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Acute effects of a multimodal training session on heart rate, blood lactate and subjective perception of effort in young athletes

Efectos agudos de una sesión de entrenamiento multimodal sobre la frecuencia cardíaca, el lactato sanguíneo y la percepción subjetiva del esfuerzo en deportistas jóvenes

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Abstract. The objective of the present study was to evaluate the acute physiological responses of MMT sessions in young athletes. The sample was made up of 13 young athletes, aged between 15 and 18 (height 170.9±11.14 cm, 70.20±15.05 kg), who practice rugby, rowing or taekwondo. Prior to the intervention, maximum dynamic strength, maximum aerobic speed (MAS) and maximum heart rate (HRmax) were measured. As acute physiological measures, blood lactate concentration ([LAC]), HR, maximum oxygen consumption (VO2max) and subjective perception of exertion (RPE) were adopted. There were no significant differences between the sexes for HRrep, HRmax and performance in muscle strength tests ($p>0.05$). VAM and VO2max values were higher in males ($p<0.05$). No differences were found between sexes in [LAC] ($p>0.05$). Significant differences were identified between the HR intensity ranges when considering the time and percentage of the total session duration ($p<0.001$). RPE presented statistically higher values among male participants when compared to female participants ($p< 0.05$). Throughout the protocol, the athletes maintained high HR and in high intensity zones, which configured the MMT session as a vigorous activity. Regarding [LAC], the athletes obtained high values, which indicates high glycolytic demand. The RPE after the session was also high, indicating that, in addition to the high physiological demand, high effort values were also obtained.
Keywords: physical fitness; athletes; training; high-intensity; physiological.

Resumen. El objetivo del presente estudio fue evaluar las respuestas fisiológicas agudas de las sesiones de MMT en atletas jóvenes. La muestra estuvo formada por 13 jóvenes deportistas, con edades comprendidas entre 15 y 18 años (170.9±11.14 cm y 70.20±15.05 kg), que practican rugby, remo o taekwondo. Previo a la intervención se midieron la fuerza dinámica máxima, la velocidad aeróbica máxima (MAS) y la frecuencia cardíaca máxima (FCmáx). Como medidas fisiológicas agudas se adoptaron la concentración de lactato en sangre ([LAC]), la frecuencia cardíaca, el consumo máximo de oxígeno (VO2max) y la percepción subjetiva del esfuerzo (RPE). No hubo diferencias significativas entre sexos para FCrep, FCmáx y rendimiento en pruebas de fuerza muscular ($p>0,05$). Los valores de VAM y VO2max fueron mayores en los hombres ($p<0,05$). No se encontraron diferencias entre sexos en [LAC] ($p>0,05$). Se identificaron diferencias significativas entre los rangos de intensidad de la FC al considerar el tiempo y el porcentaje de la duración total de la sesión ($p<0,001$). El RPE presentó valores estadísticamente más altos entre los participantes masculinos en comparación con las participantes femeninas ($p< 0,05$). A lo largo del protocolo, los deportistas mantuvieron una FC elevada y en zonas de alta intensidad, lo que configuró la sesión de MMT como una actividad vigorosa. Respecto a [LAC], los deportistas obtuvieron valores elevados, lo que indica alta demanda glucolítica. El RPE tras la sesión también fue elevado, indicando que, además de la elevada exigencia fisiológica, también se obtuvieron valores elevados de esfuerzo.
Palabras clave: aptitud física; atletas; capacitación; alta intensidad; fisiológico.

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Introduction

Physical exercise can enhance the neuromuscular and metabolic fitness of young athletes and non-athletes (FERIA-MADUEÑO et al., 2024). To achieve this, there are different possibilities for training methods, applying distinct stimuli (BUCKLEY et al., 2015; SCHAUN et al., 2020). Resistance training aimed at increasing strength is commonly employed (MERCÊ et al., 2022), as well as plyometrics to improve muscular power (HEANG et al., 2012), and aerobic predominance stimuli, which aim at increasing cardiorespiratory fitness (ACSM, 2011).

However, the use of the aforementioned methods is not absolute, as there are also training models that involve mixed loads, incorporating stimuli of different natures in the same session. In this sense, high-intensity functional training (HIFT) stands out, which utilizes multi-joint exercises such as squats, push-ups, and jumps (FEITO et al., 2018; MACHADO et al., 2024). There is also cross-training, which combines gymnastic movements with Olympic weightlifting, and functional training, which allows for full-body workouts without the need for machines or weights, using only body weight and performing movements that are functional for daily activities, adjusted for each participant (GRIGOLETTO et al., 2014).

Among the protocols that have recently emerged, multimodal nature protocols are noteworthy, as they require reduced session time and little to no equipment, as they can be performed without the need for external loads, relying solely on body mass (MCRAE et al., 2012; SCHAUN et al., 2020). Traditional multimodal training (TMM), using external loads and high intensity, aims to incorporate different physical manifestations within the same effort block, combining the benefits of resistance training and those seeking the development of cardiorespiratory fitness (BUCKLEY et al., 2015; DE OLIVEIRA SILVA et al., 2019).

Regarding MMT, this training model has been employed in interventions with healthy adults (BUCKLEY et al., 2015; BROWN et al., 2021); however, no studies investigating the acute effects of this training model in young

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athletes were found. This type of information can be useful to evaluate the physiological demand of TMM and determine whether it can be incorporated into sports conditioning routines. Thus, the objective of this study is to evaluate the acute physiological responses of young athletes in a TMM session. Understanding these responses is essential to assess the effectiveness of MMT in young athletes, as it allows us to identify whether this training model is suitable for promoting improvements in critical components for sports performance, such as cardiorespiratory endurance, muscle strength and recovery. In addition, the data obtained can help in prescribing appropriate loads and volumes for this audience, ensuring safe and effective training.

Materials and methods

Participants

The sample consisted of 13 young athletes, 7 males and 6 females, who were practitioners of rowing, rugby, or taekwondo, with ages ranging from 15 to 18 years (height 170.9±11.14 cm, 70.20±15.05 kg). In order to be included in the study, participants had to be physically active for the past 6 months. Those who reported functional limitations resulting from previous injuries that would hinder the performance of exercises, as well as individuals with cardiovascular, metabolic, respiratory, and/or other non-communicable chronic diseases that would prevent their participation in the study, were excluded during the initial anamnesis. Convenience sampling was employed, with verbal invitations extended to the young athletes, their parents, and coaches.

Ethical aspects of the research

The ethical principles of this study will be guided by CONFEF Resolution No. 056/2003, which refers to the Code of Ethics for Physical Education Professionals (RESOLUTION 251, 1997). The study was approved by the Human Research Ethics Committee of the School of Physical Education at the Federal University of Pelotas (opinion registered under protocol #3.536.069). The risks and benefits of the study will be presented to all participants, who will be required to read and sign the informed consent form in order to continue their participation.

Study designA cross-sectional observational study was conducted as shown in Figure 1. After the participants were selected in the first meeting, they underwent an initial assessment, including anthropometric measurements and evaluation of maximum dynamic strength, as well as familiarization with the TMM protocol used in the study. In the second meeting, the participants performed the proposed TMM protocol. It should be noted that there was a minimum interval of 24 to 36 hours between the meetings. The participants were instructed to abstain from consuming stimulating beverages or using any ergogenic aids in the 4 hours before data collection.

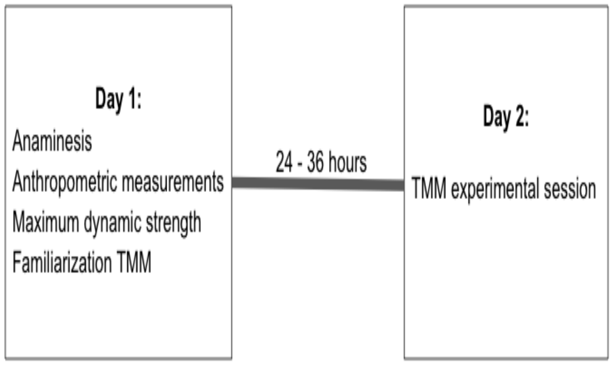

Figure 1. Experimental study design

Multimodal training protocol

Initially, the study participants were submitted to a standardized warm-up, proposed by Javorek, which consisted of 3 sets with 1 min of rest between them, with 6 repetitions being performed, with an 18 kg Olympic barbell, for the following 5 movements: i) high row; ii) squat with development; iii) curved row; iv) snatch pull; v) good morning.

After warming up, 3 to 5 min of rest were granted, and then the TMM protocol began, which consisted of 6 series of 60s, with intervals of 2 min between them. During the effort period, lasting 60s, three stages are performed: i) strength exercise (deadlift), with 4-6 RM; ii) 8-12 RM of an accessory exercise (barbell curl), for another body segment, and; iii) exercise that demands great metabolic request (skipping), until the end of the 60s (Figure 2).

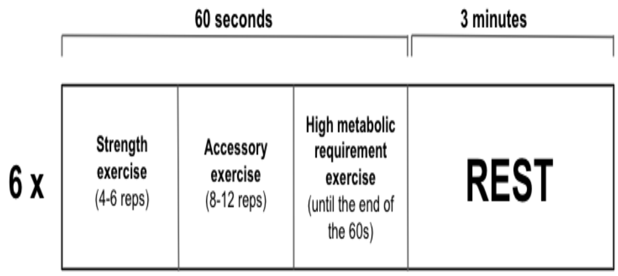

Figure 2. Protocol design of the multimodal training session.

Data collection procedure

Anthropometric measurements

Body mass was measured using a platform scale (Filizolla®) with a precision of 0.1 kg. Participants were barefoot and in an upright position. The values for participants' height were obtained through verbal inquiry. For the assessment of resting heart rate (HR), participants remained in a supine position for 5 minutes, and the lowest value was recorded.

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Maximum strength

To standardize the testing session, five strategies were adopted: i) specific warm-up (2 sets with 60% body mass); ii) participants received the same instructions regarding the execution pattern of the movements; iii) extrinsic feedback and encouragement were provided during the tests; iv) the weight plates were measured using a precision scale; and v) a standardized cadence of 3 seconds for both the eccentric and concentric phases of the test was maintained. Afterward, the physical tests were conducted with rest intervals between familiarization and testing ranging from 3 to 5 minutes (MATERKO et al., 2007; FERMINO et al., 2008).

To assess this variable, the repetition maximum test (1RM) was employed. Prior to the attempts, participants performed a general warm-up on the treadmill and standardized mobility and flexibility exercises. For quantification of the number of repetitions in the Deadlift exercise, 50% of the participant's body mass was calculated, and they performed as many repetitions as possible with proper technique. For the biceps curl exercise, participants performed the maximum number of repetitions with a 14 kg barbell.

Based on the maximum number of repetitions and the external resistance, the maximum dynamic strength was estimated using the 1RM app (Josman Tek, Google Play™), which calculates the maximum load (1RM) based on different equations (Brzycki, Epley, Lander, O'Connor, Lombardi, Mayhew, and Wathen).

Maximal aerobic speed

For the assessment of maximum aerobic speed (MAS), the progressive treadmill test was employed, in which the athletes were asked to exert maximum effort. The test involved setting the treadmill at a 1% incline, with an initial speed of 5km/h, and increasing the speed by 1km/h every minute until voluntary fatigue, which was determined by the inability to continue exercising.

The maximum heart rate (HRmax) achieved during the test was recorded and used to estimate the percentage of heart rate zones during the training session. The maximum oxygen uptake (VO2max) was also estimated using the equation (BILLAT; KORALSZTEIN, 1996):

$$VO2max = 2{,}209 + 3{,}163 * vVO2max + 0{,}000525542 * vVO2max^3$$

Heart rate

Prior to testing, resting HR (HRrest) was recorded, and during testing, HRmax, average HR (HRmed) and HR ranges (zone 1 = <60% HRmax; Zone 2 = 60 to 69% HRmax; zone 3 = 70 to 79% HRmax; zone 4 = 80 to 89% HRmax; zone 5 = ≥90% HRmax), a heart rate monitor (Polar®, model H7, Kempele, Finland) was used together with a chest strap. To capture the data, the Polar Beat® application was used, in which the athletes' HR was recorded. After collecting the record, the data were recorded in spreadsheets and the time in which each participant stayed in the respective zones of %HRmax.

Blood lactate

Blood lactate concentration ([LAC]), only collected post-testing, was determined by obtaining 5 µL of blood from a finger prick, previously sterilized with 70% alcohol, and applying it onto a reagent strip for subsequent analysis. During the procedure, gloves and disposable lancets (Softclick®) were used. The sample was then analyzed using a portable Lactate Detect TD-4261 device.

Rate perceived effort

The rate perceived effort (RPE) was measured at the end of each session, using the methodology proposed by Borg (1982), which consists of an effort scale starting at 6 and ending at 20, in which participants indicated the best number related to your effort. In addition, the modified Borg scale was also used, which starts at 0 and ends at 10.

Statistical analysis

The normality of the data was tested using the *Shapiro-Wilk* test. Descriptive analysis was performed, assuming mean and standard deviation (SD) as measures of centrality and dispersion. Comparisons between sex were performed using Student's t test. In this case, the magnitude of the difference was calculated using Cohen's d, which can be classified as small (d = 0.20), medium (d = 0.50) and large (d = 0.8) and very large, when d = 1.2 (Sawilowsky, 2009).

Comparison of durations (in minutes and percentage) in each training zone (zone 1 = <60% HRmax; zone 2 = 60 to 69% HRmax; zone 3 = 70 to 79% HRmax; zone 4 = 80 to 89 % HRmax; zone 5 = ≥90% HRmax) was performed with one-way analysis of variance and, when differences were identified, they were located using Tukey post-hoc. The magnitude of differences was presented using eta squared (η^2), which can be classified as small (0.1), medium (0.24) or large (0.37) (Cohen, 1988). The significance level was set at 5%.

Results

In the present study, 13 athletes were involved (4 from taekwondo, 4 from rugby and 5 from rowing), aged 16.4 ± 1.6 years, 171.6 ± 11.8 cm, 71.8 ± 15.5 kg and BMI of 24.46 ± 4.9, respectively. When comparing by gender, the groups differed in terms of competitive level (table 1).

Table 1.
Sample data, according to sex (N = 13)

	Male	(n = 7)	Female	(n = 6)	p	Effect Size
	mean	±DP	mean	± DP		
Age (anos)	15.8	± 1.2	17.0	± 1.0	0.10	-0.98
Estature (cm)	177.8	± 7.8	164.3	± 11.9	0.03	1.36
Body mass (kg)	76.3	± 20.4	66.6	± 4.1	0.28	0.63
BMI	24.1	± 6.4	24.8	± 2.9	0.78	-0.15
Experience (years)	4.4	± 3.1	3.4	± 1.0	0.48	0.40
Weekly frequency	5.1	± 1.5	4.0	± 1.5	0.21	0.73
Competitive Level (0-10)	7.4	± 0.9*	8.6	± 1.0	0.04	-1.23

*Statistically significant difference.

Concerning physiological and physical fitness variables, no differences were observed according to sex for HRrest (male = 68.4 ± 10.5 bpm; female = 75.0 ± 8.22 bpm; p = 0.24; d = 0.68) indicating that both groups began the test

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with similar cardiorespiratory parameters. Similarly, maximum heart rate (HRmax) was comparable between males (194.3 ± 12.6 bpm) and females (196.8 ± 6.6 bpm; p = 0.66; d = 0.56), suggesting that both groups reached similar peak effort. As for muscular strength tests, no significant differences were found between sexes, as illustrated in Figure 3, highlighting the homogeneity in the strength capacities measured. However, the values of MAS and VO2max were significantly higher in male athletes, as shown in Figure 4, indicating a physiological advantage in aerobic capacity for males, which is consistent with known sex-based physiological differences.

Regarding the MMT session, which had an average duration of 19.3 ± 1.4 min, no differences were observed between sexes for most variables. It was identified that, for the entire group, the average heart rate was 75.6 ± 7.3% of HRmax and the peak heart rate was 95.8 ± 3.8% of HRmax. Additionally, the lactate concentration at the end of the session was 11.6 ± 2.5 mmol/L (table 2).

About the activity time (in minutes and relative to the duration of the session) in each of the intensity zones, it was identified that the participants showed no differences according to gender. This way, the data will be presented considering the entire group. Significant differences were identified between the intensity zones when considering time (in minutes; $F(4;60) = 7.28$; $p < 0.001$; $\eta^2 = 0.33$) and the percentage in relation to the total duration of the session ($F(4;60) = 7.51$; $p < 0.001$; $\eta^2 = 0.33$), and the data are in figure 3.

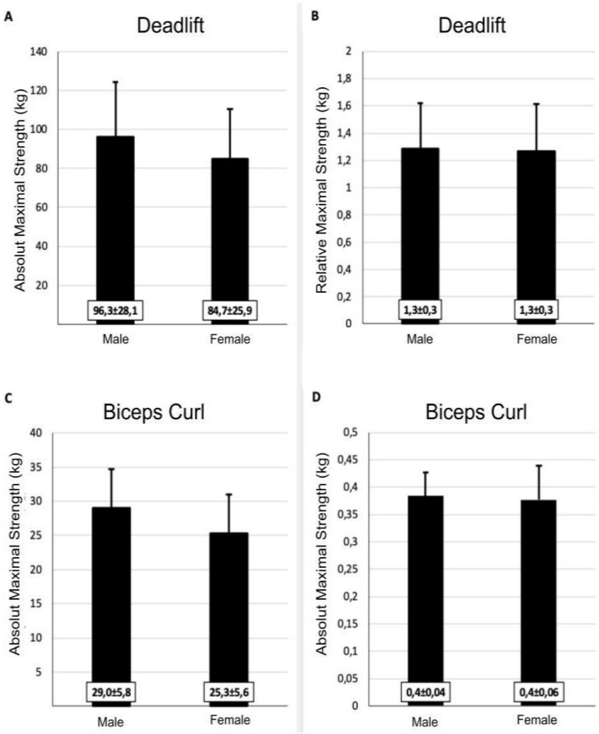

Figure 3. Absolute maximum strength (in kg; panels A and C) and relative strength (kg/kg of body mass; panels B and D) in the Deadlift and Barbell Curl exercises, according to gender (N = 13).

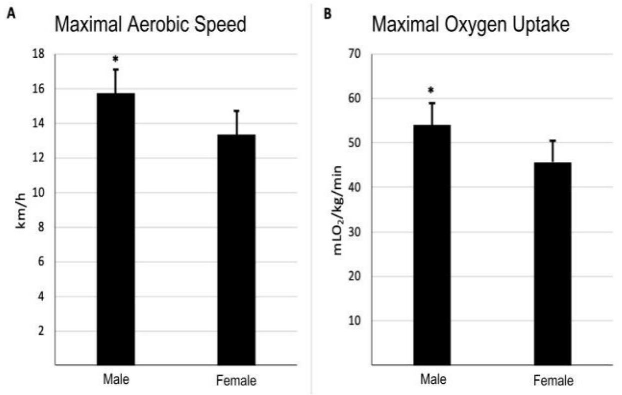

Figure 4. Maximum aerobic speed (panel A) and maximum oxygen uptake (panel B), according to sex (N = 13).
*Statistically different from females.

Table 2.
Duration and acute physiological responses in a TMM session (N = 13)

	Male (n = 7)		Female (n = 6)		p	d
	Mean	± sd	mean	± sd		
Duration (min)	19.4	± 1.7	19.0	± 1.0	0.07	-1,11
HRmean (bpm)	140.0	± 17.6	157.5	± 12.9	0.12	-0,91
HRmean (%HRmax)	71.9	± 7.2	79.9	± 4.8	0.95	0,03
HRpeak (bpm)	183.1	± 11.7	192.1	± 6.7	0.66	0,25
HRpeak (%HRmax)	94.3	± 3.7	97.6	± 3.2	0.38	0,50
Lactate (mmol/L)	11.6	± 3.3	11.6	± 1.1	0.20	0,75
RPE (6-20)	17.0	± 1.5	16.3	± 1.0	0.04*	-1,26
RPE (0-10)	7.1	± 2.2	5.6	± 1.5	012	-0,93

HR = heart rate; RPE = rate perceived effort.

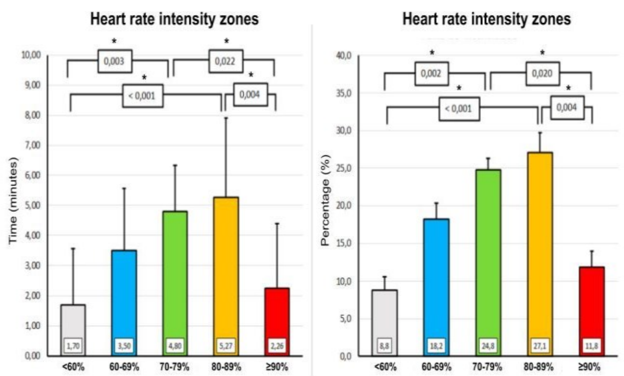

Figure 5. Absolute (min) and relative time (to the total session) in each of the intensity ranges in a Multimodal Training session (N = 13). *Statistically significant difference.

Discussion

The purpose of the present study was to investigate the acute effects of a TMM session at physiological intervals in young athletes. The main results of this research are: i) high physical level (VO2max and strength) of the sample; ii) great cardiovascular demand in the TMM session, affected by heart rate, and; iii) high glycolytic demand, understood by [LAC] values.

Regarding the physical fitness of the sample studied, it is highlighted that VO2max is a very relevant variable, as it identifies the amount of oxygen that is being captured, transported, and used in the body (UNESCO, 2013). Broadly speaking, regardless of how they were evaluated, a

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meta-analysis of 168 studies identified that VO2max values have shown a secular downward trend over the decades among children and adolescents (FÜHNER et al., 2021). In addition, it is recognized that low cardiorespiratory fitness values (close to 24.7 mLO2/kg/min) in adolescence are associated with a greater risk of early mortality (HÖGSTRÖM et al., 2016). In the sports scenario, knowing the VO2max of young athletes is very relevant, especially so that coaches and physical trainers can carry out better training plans (NUNES et. al. 2021).

To compare VO2max, Watson et al. (2017), who tested the pre-season aerobic fitness of young female athletes, found a VO2max of 58 mLO2/kg/min. In the study by Shi (2002), with young endurance athletes, males reached 54.4 mLO2/kg/min while females reached 59.69 mLO2/kg/min. According to Klusiewicz et al. (2016), who tested VO2max in young male and female rowers, with an average age of 18 years, in the 2 km rowing ergometer test, found similar results to the present study. For men, the result was 62 mLO2/kg/min, while for women it was 50 mLO2/kg/min. Indirectly, inferred from MAS, male participants in the present study reached 55 ± 4.8 mLO2/kg/min and, in females, VO2max was 45 ± 5.8 mLO2/kg/min, with significant differences between the sexes, which classify them between the 75th and 90th percentiles based on reference data from 2997 young people from the United States of America who participated in NHANES (EISENMANN et al., 2011). In general, males have higher VO2max compared to females depending on body composition or total muscle mass.

Regarding strength parameters, in the present study, two exercises were used, the deadlift and the straight curl, which were used in the preparation of the TMM session. To measure strength in these two exercises, the maximum repetitions test was used. According to Mayer et al (2011), muscle strength decreases throughout life, especially after the age of 30; however, it is important to train it regardless of age group, to: i) better recruitment of motor units, ii) avoid loss of muscle mass, iii) protect joints and iv) prevent injuries. One of the advantages of MMT is that, in addition to improving the aerobic component, there are also extensive gains in the neuromuscular component, with increased strength, power, and endurance (BUCKLEY et al., 2015). In the case of the athletes in the study, it is important that this strength training occurs, as carrying it out is transferable to the sports they practiced - rowing, rugby, or taekwondo. Furthermore, strength training also promotes improvements in speed, agility, and stability (UGHINI et. al., 2011). No reference values were found for performance in the strength test for upper limbs (barbell curl). However, regarding performance in the Deadlift, it is indicated that adolescents competing in Basismo (16.6 ± 1 years and 74.1 ± 16.5 kg) reach a 1RM of 146.5 ± 25.9 kg (relative strength = 1.97), with a range of 88.6 to 227.3 kg (MAYHEW et al., 1993). The practitioners in the present study reached lower values, 96.3±28.1 kg in males and 84.7 ± 25.9 kg in females, which can be explained by the specificity of the training.

Regarding the heart rate measured in the multimodal training session, male participants had an average HR of 140 bpm, HRpeak of 183 bpm (which was equivalent to 94% of the maximum HR). Meanwhile, female participants had an average HR of 157bpm and peak HR of 192bpm (97% of HRmax). According to the American College of Sports Medicine (1998), in a vigorous training session, the average HR of the session must remain between 77% and 93% of the maximum HR. It is noteworthy that, in our study, the average heart rate was 71.9% in men and 79.9% in women, which shows that the training session was vigorous, especially if recovery periods are taken into account. passive for 2 minutes between sets.

To evaluate the acute metabolic effect of the session, we measured lactate values at the end of physical effort. In general, it is indicated that blood lactate is considered one of the best physiological indicators of intensity in training and conditioning, both for prescription and evaluation (VEIGA et al., 2020). According to Silva et al. (2007), when acute blood lactate responses were investigated after specific training for the study modalities, which were swimming, tennis and futsal, in adolescent athletes, the following values were found: ages 9 to 11 years (4 mmol/L); 12 to 14 years (7.7 mmol/L) and 15 to 17 years (8.7 mmol/L). Strong et al. (2021), investigated the lactate response immediately after a WOD and 30 minutes later, and obtained the following results: the results immediately after exercise for men and women were similar at a value of 15.8 ± 4.9. Researchers Shaw and collaborators (2017) analyzed the effect of a single CrossFit session on blood lactate, and differences were found in pre- and post-session values: from 2.20 ± 1.35 mmol/L to 5.95 ± 3.24 mmol/L. In our study, the average [LAC] at the end of the session was 11.6 mmol/L, with no differences between genders. Considering that values of 3.5 to 4 mmol/L can be considered as related to the physiological threshold that separates two domains of intensity of physical effort, moderate and severe (LAURSEN; JENKINS, 2002), it is indicated that the proposed session presented high metabolic demand.

Exercise intensity can be assessed by RPE, however, it is necessary that the athlete being analyzed knows and is aware of what each level of the scale represents in the exercise. The scale created by Borg in 1971 relates to intensity levels in relation to exercise, on a scale of 6-20. According to ACSM guidelines (2011), values of <10 correspond to very light activity; 10-11 as a light activity; 12-13 can be considered moderate activity; 14-16 heavy activity; 17-19 very heavy activity and 20 as maximum activity. In the present study, RPE reached 17.0 ± 1.5 points in males and 16.3 ± 1.0 points in females, with significant differences between sexes ($p = 0.04$). Furthermore, there is the modified Borg scale (0-10), which is also widely used (MCGUIGAN et al. 2004), including in the protocol of the present study. In this case, values from 0-2 are considered easy activity; 3-4 moderate/somewhat

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difficult activity; 5-6 difficult activity; 7-9 very difficult activity and 10 maximum activity. On the 0-10 scale, participants in the present study achieved 7.1 points among men and 5.6 for women.

Although the present study provides original data, it is not free from limitations. The first of these deals with the profile of the sample. The study participants were: i) physically active and ii) competitors in sports (rowing, rugby and taekwondo). Therefore, the results found in this investigation cannot be generalized to other groups of athletes. Secondly, although MMT sessions present similar structures - the first multi-joint exercise for strength, the second single-joint exercise for resistance and the third with high metabolic demand - the heart rate and lactate values may have presented a certain behavior depending on the exercises chosen for the exercise. multimodal training session. Therefore, other compositions may lead to different results. Thirdly, the data presented here are from acute responses to the session, which does not imply any type of chronic effect, although previous studies have observed the effectiveness of MMT in increasing physical fitness (Buckley et al., 2015).

Conclusion

It is concluded, based on the data from the present study, that the strength of young men and women, in the deadlift, exerted a force of 1.3 x their body weight. The barbell curl results exert a force of just 0.4x your body weight. When analyzing the results of Maximum Oxygen Consumption (VO2max) and compared with athletes from other studies, we can see that the VO2max of the subjects in the present study is at a high level.

The results found on the athletes' Heart Rate (HR) during the protocol remained at high levels and in vigorous intensity ranges, which suggests that the training protocol was at a high intensity. Regarding blood lactate, we concluded that the athletes had a high level of this physiological marker in the session. Regarding the PSE results, we obtained significant results, given that the athletes were close to the maximum number on the scale, being 17 for men and 16.3 for women.

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