TRAINING LOAD THROUGH HEART RATE AND PERCEIVED EXERTION DURING CROSSFIT®

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CARGA DE TREINAMENTO ATRAVÉS DE FREQUÊNCIA CARDÍACA E ESFORÇO PERCEBIDO NO CROSSFIT®

CARGA DE ENTRENAMIENTO ATRAVÉS DE LA FRECUENCIA CARDÍACA Y EL ESFUERZO PERCIBIDO EN EL CROSSFIT®

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ABSTRACT

Introduction**:** Monitoring of CrossFit® training load should be considered to facilitate training outcomes and avoid overtraining. Objective: The purpose of the present study was to examine the heart rate (HR), rating of perceived exertion (RPE), and internal load responses to each segment of a CrossFit® training session. Methods: An observational, cross-sectional design was used in this study. Fifteen healthy male recreational athletes with at least six months experience in CrossFit® training participated in this study. Seven non-consecutive CrossFit® training sessions consisting of mobility, warm-up, skill, and workout segments were performed with a minimum of 48 hours between sessions. Exercise modalities within sessions were constantly varied according to the CrossFit® training programming template. HR was measured every two minutes throughout each session. Peak HR, average HR, RPE after each segment, and session RPE were recorded. Results: HR significantly increased during each segment of the training sessions ($p < 0.01$), except between the warm-up and skill segments ($p = 0.180$). Mean total session HR was 65.1 ± 5.4% HR_{max} and peak HR was 95.3 ± 4.1% HR_{max}. RPE and internal load increased significantly in each segment ($p < 0.05$). While intensity measurements increased during CrossFit® training, the HR responses differed from the RPE and internal load. Conclusion: When switching from one segment to another, HR fell below the HR_{peak} of the previous segment, which shows that the time spent switching between the training segments influenced the average HR of the entire session. ***Level of evidence III; Case control study; Investigating the results of treatment.***

Keywords: High-intensity interval training; Physical fitness; Physical endurance.

RESUMO

Introdução: O monitoramento da carga de treinamento deve ser considerado para facilitar os resultados e evitar o excesso de treinamento no CrossFit®. Objetivo: O objetivo do presente estudo foi examinar a frequência cardíaca (FC), a percepção de esforço (RPE) e as respostas da carga interna em cada segmento de uma sessão de CrossFit®. Métodos: Estudo transversal observacional. Quinze homens saudáveis com pelo menos seis meses de experiência de treinamento recreativo de CrossFit® participaram deste estudo. Sete sessões não consecutivas de CrossFit® que consistiram em segmentos de mobilidade, aquecimento, habilidade e treino foram realizadas com um mínimo de 48 horas entre as sessões. As modalidades de exercício das sessões foram constantemente variadas de acordo com o modelo de programação de treinamento CrossFit®. A FC foi medida a cada dois minutos ao longo de cada sessão e a FC pico, a FC média e a RPE depois de cada segmento e a RPE de cada sessão foram registradas. Resultados: A FC aumentou significativamente durante cada segmento das sessões de treinamento ($p < 0,01$), exceto entre os segmentos de aquecimento e habilidade ($p = 0,180$). A FC média total da sessão foi 65,1 ± 5,4% da $FC_{máx}$ e a FC pico foi 95,3 ± 4,1% da $FC_{máx}$. A RPE e a carga interna aumentaram significativamente em cada segmento ($p < 0,05$). Enquanto as medidas de intensidade aumentaram durante o treinamento de CrossFit®, as respostas da FC diferiram da RPE e da carga interna. Conclusão: Ao mudar de um segmento para outro, a FC diminuiu abaixo da FC pico do segmento anterior, o que mostra que o tempo gasto na mudança entre os segmentos de treinamento influenciou a FC média de toda a sessão. **Nível de evidência III; Estudo de caso controle; Investigação dos resultados do tratamento.**

Descritores: *Treinamento intervalado de alta intensidade; Condicionamento físico; Resistência física.*

RESUMEN

Introducción: El monitoreo de la carga de entrenamiento debe considerarse para facilitar los resultados y evitar el sobreentrenamiento en el CrossFit®. Objetivo: El propósito del presente estudio fue examinar la frecuencia cardíaca (FC), la calificación del esfuerzo percibido (RPE) y las respuestas de carga interna en cada segmento de una sesión de CrossFit®. Métodos: Estudio observacional transversal. En este estudio participaron quince hombres sanos, con al menos seis meses de experiencia en el entrenamiento recreativo de CrossFit®. Se realizaron siete sesiones de entrenamiento de CrossFit® no consecutivas, consistentes en segmentos de movilidad, calentamiento, habilidad y entrenamiento, con un mínimo de 48 horas entre sesiones. Las modalidades de ejercicio de las sesiones variaron constantemente de acuerdo con el modelo de programación del entrenamiento de CrossFit®. Se midió la FC cada dos minutos a lo largo de cada

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sesión y se registraron la FC pico, la FC media, la RPE después de cada segmento y la RPE de cada sesión. Resultados: La FC aumentó significativamente durante cada segmento de las sesiones de entrenamiento (p < 0,01), excepto entre los segmentos de calentamiento y habilidad (p = 0,180). La FC media total de la sesión fue de 65,1 ± 5,4% $FC_{máx}$ y la FC pico fue de 95,3 ± 4,1% $FC_{máx}$. La RPE y la carga interna aumentaron significativamente en cada segmento (p < 0,05). Mientras que las medidas de intensidad aumentaron en el entrenamiento de CrossFit®, las respuestas de la FC difieren de la RPE y la carga interna. Conclusión: Al cambiar de un segmento a otro, la FC cayó por debajo del pico de la FC del segmento anterior, lo que demuestra que el tiempo empleado en cambiar de segmento de entrenamiento influyó en la FC media de toda la sesión. ***Nivel de evidencia III; Estudio de casos y controles; Investigación de los resultados del tratamiento.***

***Descriptores**: Entrenamiento de intervalos de alta intensidad; Condicionamiento fisico; Resistencia física.*

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INTRODUCTION

CrossFit® training (CT) is a type of high intensity functional training that consists of alternating short periods of recovery using varied aerobic exercise, gymnastics movements and Olympic weightlifting techniques.[1,2] Unlike high intensity interval training, where specific predetermined breaks are used between repetitions of the same activity (e.g., cycling), CT often uses a combination of movements and self-selected time periods of work and rest.[2] Due to the intensity of CT, monitoring of training load should be potentially considered to facilitate training outcomes and avoid over training. The prescription of adequate intensity is crucial to obtain both an acceptable training stimulus and reasonable control of the exercise-related risk.[3] Although CT has been widely practiced around the world (https://map.crossfit.com), there is currently limited evidence of training load monitoring among participants.[4]

To quantify training load magnitude measures of various factors including metabolic,[5] cardiovascular,[4-6] and perceptual[5,6] characteristics have been used. However, not all of these measures may always be practical in an applied exercise setting. Heart rate (HR) and rating of perceived exertion are variables commonly used in practice. HR is a cardiovascular variable with excellent validity for intensity control during sports activities,[7] but it is little understood throughout a CT session. While the average HR recorded during each CT session can be considered vigorous and close to the maximum, i.e., ~ 90-93% of HR_{max},[6,8,9] it is unknown how HR variations across a session influence the magnitude of cardiovascular stress in CT.

On the other hand, the use of session rating of perceived exertion (sRPE) to evaluate and quantify training load is considered a potential tool in different sports.[10] While sRPE has been used to assess CT load,[4,5] differences in the effort to perform each exercise or segment of a session have been limited. Measurements of sRPE, muscular RPE, and cardiovascular RPE have been found to be similar to each other and were significantly different between gymnastics and weightlifting workouts of the day (WOD) but did not differ when compared with a cardiovascular WOD.[9]

To date, no studies have examined differences in training load for each segment of a CT session (joint mobility, general warm-up, specific skill [i.e., core, weightlifting, strength, or complex movement], and WOD [main part of the session]), which is important due to the inclusion of several distinct movements that vary in repetition and loading and require varying levels of effort. However, it is known that more intense activities result in higher physiological responses. In the case of a CT session, the stimuli should increase progressively with each segment. Understanding how HR and RPE change throughout training sessions would add to the literature by providing parameters for cardiovascular responses to each training segment. Thus, the purpose of this study was to examine the HR, RPE and internal load responses to each segment of CT session. We hypothesized that HR, RPE and internal load would progressively increase with each segment.

MATERIALS AND METHODS

Participants

Fifteen healthy male recreational participants (26 ± 6.5 years, 71.2 ± 17 kg, 175.9 ± 8.1 cm, 11.4 ± 4.6 % fat) with at least six months experience in CT (14.4 ± 4.1 months) of completing WODs three to five days/week at a CrossFit® gym participated in the study. A maximum load test on the back squat was used to characterize the sample. The sample size was estimated for 14 subjects (power = 0.849) a priori using the G-Power package (version 3.1.9.2, Heinrich-Heine-Universitat in Dusseldorf, Germany), considering an effect size (f) = 0.35; power (1-β) = 0.80; α = 0.05; with correction among repeated measures = 0.5 and nonsphericity correction = 1 calculated by the procedures suggested by Beck.[11] No subject consumed any type of medication or performance-enhancing drugs 24 hours before or during the study. Further exclusion criteria were having cardiovascular, metabolic, neurologic, or lung disease, or any orthopedic condition that could limit performance of the exercises. All subjects were screened with the PAR-Q questionnaire and completed written informed consent form according to the declaration of Helsinki (2000). Experimental procedures were approved by the Human Research Ethics Committee of the Federal University of Juiz de Fora (Protocol number: 3.749.878).

Study design and procedures

This is an observational cross-sectional study, in which the HR and RPE responses were examined for each segment of the CT sessions. Participants performed seven non-consecutive CT sessions in different randomized orders separated by approximately 48 to 72 hours (see Table 1). To determine the order in which the sessions were executed, a computer generated list of random numbers was used. Each session followed the CrossFit® programming template of constantly varied training,[1] in which cardiovascular (M), gymnastic (G) and weightlifting (W) movements were programmed. In addition, the cycled combination of these elements, i.e., M, G, W, MG, MW, GW and MGW, was used.

Each 60 minute training session was divided into four segments: mobility, warm-up, skill, and WOD. Between segments, a minimum time (2 to 4 min) was used for storing the materials/equipment. When starting the skill and WOD segment, a movement-specific warm-up was performed. The intensity used by each subject was self-selected according to their experience, that is, the chosen load met the movement patterns without the subject losing their technical quality of movement. Table 1 details the seven training sessions. To standardize the experimental conditions, subjects were instructed to (a) not drink alcohol during their entire participation in the study; (b) come to the laboratory two hours

Table 1. Details of the seven CrossFit® training sessions.

Segment	M	G	W	MG	MW	GW	MGW
Mobility	Static squat hold + roll lower back	Static squat hold + roll lower back	Shoulder flexion + static squat hold + wrist extension	Shoulder extension + roll lower back	Shoulder flexion + static squat hold + wrist	Static squat hold + roll lower back + wrist extension	Static squat hold + roll lower back + wrist extension
Warm-up	3 rds: 100 m run + 20 jumping jacks	3 rds: 5 no push-up burpees + 10 PVC pipe pass-throughs	3 rds: 8 air squats + 8 PVC pipe muscle snatches	3 rds: 5 vertical jumps + 5 wall throws	3 rds: 10 PVC pipe shoulder presses + 100 m run	3 rds:7 front squats + 7 good mornings	2 rds: 100 m run + 10 air squats + 10 PVC pipe deadlifts
Skill	Focus: core 4 rds: 10 hollow rocks + 10 supermans + 10 V-ups	Focus: handstand push-up technique 5 min EMOM: 10 kipping handstand push-ups	Focus: snatch technique 4 rds: 3 hang power snatches (1 min rest between rds)	Focus: rowing technique 5 rds: 300 m row (1 min rest between rds)	Focus: clean and jerk technique 4 rds: 3 hang power cleans (1 min rest between rds)	Focus: DU technique 5 rds: 1 min of D.U. (1 min rest between rds)	Focus: back squat technique 3 rds: 5 back squats (1 min rest between rds)
WOD	For time: 1 km row + 1 km run + 400 D.U. (5 min rest between exercises)	For reps: 6 rds of 2 min each: 10 burpees +10 sit-ups (1 min rest between rds)	5 rds for time: 20 snatches + 20 wall balls (1 min rest between rds)	2 rds of 10 min AMRAP: 30 calorie row + 20 box step-ups + 10 push-ups (2 min rest between rds)	16 min EMOM: 100 m run + 20 cleans + 100 m run + 20 jerks	21 min AMRAP: 10 front squats + 20 lunges (30 seconds rest between rds)	2 rds of 9 min AMRAP: 100 D.U + 24 kettlebell swings + 12 hang cleans (5 min rest between rds)

M: metabolic exercises in WOD, G: gymnastics exercises in WOD, W: weightlifting exercises in WOD; WOD: workout of the day; rds: rounds; min: minute; D.U: double-under; AMRAP: as many repetitions as possible; EMOM: every minute on the minute.

after their last meal in the morning; (c) not consume drinks and foods that contain caffeine prior to training, and (d) not practice vigorous exercise 48 hours before testing.

Heart rate monitoring and rating of perceived exertion

Every two minutes of the training sessions HR was measured using a HR-monitor (Polar®, FT 60, Finland). Data were recoded into pre, peak and average HR. At the end of each segment the RPE was measured using the OMNI-RES RPE 0-10 scale.[12] Participant sRPE was measured 30 minutes after the session. Training load was expressed in arbitrary units (AU) by multiplying the segment and session duration by the RPE and sRPE, respectively. HR during the workout was calculated as percent of estimated HR_{max} = 208 – (0.7 x age).

All participants were oriented and familiarized with RPE reporting during three sessions before procedures, as per the following instructions: (a) look at the illustrations and words to assist in the selection of a number from 0 to 10; (b) if you feel as shown in the illustration, that the effort is "extremely difficult," indicate number 10; (c) if you feel your effort is between "extremely easy" and "extremely difficult," you should indicate a number between 0 and 10, gradually, according to the illustrative descriptors present on the scale.

Statistical analysis

To calculate inferential statistics, normality of distribution was assessed with the *Shapiro-Wilk* test and homoscedasticity with the *Levene* test. HR was stratified into zones for each segment: start, ¼, ½, ¾, and end. HR was compared using a two-way analysis of variance (ANOVA) with repeated measures five (zones) × four (segments), followed by post hoc analysis with *Bonferroni's* correction for multiple comparisons at each segment. For this, sphericity was assumed for the segment and not for time through the *Mauchly* test. A two-way ANOVA with repeated measures (segments) was used to analyze the HR pre, HR average, HR peak, RPE, and internal load, followed by post hoc analysis with *Bonferroni* correction for multiple comparisons at each segment. Again, sphericity was assumed through the *Mauchly* test. A paired *t*-test was used to compare HR during the transition from one segment to the next. The level of significance was set at $p < 0.05$. All analyses were performed using SPSS software version 20.0.0 for Mac (SPSS Inc., Chicago, IL, USA).

RESULTS

The maximum load found in the back squat was 96.9 ± 15.7 kg, corresponding to 132 ± 29% of total body mass, showing an advanced level of strength, according to the study by Junior et al.[13] The two-way ANOVA with repeated measures showed that there were main effects of time [$F (2.410, 33.745) = 252.371$; $p < 0.001$] and training session segment [$F (3, 42) = 108.807$; $p < 0.001$] on HR. The Bonferoni post-hoc test confirmed that HR increased over time, at each segment, from the warm-up. This increase occurred according to the order of the segments: mobility, warm-up, skill and WOD, respectively.

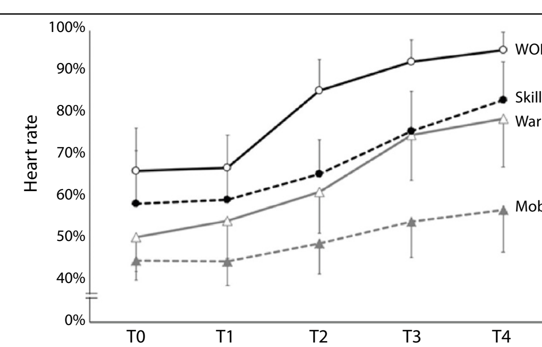
Table 2 shows average HR responses for each quartile of each session segment. HR increased across each quartile and started at a higher rate each following segment of the session. As shown in Figure 1, the percentage of HR_{max} achieved differed significantly by segment, except for between warm-up and skill ($p = 0.180$), showing that HR remained highest during the WOD (see Figure 1).

According to the one-way ANOVA with repeated measures, there was a significant effect of training segment on average HR [$F (3, 42) = 95.847$;

Table 2. HR average (bpm) responses during each CrossFit® training session segment (n = 15).

	T0	T1	T2	T3	T4
Mobility^{u,s,w}	85.4±9.1 (10.6)	84.9±11.1 (13)	93.2±13.9 (14.9)*	103.3±16.4 (15.8)*	108.7±19.3 (17.7)*
Warm-up^{m,w}	96±15.6 (16.3)	103.7±17.4 (16.7)	116.9±18.9 (16.2)*	142.9±20.7 (14.5)*	150.2±21.9 (14.6)*
Skill^{m,w}	111.4±24.4 (21.9)	113.4±15 (13.2)	125.1±15.5 (12.4)*	144.5±18.4 (12.8)*	158.9±17.4 (10.9)*
WOD^{m,u,s}	126.3±19.6 (15.6)	127.8±15.1 (11.8)	163.1±14.3 (8.7)*	176.4±9.9 (5.6)*	181.7±8.3 (4.6)*

Mean ± standard deviation (coefficient of variation). T0: at start; T1: 1/4 time; T2: 1/2 time; T3: 3/4 time; T4: ending time. *Significant difference in relation to the previous time ($p < 0.01$). ^{m} Significant difference in relation to mobility ($p < 0.05$). ^{u} Significant difference in relation to the warm-up ($p < 0.05$). ^{s} Significant difference in relation to skill ($p < 0.05$). ^{w} Significant difference in relation to the WOD ($p < 0.05$).



T0: at start, T1: 1/4 of the time, T2: 1/2 of the time, T3: 3/4 of the time, T4: ending time. m Significant difference in relation to mobility ($p < 0.05$). u Significant difference in relation to the warm-up ($p < 0.05$). s Significant difference in relation to skill ($p < 0.05$). w Significant difference in relation to the WOD ($p < 0.05$).

Figure 1. Percentage responses of HRmax throughout each segment of a CrossFit® training session (n =15).

$p < 0.001$], peak HR [$F(1.014, 14.198) = 41.274$; $p < 0.001$], total time [$F(1.591, 22.275) = 19.192$; $p < 0.001$], RPE [$F(1.014, 14.19) = 41.274$; $p < 0.001$] and internal load [$F(1.181, 16.532) = 81.243$; $p < 0.001$]. As shown in Table 3, the Bonferoni post-hoc test showed that there were no significant differences for average HR during warm-up and skill ($p = 0.459$), total time for mobility in relation to the warm-up ($p > 0.05$) or skill in relation to the WOD ($p > 0.05$).

Figure 2 shows that, on average, the transition from one segment to another was enough to decrease HR. Thus, when starting a new segment in the training session, HR was significantly lower in relation to HR at the end of the previous segment (mobility to warm -up: $t(14) = 3.103$, $p = 0.008$; warm-up to skill: $t(14) = 6.830$, $p < 0.001$; skill to WOD: $t(14) = 5.573$, $p < 0.001$).

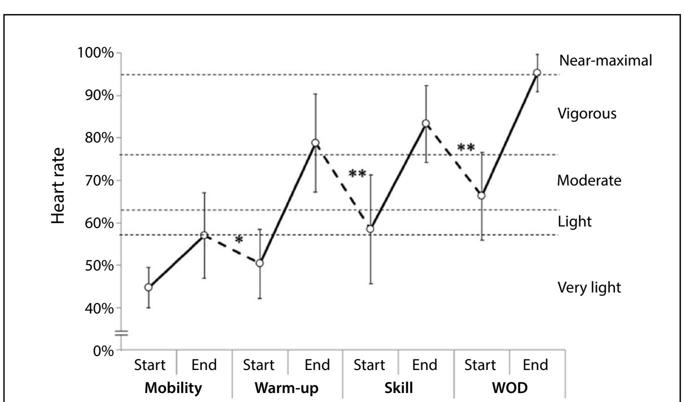
DISCUSSION

The objective of our study was to examine the HR, RPE and internal load responses to each segment of a CT session. Training sessions were conducted using aerobic exercises, gymnastics movements and Olympic weightlifting techniques. Our hypothesis that HR, RPE and internal load would progressively increase with each segment was supported, although average HR did not significantly increase from the warm-up to the skill segment. Knowing the HR and RPE responses and training load generated by the different segments of a CT session is useful for tailoring external loads to each individual. An adequate training load will induce beneficial adaptations and help prevent injury or disease.[14]

Table 3. Average HR, total time, RPE, and internal load for each CrossFit® training session segment (n =15).

	Mobility	Warm-up	Skill	WOD	Total session
HR_{pre} (bpm)	85.4 ± 9.1 (10.6)	96 ± 15.6 $(16.3)^{m}$	111.4 ± 24.4 $(21.9)^{m}$	126.3 ± 19.6 $(15.6)^{m,u}$	85.4 ± 9.1 (10.6)
HR_{pre} (%)	44.8 ± 4.4 (9.7)	50.3 ± 7.7 (15.3)	58.4 ± 12.5 (21.4)	66.2 ± 10 (15.1)	44.8 ± 4.4 (9.7)
$HR_{average}$ (bpm)	93.9 ±13.5 (14.4)	120.4 ± 16.9 $(14)^{m,w}$	128 ± 13.9 $(10.9)^{m,w}$	154.5 ± 10.9 $(7.1)^{m,u,s}$	124.2 ±11.1 (8.9)
$HR_{average}$ (%)	49.2 ± 6.5 (13.2)	63.1 ± 8.5 (13.5)	67.1 ± 7.1 (10.6)	81 ± 5.8 (7.2)	65.1 ± 5.4 (8.3)
HR_{peak} (bpm)	108.7±19.3 (17.7)	150.2 ± 21.9 $(14.6)^{m,w}$	158.9 ± 17.4 $(10.9)^{m,w}$	181.7 ± 8.3 $(4.6)^{m,u,s}$	181.7 ± 8.3 (4.6)
HR_{peak} (%)	56.9 ± 9.4 (16.6)	78.8 ± 11.6 (14.8)	83.3 ± 8.7 (10.5)	95.3 ± 4.1 (4.3)	95.3 ± 4.1 (4.3)
Total time (min)	10.8 ± 3.6 $(33.4)^{s,w}$	10.3 ± 2.5 $(24.3)^{s,w}$	19.6 ± 6.1 $(30.9)^{m,u}$	22.1 ± 5.9 $(28.8)^{m,u}$	62.8 ± 4.5 (7.1)
RPE	2.7 ± 0.6 $(23.1)^{u,s,w}$	5.6 ± 0.9 $(16.3)^{m,s,w}$	7.3 ± 1.1 $(15.2)^{m,u,w}$	9.8 ± 0.4 $(4.2)^{m,u,s}$	6.4 ± 0.5 (8.1)
Internal load(AU)	29.3±13.4 $(45.6)^{u,s,w}$	56.7 ± 13.6 $(24)^{m,s,w}$	141.5 ± 41 $(29)^{m,u,w}$	216.9 ± 59.7 $(27.5)^{m,u,s}$	398.7 ± 42.6(10.7)

Mean ± standard deviation (coefficient of variation); HR: Heart Rate; RPE: Rating of Perceived Exertion; AU: Arbitrary Units. ^{m} Significant difference in relation to mobility ($p < 0.01$). ^{u} Significant difference in relation to the warm-up ($p < 0.001$). ^{s} Significant difference in relation to skill ($p < 0.05$). ^{w} Significant difference in relation to the WOD ($p < 0.05$).



* Significant difference from the end of the previous segment ($p < 0.01$). ** Significant difference from the end of the previous segment ($p < 0.001$).

Figure 2. HR at the beginning and end of each CrossFit® training session segment (n =15).

No other study has examined HR during a full CT session. Only one study[15] analyzed the energy expenditure and intensity during the warm-up and WOD segments. The total session was 43.9 minutes, with 8.3 minutes for the warm-up (78.1% HR_{max}) and 35.6 minutes for the WOD (82.7% HR_{max}). Kliszczewicz et al.[8] found a significant increase in HR over a WOD ('Cindy' – as many rounds possible of 5 pullups, 10 push-ups, and 15 air-squats in 20 minutes). On the other hand, Maté-Muñoz et al.[9] indicated high HR recorded both in the middle section and during the final session in the three CrossFit® WODs ('Cindy'; as many double-under as possible in eight sets of 20 seconds with 10 seconds rest between sets; and maximum number of power cleans possible in five minutes lifting a load equivalent to 40% of 1RM).

We found that HR progressively increased at each segment of the training session. When we examined exercise intensity at the cardiovascular level, HR was near maximum (95%) in the last segment (i.e., WOD). However, the increase in HR from the warm-up to the skill was not significant. This lack of significance might be explained by the technical focus of the skill segment, often with light-to-moderate load. If we consider the session average HR (65% of HR_{max}), the exercise session would be considered moderate as the ASCM defines moderate intensity as being between 64-76% of $HR_{max.}$[16] However, when time in each intensity zone was analyzed, subjects spent 12.5 minutes in very light activity (51% of HR_{max}), 18 minutes in moderate activity (64.2% of HR_{max}), and 31.5 minutes in vigorous activity (85% of HR_{max}). Therefore, over half of the session was spent completing vigorous intensity activity.

The high cardiovascular response noted at the end of the session is comparable to that described by others who have found peak HR of 92.1 ± 3.1% $HR_{max,}$[17] 91.3 ± 3% $HR_{max,}$[18] and 97 ± 5% $HR_{max.}$[9] Two studies that described similar HR_{max} as our findings, related HR_{max} to VO_{2max} reporting values of around 66% of VO_{2max}[19] and 64% of VO_{2max}.[20] These proportions indicate vigorous exercise intensity (60-85% of VO_{2max}) and are considered more effective than moderate intensity exercise (40-60% VO_{2max}) for improving $VO_{2max.}$[21] In the present study, HR average across each segment was at a vigorous intensity during the WOD (81% of HR_{max}), as compared to moderate during the skill (67% of HR_{max}), and light during the warm-up (63% of HR_{max}) and the mobility (49% of HR_{max}) segments.

It is worth mentioning that in the transition from one segment to the next, HR decreased significantly. These transition periods added up to 15 total minutes of the training session, which may be why HR averaged across each segment presented moderate average values. Salagas et al.[22] submitted 17 young gymnasts to a high-intensity circuit training program with a three-minute break between circuits. It was observed that the HR decreased ~ 70 bpm in the interval between circuits. Likewise, runners and untrained individuals experienced a significant reduction in HR after submaximal treadmill exercise.[23] Such results can be explained by regulatory mechanisms that act on beat by beat HR control such as increased baroreflex function, in addition to other extrinsic and intrinsic HR regulation factors.[24]

The use of RPE as a method to control the training intensity, particularly with more experienced athletes,[4] could easily allow participants and coaches better control over training intensity, as well as preventing over-training. The RPE-scale is an inexpensive, non-invasive method of self-monitoring of training intensity during CT sessions that positively correlates with lactate and the number of repetitions completed.[25] In the present study, results showed internal training load increased each segment, as well as RPE. Participant HR responses did not follow the internal load, as shown in the Tibana et al.[25], that demonstrated RPE was more effective in regulating the intensity of CT. This result is different from studies of HIIT sessions with walking/running,[3] volleyball training sessions,[26] and different intensities in treadmill exercise,[27] in which there were no differences between when regulated by HR or RPE in young individuals.

Despite the significant findings of this study, some limitations need to be mentioned. First, only seven training sessions were included in the analysis. Second, the time recall of sRPE was limited to 30 minutes after exercise.[28] Third, it should be noted, that these results are only applicable to CrossFit® trained men. Future research should examine these variables among untrained participants and women.

CONCLUSION

We conclude that HR increased in each segment of a CT session, however the increase was similar between the warm-up and skill segments. RPE and internal load increased significantly with each segment, showing that HR and RPE responded differently to the training stimuli. At the end of each segment, after the warm-up, HR reached its peak > 76% of HR_{max}, which is considered high intensity by the ACSM. It is worth mentioning that the duration of session time that remained at HR_{peak} was low. In addition, when switching from one segment to another, the HR fell below the HR_{peak} of the previous segments, thus influencing the average HR of the entire session.

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