampinini E, Marcora SM. Physiological assessment of aerobic training in soccer. J Sports Sci. 2005; 23:583-92.
5. Viru A. The mechanism of training effects: a hypothesis. Int J Sports Med. 1984;5:219-27.
6. Buchheit M, Simon C, Piquard F, Ehrhart J, Brandenberger G. Effects of increased training load on vagal-related indexes of heart rate variability: a novel sleep approach. Am J Physiol Heart Circ Physiol. 2004;287:H2813-18.
7. Pichot V, et al. Autonomic adaptations to intensive and overload training periods: a laboratory study. Med Sci Sports Exerc. 2002;34:1660-1666.
8. Pichot V, et al. Relation between heart rate variability and training load in middle-distance runners. Med Sci Sports Exerc. 2000;32:1729-1736.
9. Moreira A, Nakamura FY, Cavazzoni PB, Gomes JH, Martignano P. O efeito da intensificação do treinamento na percepção de esforço da sessão e nas fontes e sintomas de estresse em jogadores jovens de basquetebol. R Educ Fís/UEM. 2010;21:287-96.
10. Kellmann M, Gunther KD. Changes in stress and recovery in elite rowers during preparation for the Olympic Games. Med Sci Sports Exerc. 2000;32:676-83.
11. Coutts A, Reaburn P, Piva TJ, Murphy A. Changes in selected biochemical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. Int J Sports Med. 2007;28:116-24.
12. Task-Force. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force

of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur Heart J. 1996;17:354-81.

13. Buchheit M, Peiffer JJ, Abbiss CR, Laursen PB. Effect of cold water immersion on postexercise parasympathetic reactivation. Am J Physiol Heart Circ Physiol. 2009;296:H421-7.
14. Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. Br J Sports Med. 2012;44:179-87.
15. Al Haddad H, Laursen PB, Ahmaidi S, Buchheit M. Nocturnal heart rate variability following supramaximal intermittent exercise. Int J Sports Physiol Perform. 2008;4:435-47.
16. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? Front Physiol. 2014;5:1-19.
17. Barnett, A. Using recovery modalities between training sessions in elite athletes: does it help? Sports Med. 2006;36:781-96.
18. Pastre CM, Bastos FN, Netto Júnior J, Vanderlei LCM, Hoshi RA. Métodos de recuperação pós-exercício: uma revisão sistemática. Rev Bras Med Esporte. 2009;2:138-144.
19. Hayworth CR, Rojas JC, Padilla E, Holmes GM, Sheridan EC, Gonzalez-Lima F. In vivo low-level light therapy increases cytochrome oxidase in skeletal muscle. Photochem Photobiol. 2010;86:673-80.
20. Lim W, et al. The anti-inflammatory mechanism of 635 nm light-emitting-diode irradiation compared with existing COX inhibitors. Lasers Surg Med. 2007;39:614-21.
21. Choi H, et al. Inflammatory cytokines are suppressed by light-emitting diode irradiation of P. gingivalis LPS-treated human gingival fibroblasts: inflammatory cytokine changes by LED irradiation. Lasers Med Sci. 2012;27:459-67.
22. Pires D, Xavier M, Araújo T, Silva Júnior JA, Aimbire F, Albertini R. Low-level laser therapy (LLLT; 780 nm) acts differently on mRNA expression of anti- and pro-inflammatory mediators in an experimental model of collagenase--induced tendinitis in rat. Lasers Med Sci. 2011;26:85-94.
23. De Marchi T, Leal Junior EC, Bortoli C, Tomazoni SS, Lopes-Martins RA, Salvador M. Low-level laser therapy (LLLT) in human progressive-intensity running: effects on exercise performance, skeletal muscle status, and oxidative stress. Lasers Med Sci. 2012;27:231-36.
24. Thayer JF. Vagal tone and the inflammatory reflex. Cleve Clin J Med. 2009;2:S23-6.
25. Haensel A, Mills PJ, Nelesen RA, Ziegler MG, Dimsdale JE. The relationship between heart rate variability and inflammatory markers in cardiovascular diseases. Psychoneuroendocrinology. 2008;33:1305-12.
26. Main LC, Dawson B, Grove JR, Landers GJ, Goodman C. Impact of training on changes in perceived stress and cytokine production. Res Sports Med. 2009;17:121-32.
27. Main LC, Dawson B, Heel K, Grove JR, Landers GJ, Goodman C. Relationship between inflammatory cytokines and self-report measures of training overload. Res Sports Med. 2010;18:127-39.
28. Leal Junior EC, et al. Effect of cluster multi-diode light emitting diode therapy (LEDT) on exercise-induced skeletal muscle fatigue and skeletal muscle recovery in humans. Lasers Surg Med. 2009;41:572-7.
29. Baroni BM, Leal Junior EC, De Marchi T, Lopes AL, Salvador M, Vaz MA. Low level laser therapy before eccentric exercise reduces muscle damage markers in humans. Eur J Appl Physiol. 2010;110:789-96.
30. De Almeida P, et al. Low-level laser therapy improves skeletal muscle performance, decreases skeletal muscle damage and modulates mRNA expression of COX-1 and COX-2 in a dose-dependent manner. Photochem Photobiol. 2011;87:1159-63.
31. Paolillo FR, Arena R, Dutra DB, et al. Low-level laser therapy associated with high intensity resistance training on cardiac autonomic control of heart rate and skeletal muscle remodeling in wistar rats. Lasers Surg Med. 2014; 46:796-803.
32. Baroni BM, Leal Junior EC, Geremia JM, Diefenthaeler F, Vaz MA. Effect of light-emitting diodes therapy (LEDT) on knee extensor muscle fatigue. Photomed Laser Surg. 2010;28:653-8.
33. De Almeida P, et al. Red (660 nm) and infrared (830 nm) low-level laser therapy in skeletal muscle fatigue in humans: what is better? Lasers Med Sci. 2012;27:453-58.
34. Leal Junior EC, et al. Effect of 830 nm low-level laser therapy applied before high-intensity exercises on skeletal muscle recovery in athletes. Lasers Med Sci. 2009;24:857-63.
35. Leal Junior EC, et al. Effect of 655-nm low-level laser therapy on exercise-induced skeletal muscle fatigue in humans. Photomed Laser Surg. 2008;26:419-24.
36. Leal Junior EC, et al. Comparison between cold water immersion therapy (CWIT) and light emitting diode therapy (LEDT) in short-term skeletal muscle recovery after high-intensity exercise in athletes--preliminary results. Lasers Med Sci. 2011;26:493-501.
37. Foster C, et al. A new approach to monitoring exercise training. J Strength Cond Res. 2001;15:109-15.

38. Borg G. Borg's perceived exertion and pain scales. Champaign: Human Kinetics; 1998.
39. Pedro RE, Oliveira RS, Vasconcelos PSS, Pires Junior R, Milanez VF. Temporal effect on the response of subjective perceived exertion. Rev Bras Med Esporte. 2014;20:350-3.
40. Nakamura FY, Moreira A, Aoki MS. Monitoramento da carga de treinamento: a percepção subjetiva do esforço da sessão é um método confiável? R Educ Fís/UEM. 2010;21:1-11.
41. Moreira A, Cavazzoni PB. Monitorando o treinamento através do wisconsin upper respiratory symptom survey -21 e Daily Analysis of Life Demands in Athletes nas versões em língua portuguesa. R Educ Fís/UEM. 2009;20:109-19.
42. Yamamoto Y, Hughson RL, Peterson JC. Autonomic control of heart rate during exercise studied by heart rate variability spectral analysis. J Appl Physiol. 1991;71:1136-42.
43. Vanderlei LCM, Pastre CM, Hoshi RA, Carvalho TD, Godoy MF. Noções básicas de variabilidade da frequência cardíaca e sua aplicabilidade clínica. Rev Bras Cir Cardiovasc. 2009;24:205-17.
44. Hopkins WG. A new view of statistics [Internet]. 2002 - [cited 2014]. Available from: http://www.sportsci.org/resource/stats/effectmag.html www.sporsci.org/stat.
45. Camargo MZ, et al. Effects of light emitting diode (LED) therapy and cold water immersion therapy on exercise--induced muscle damage in rats. Lasers Med Sci. 2012;27:1051-8.
46. Koch AJ, Pereira R, Machado M. The creatine kinase response to resistance exercise. J Musculoskelet Neuronal Interact. 2014;14:68-77.
47. Perandini LAB, Chimin P, Okuno NM, Lima JRP, Buchheit M, Nakamura FY. Parasympathetic withdrawal during 30-15 Intermittent Fitness Test correlates with its' maximal running speed. J Exerc Physiol Online. 2009;12:29-39.
48. Buchheit M, Laursen PB, Ahmaidi, S. Parasympathetic reactivation after repeated sprint exercise. Am J Physiol Heart Circ Physiol. 2007;293:H133-41.
49. Nakamura FY, Soares-Caldeira LF, Laursen PB, Polito MD, Leme LC, Buchheit M. Cardiac autonomic responses to repeated shuttle sprints. Int J Sports Med. 2009;30:808-13.
50. Oliveira RS, et al. Acute cardiac autonomic responses after a bout of resistance exercise. Sci Sport. 2012;27:357-64.
51. Bastos FN, et al. Effects of cold water immersion and active recovery on post-exercise heart rate variability. Int J Sports Med. 2012;33:873-9.
52. Oliveira RS, Leicht AS, Bishop D, Barbero-Álvarez JC, Nakamura FY. Seasonal changes in physical performance and heart rate variability in high level futsal players. Int J Sports Med. 2013;34:424-40.
53. Manzi V, et al. Dose-response relationship of autonomic nervous system responses to individualized training impulse in marathon runners. Am J Physiol Heart Circ Physiol. 2009;296:H1733-40.
54. Moreira A, Freitas CG, Nakamura FY, Aoki MS. Percepção de esforço da sessão ea tolerância ao estresse em jovens atletas de voleibol e basquetebol. Rev Bras Cineantrop Desempenho Hum. 2010;12:345-51.
55. Enwemeka CS. Attenuation and penetration of visible 632.8 nm and invisible infra-red 904 nm light in soft tissue. Laser Ther. 2001;13:95-101.
56. Da Costa Santos VB, et al. LED therapy or cryotherapy between exercise intervals in Wistar rats: anti-inflammatory and ergogenic effects. Lasers Med Sci. 2014;29:599-605.

ADDRESS
Ricardo Santos Oliveira
College of Life and Environmental Sciences
University of Exeter
St Luke's Campus
Heavitree Road Exeter
Exeter EX1 2LU
United Kingdom of Great Britain and Northern Ireland
e-mail: rsobaski@yahoo.com.br

Submitted: 30/09/2014
1st. Review: 12/01/2015
2nd. Review: 27/07/2015
3rd. Review: 22/09/2015
Accepted: 09/10/2015