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Original Article

Fight-or-flight CrossFit® athletes with temporomandibular joint disorders: aerobic power and capacity until fatigue

PAMELA HERNÁNDEZ ARAVENA[1], ESTEBAN AEDO-MUÑOZ[2], BIANCA MIARKA[3], MICHELE ANDRADE DE BRITO[4], ANA PAULA VARELA BROWN MARTINS[5], DIEGO IGNÁCIO VALENZUELA PÉREZ[6], CIRO JOSÉ BRITO[7], MAURÍCIO MALHEIROS BADARÓ[8], MANUEL SILLERO QUINTANA[9]
[1,9]. Sports Department. Faculty of Physical Activity and Sport Sciences, Universidad Politécnica de Madrid, ESPAÑA.
[2,3,4]. Postgraduate Program in Physical Education, School of Physical Education and Sport, Federal University of Rio de Janeiro, Rio de Janeiro, BRAZIL.
[2,3]. Universidad Metropolitana de Ciencias de La Educación, CHILE.
[5,7]. Federal University of Juiz de Fora, Governador Valadares campus, Minas Gerais, BRAZIL.
[6]. Escuela de Kinesiología - Facultad de Salud, Universidad Santo Tomás, Santiago, CHILE.
[8]. Federal University of Santa Catarina (UFSC), BRAZIL.

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Abstract:
Temporomandibular disorder (TMD) has a complex and multifactorial etiology, affecting masticatory muscles and / or the temporomandibular joint. Continuous exposure to episodes of facial trauma, anxiety, and stress by sports practices are considerable factors in the high prevalence of myofascial pain. Therefore, this study aimed to: i) typify the performance effects during continuous self-paced sequential squats until fatigue with a submaximal load; ii) verify the Temporomandibular disorder (TMD) effects in the Ergospirometry results of CrossFit® athletes during sequential squats until fatigue; and iii) confirm the relationship of the sequential self-paced squats until fatigue with aerobic fitness indices. First, two paired groups were composed from a total of 158 ranked CrossFit® athletes, namely the TMD group (n=10; age=32.8±6.7 years-old; training experience=20.2±8.3 months; weight=84.5±10.9kg; height=177.3±7.7cm) and the WTMD (without Temporomandibular disorder) group (n=10; age=25±4.7 years-old; training experience=12±6.2 months; weight=76.5±10.3kg; height=173.1±56.0cm). Statistical analysis: It was used the t-test and ANOVA with repeated measures, p≤0.05. Our results showed that sequential squats until fatigue with submaximal load induces elevated cardiorespiratory and metabolic demands, while the TMD condition demonstrates higher Tv during the test than athletes WTMD, with 2.2±0.8 L versus 1.6±0.5 L (p≤0.05); furthermore, the sequential submaximal deep squats impacted the acute physiological responses given the partial glycogen replenishment in both groups (p≤0.05), thus presenting the use of sequential deep squats until fatigue as a way to evaluate the aerobic performance of CrossFit® athletes. The results suggest the necessity of physical therapists for athletes with TMD, restoring the natural respiratory movement and decreasing their pain. This application could help athletes in aerobic demands until fatigue with a submaximal load.
Keywords: Sports Dentistry, Orofacial Injury, Psychophysiology, Respiratory Physiological Phenomena, Crosstraing.

Introduction

Temporomandibular disorder (TMD) has a complex and multifactorial etiology, affecting masticatory muscles or the temporomandibular joint (Sharma, Rattan, Rai, & Malhi, 2019). The related signs and symptoms are cranial or muscular pain (orofacial pain), joint noise, and limited movement (Herpich et al., 2014). It is considered one of the main responsible of non-dental pain affecting the orofacial region (Sharma et al., 2019). Sports practices generate more intense and frequent forces than other daily activities, especially for high-performance athletes with extensive training routines (Bonotto et al., 2016).

The significance of psychosocial and physical factors in the assessment evaluation and long-term management of patients with TMD is receiving improved appreciation (Bartley, 2011; Qu & Zhou, 2020). Continuous exposure to episodes of facial trauma, anxiety, and stress by sports practices are essential factors in the high prevalence of myofascial pain (Bonotto et al., 2016). It was believed that the patients with these disorders might be more susceptible to the impact of social stress events and should be paid more consideration by CrossFit® coaches and dental specialists. A whole literature review did not produce any studies addressing the impact of workouts on athletes with TMD. It is essential to highlight that breathing and TMD during submaximal exercise until fatigue could interfere with self-pacing strategies and determine the metabolic profile. In addition, the breathing pattern can change from a diaphragmatic (or abdominal) breathing pattern to a thoracic

Corresponding Author: DIEGO IGNÁCIO VALENZUELA PÉREZ, E-mail: diegovalenzuela@santotomas.cl

(or chest) breathing pattern (Bartley, 2011; Sharma et al., 2019). Based on these statements, a well-established experimental study to investigate pacing and the aerobic power and capability of athletes with TMD during sequential submaximal specific actions until fatigue require a validated and reliable aerobic test such as Ergospirometry.

Ergospirometry is a non-invasive and helpful method for evaluating the specific functional capacity of an athlete with or without TMD, which analyzes the gas, sneezing, respiratory variables, and oximetry (Karatzanos, 2020). Oxygen uptake (VO2max) can be well-defined as a maximal volume of oxygen that an athlete can absorb per unit and could be used to predict CrossFit workout performance (Dexheimer et al., 2019; Ferreira et al., 2020). While VO2 Peak is the higher value detected during the effort test, it has been considered an important performance parameter because the capacity of an athlete to be able to perform long-term exercise depends on the aerobic metabolism priority (Burr, Beck, & Durocher, 2019; Durkalec-Michalski, Nowaczyk, & Siedzik, 2019). It is a valuable index to determine the overall cardiorespiratory functional capacity in athletes with TMD (Burr et al., 2019; Harrell, Tatum, & Koslin, 2017; Tay & Pang, 2018). Oxygen Uptake was considered the more critical measure and more used pathway to show aerobic ability for a long time (Dexheimer et al., 2019; Feito, Giardina, Butcher, & Mangine, 2019), but some studies have been showing that the index is not sufficient to discriminate performance in specific workouts (Bellar, Hatchett, Judge, Breaux, & Marcus, 2015; Feito et al., 2019). This statement also reflects a lack of information regarding extreme circumstances in which a lung ventilation machine is required for an athlete.

Initial tidal volumes (Tv) were set at 10 to 15 mL/kg of actual body weight for patients with neuromuscular diseases (Brown, Mucci, Hetzler, & Knowlton, 1989). On the other hand, professional athletes may require higher Tv during mechanical ventilation, assuming that they have significantly higher "normal" lung volumes. Authors have also specified that an additional Tv of 0.6 for males and 0.5 ml/kg for females may be required for high-level athletes under mechanical ventilation compared to non-athletes (Myrianthefs & Baltopoulos, 2013).

Regarding performance and workout monitoring, the anaerobic threshold is where the transition from aerobic to anaerobic metabolism occurs and is also an index that acceptably reflects CrossFit® physical fitness (Barbieri et al., 2019; Conde et al., 2022; Durkalec-Michalski et al., 2018). CrossFit® exercises are demanding and require high power outputs sustained over time. Therefore, short, high-intensity functional daily workouts (WOD) could provoke considerable fatigue and injury in subsequent exercise sessions. In turn, research that can observe the effect of pacing strategies by observing how TMD modifies the breathing biodynamics until muscle failure can reduce cardiorespiratory risks (Claudino et al., 2018), improve performance (Burr et al., 2019), and also prevent injury (de Almeida, Carvalho, & Ribeiro Neto, 2018; Feito, Burrows, & Tabb, 2018; Hopkins et al., 2017). This observation has a psychosocial and physiological health significance, as it designates that the round ratio intensity during the WOD is self-regulated relative to the athlete's physical capability near the best scored WOD in its entirety and not round-by-round, which makes the exercise pacing strategy per round essential (Banaszek et al., 2019).

In addition, a prolonged 'fight-or-flight" effect could contribute to musculoskeletal disorders in athletes with TMD, as the improved neural excitation associated with the central nervous system arousal contributes to muscle tension and muscle spasms (Bartley, 2011). Respiratory alkalosis reduces the release of oxygen from hemoglobin, as skeletal muscle fatigues more readily in this condition (Driss & Vandewalle, 2013). Muscle lactic acid efflux also increases in an alkalotic state, leading to increased blood lactic acid levels in athletes (Correia-Oliveira et al., 2017). However, the acute effects of continuous exercise sessions with submaximal load until fatigue on cardiorespiratory, metabolic, and performance responses are still unknown in TMD athletes.

Therefore, the present study aims to: i) typify the performance effects during continuous self-paced sequential squats until fatigue with a submaximal load, ii) verify the TMD effects in the Ergospirometry results of CrossFit® athletes during sequential squats until fatigue, and iii) verify the relationship of the sequential self-paced squats until fatigue with aerobic fitness indices. The hypotheses were that sequential squats until fatigue with submaximal load induces elevated cardiorespiratory and metabolic demands, while the TMD condition demonstrates lower Tv during the test than athletes without TMD; and the sequential submaximal deep squats would impact the acute physiological responses because of the partial glycogen replenishment.

Material & methods

This comparative and descriptive applied research study uses physiological and electromyographic analysis. The sample was determined based on specific physiological effects by elite-level athletes with TMD and without (W) TMD participating in the CrossFit® Program. This information brings new knowledge of self-regulated pacing relative to the athlete's physical capability by implementing a validated protocol of sequential squats with submaximal load until fatigue. The data were collected from participants in an air-conditioned laboratory between 18:30 and 21:30, with temperatures between 24.5 and 26.0°C. The experimental period was four weeks. In addition, paired comparisons between moments with an independent factor (group). This study was approved by the Local Committee of Ethics in Research (no. 013456719), according to the rules of resolution 466/12 of the National Health Council and according to the WMA Declaration of Helsinki.

Participants

First, two paired groups were composed from a total of 158 ranked CrossFit® athletes, namely the TMD group (n=10; age=32.8±6.7 years-old; training experience=20.2±8.3 months; weight=84.5±10.9kg; height=177.3±7.7cm) and the WTMD group (n=10; age=25±4.7 years-old; training experience=12±6.2 months; weight=76.5±10.3kg; height=173.1±56.0cm). During the experimental protocol, athletes competed in representative competitions (state and national levels) and were habitually trained seven to nine times per week. Participants were required to meet the following criteria to be eligible for this study: (a) no consumption of any supplements or drugs; (b) no history of use of medications that could alter the hypothalamic-pituitary-gonadal (HPG) axis, such as anabolic steroids; (c) no history of chronic disease, bronchospasm or atopy; (d) regular eating patterns; (e) no respiratory infections or injuries during the preceding month; (f) no recognized asthma or allergy during the five years prior to the study; (g) not performing treatment for a previously diagnosed temporomandibular disorder. Participants were also excluded from the study if they had missing teeth, use of removable dentures, trauma history on the face or temporomandibular joint dislocation, undergoing orthodontic treatment, or continuous use of any analgesic, anti-inflammatory, or muscle relaxant medications in the last three months (Herpich et al., 2014).

All participants attended a briefing meeting before beginning the study and signed an informed consent form to ensure their understanding of the testing parameters and the benefits and risks of the present study. Subjects who were unable to provide informed consent or who were unable to perform deep squats were excluded. At the same time, the inclusion criteria consisted of continuously training for over six months and competing in official and ranked CrossFit® competitions.

Procedures

The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) questionnaire was used and applied for the TMD diagnosis (Herpich et al., 2014), is applied by a dentist researcher familiar with it and previously calibrated for clinical interventions (axis I - RDC/TMD) regarding the palpation forces of the muscles and temporomandibular joint. Tests calibrated the palpation pressure on a precision electronic scale. The application of axis I (RDC/TMD) also makes it possible to check for the presence of symptoms frequently associated with TMD, such as pain, clicking, crepitation, limited mouth opening, deviation, deflection, or the presence of pain during excursive jaw movements (among others). The participant was examined sitting on a chair to keep the Frankfurt plane parallel to the ground. The torso was erected with the back fully supported and its feet on the floor (Herpich et al., 2014).

Subjects attended a single session in a private room inside the CrossFit® Box. Each subject was instructed to perform the proper back squatting technique during the session. Their feet were positioned at hip width and vertically aligned with the barbell position. The barbell was positioned on their shoulders (high-bar position) with 40% of their maximal load for all subjects. The maximal load was previously calculated from a 1RM test. Before beginning the test, they were already familiarized with the equipment, and all subjects had at least 12 months of experience with CrossFit®. With their feet evenly spaced, each participant began the descent (eccentric phase) with their hips moving backward and not bending their knees to allow the hips to drop down while still keeping the lower legs in an upright position concerning the floor. Once at the bottom of the lift, participants began moving upwards with the weight centered over the middle to back part of their feet. The bar was accelerated throughout the lift until reaching the top of the lift (concentric phase). The movement was repeated as often as possible until task failure (exhaustion).

Measures

After the anthropometry was performed, we measured body weight (Welmi® 104A Scale, SP, Brazil), height (Auturexata® Stadiometer, SP, Brazil), and skinfold thickness (Cescorf® caliper, SP, Brazil). We applied the seven-fold equations of Jackson and Pollock (1978) and the Siri equation (Johnson, 1996) to estimate the fat percentage.

Spirometric variables were measured during the deep squat test but were interrupted when: a) the frequency of squats was not maintained; b) they did not reach the mark determined on the CrossFit validation, or c) they voluntarily stopped. Participants were advised to avoid exercise and to refrain from caffeine and alcohol consumption 48 h before the experiment. Moreover, participants were instructed to maintain their regular dietary habits.

The spirometer was calibrated before each test according to the manufacturer's indications (breath-to-breath gas analyzer, Metalyzer 3BR2, Cortex®, Leipzig, Germany). The following criteria described by Laursen, Shing, Peake, Coombes, and Jenkins (2002) were followed for a test to be considered as maximum: a) Blood lactate ≥8.0 mmol·L-1 (Accutrend Plus, Roche®, Rotkreuz, Switzerland) (Da Silva et al., 2018); b) respiratory exchange ratio (RER) >1.1; and c) heart rate (HR) > 90% of predicted (Polar®, RS800, Kempele, Finland).
Moreover, the Rating of Perceived Exertion (RPE) scale was collected at the beginning and the end of the test, and blood samples (25 µL) were collected. Lactate dosage was collected using a 30 triangular fine-point digital puncture (G-TECH, Accumed-Glicomed, Duque de Caxias, Brazil). The first drip was discarded. The second

was then collected and immediately treated with reagents (Roche, Accusport BM-Lactate, São Paulo, Brazil). The enzymatic reaction analysis was carried out through blood-dosage equipment (Roche, Accutrend Plus, São Paulo, Brazil) in 2 moments: pre, and 3-min after the task.

Statistical Analysis

Data were presented as means and standard deviations. We used the t-test to compare the TMD vs. WTMD groups, and ANOVA with repeated measures was used to rate differences among pre and post-test with one independent factor (TMD vs. WTMD). A Bonferroni post hoc followed it if significant interactions were detected. Partial eta squared (Pn2) values were calculated to evaluate ANOVA effect size, following the classification: small with Pn2 ≥ 0.10; medium with Pn2 ≥ 0.30; and large with Pn2 ≥ 0.50. A significance level of p≤.05 and SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA) was used in all analyzes.

Results

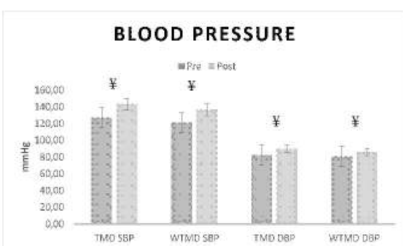
Table 1 showed de results for Table 1 presents the results for the spirometric measurements in the groups DTM and WDTM.

Table 1. Descriptive analysis of Ergospirometry and the ANOVA with repeated measures results.

Variable	Group	Pre-moment		Post-moment		F	p-value	Pn^2
		Mean	SD	Mean	SD			
VO_{2Peak} (L/min)	TMD*	1.0	0.9	2.7	1.4	49.28	≤.001	.73
	WTMD	1.1	1.1	2.9	0.8			
VO_{2Peak} (mL/kg·min)	TMD*	13.5	11.5	34.2	15.9	49.42	≤.001	.73
	WTMD	14.6	12.2	36.0	10.5			
VO2/HR (L/ bpm/ min)	TMD*	6.8	4.1	15.2	5.2	32.11	≤.001	.64
	WTMD	8.1	6.2	16.6	6.4			
VE/VO_2 (mL/kg·min)	TMD*	24.2	4.9	34.5	6.5	12.90	.002	.42
	WTMD	23.6	6.6	34.0	11.5			
VE/VCO_2 (mL/kg·min)	TMD*	23.7	3.1	28.3	4.3	4.83	.041	.21
	WTMD	22.1	5.1	26.9	8.6			
RER (a.u)	TMD	1.0	0.0	1.0	0.0	0.42	.527	.02
	WTMD	1.0	0.0	2.9	6.9			

Temporomandibular disorder (TMD); Without temporomandibular disorder (WTMD) RER – respiratory exchange ratio. * p≤ 0.041 vs. WDTM

A significant difference between moments was observed in absolute and relative VO2Peak with a large effect size, where the post-test had higher values than pre-test. VO2/HR and VE/VO2 post-test had higher results with a large effect size, while VE/VCO2 comparisons demonstrated a significant medium effect size between pre and post-test. Figure 1,2 and 3 show descriptive analysis of the [Lac], HR, SBP and DBP separated by moments.



Note. ¥ = different from pre-moment intra-comparison, p=.001.

Figure 1. Descriptive analysis of the Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) separated by moments in CrossFit® athletes without (WTMD) and with temporomandibular joint disorders (TMD).

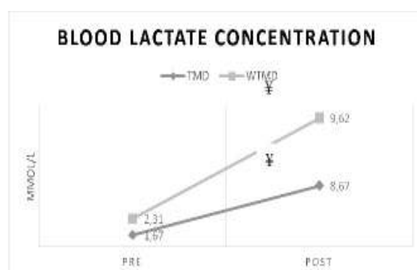
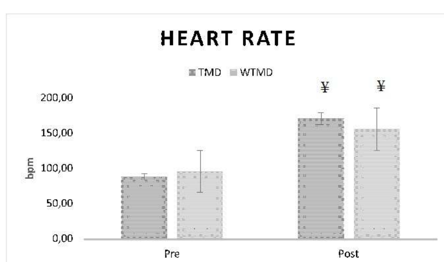


Figure 2. Descriptive analysis of the Blood Lactate Concentration [Lac] separated by moments in CrossFit® athletes without (WTMD) and with temporomandibular joint disorders (TMD).



Note. ¥ = different from pre-moment intra-comparison, p=.001.

Figure 3. Descriptive analysis of the Heart Rate (HR) separated by moments in CrossFit® athletes without (WTMD) and with temporomandibular joint disorders (TMD).

Statistical analysis indicated significant differences between moments when compared blood lactate concentration and heart rate with higher values in post-test moment to the both groups, as the systolic and diastolic blood pressure increased during the test and demonstrated significant differences between moments with large effect size for all comparisons ($p \leq 0.001$).

Table 2. Descriptive analysis of the average values from Ergospirometry, HR, total test time and t-test results.

Variables	DTM	Mean	SD	t	df	p-value	95% C.I. Lower	95% C.I. Upper
V'O2 (L/min)	DTM	2.2	.8	.223	18	0.826	-0.801	0.992
	WDTM	2.1	.9					
VO_{2Peak} (mL/kg·min)	DTM	28.5	11.1	-.029	18	0.977	-10.464	10.179
	WDTM	28.6	9.6					
VO2/HR (L/ bpm/ min)	DTM	14.7	3.4	-.567	18	0.578	-51.667	29.714
	WDTM	25.6	46.7					
HR/min	DTM	153.3	33.4	.795	18	0.437	-28.327	62.851
	WDTM	136.1	48.1					
VE/VO_2 (mL/kg·min)	DTM	32.3	4.0	.770	18	0.451	-2.798	6.036
	WDTM	30.7	4.4					
VE/VCO_2 (mL/kg·min)	DTM	28.0	3.2	.091	18	0.928	-3.150	3.436
	WDTM	27.9	3.2					
VE (L/min)	DTM	83.3	31.5	.307	18	0.762	-28.610	38.420
	WDTM	78.4	33.1					
TV (L)	DTM*	2.2	.8	2.068	18	0.05	-0.009	1.200
	WDTM	1.6	.5					
Heart Rate (pbm)	DTM	41.8	20.1	-.506	18	0.619	-22.211	13.591
	WDTM	46.1	16.3					
Total time (seconds)	DTM	210.8	81.0	-.654	18	0.521	-134.823	70.776
	WDTM	242.9	106.8					

Temporomandibular disorder (TMD); Without temporomandibular disorder (WTMD). * $p \leq 0.05$ vs. WDTM

Table 2 demonstrates statistical results with comparisons between DTM and WDTM groups. A main effect was observed when compared TV between DTM and WDTM groups, with higher values for DTM ($p=0.05$). No other effects were observed between groups or moments ($p>0.05$ for all comparisons).

Discussion

The present study intended to typify the performance effects during continuous self-paced sequential squats until fatigue with a submaximal load, verifying TMD effects in the Ergospirometry results of CrossFit® athletes during sequential squats until fatigue, and the relationship of sequential self-paced squats until fatigue with aerobic fitness indices. The hypotheses that sequential squats until fatigue with submaximal load induces elevated cardiorespiratory and metabolic demands were confirmed, while the TMD condition demonstrated lower Tv during the test than the athlete's WTMD; also, the sequential submaximal deep squats impacted the acute physiological responses given the partial glycogen replenishment.

Breathing plays a crucial role in CrossFit®, especially regarding fatigue and energy. Our results indicated that TMD had differences in how to realize the maximum oxygen consumption in their lungs. This difference in the functional lung performance could affect their ventilator capacity to bring air (thus O2) into alveoli and their capacity to transfer O2 and CO2 into and from the pulmonary capillary bed. Hence, the O2 and CO2 diffusion coefficients, the O2 consumption rate, and the CO2 production rate represent the lung performance indices. Both gases are relevant to athletes' body energy expenditure, and we used one of the best instrumentations used for this purpose in the present study, namely an ergospirometer. It enabled us to know the maximum oxygen consumption or the maximum aerobic VO2 power, which is the maximum amount of energy (moles of ATP) produced by different substances (carbohydrates, lipids, and proteins) per unit of time.

CrossFit® athletes with TMD showed a readjustment in the respiratory rate and the practical use of the lungs, which could consequently affect the muscles associated with breathing. This compensatory reflex may signal a functional change in the Tv condition. Preceding reports have indicated that CrossFit training with a training approach based on ACSM recommendations reported training as more strenuous and was considered a "very hard" activity with great muscle pain and swelling and limb movements difficulties within 48 hours post-WOD (Drum SN, Bellovary BN, Jensen RL, Moore MMT, & L., 2017). The acute effect of a CrossFit® benchmark used is complex and presented greater magnitudes for heart rate with 95–97% HRmax, using 57-66% VO2max with 14-15 mmol/L blood lactate (Fernández et al., 2015). Significant differences were found between moments regarding acute responses of the deep squat until the total fatigue in the present study. Physiological responses showed increased blood lactate concentration, blood pressure, and heart rate frequencies in the TMD and WTMD group.

Our blood lactate values align with previous research analyzing long and short HIIT protocols and acute CrossFit® workouts effects, demonstrating a range between 8 and 15 mmol/l (Dexheimer et al., 2019; Feito et al., 2019; Martinez-Gomez et al., 2019). A preceding study demonstrated a correlation analysis between squat variables and CrossFit® performance. Moderate to strong (r=.47 to r=.69) positive correlations were found between squat variables and performance in five WODs (Martinez-Gomez et al., 2019). Our mathematical analysis with the test with deep squat demonstrated external validity associated with the determination of whether generalization across heterogeneous participants - with and without TMD - and statistical analysis indicated a valid generalization with a large effect size for the physiological effects of deep squat analysis until fatigue, without differences between either group.

Conclusions

Our results showed that sequential squats until fatigue with submaximal load induces elevated cardiorespiratory and metabolic demands, while the TMD condition demonstrates lower Tv during the test than athletes WTMD; furthermore, the sequential submaximal deep squats impacted the acute physiological responses in view of the partial glycogen replenishment in both groups, thus presenting the use of sequential deep squats until fatigue as a way to evaluate the aerobic performance of CrossFit® athletes.

Conflicts of interest – None.

References:

Banaszek, A., Townsend, J. R., Bender, D., Vantrease, W. C., Marshall, A. C., & Johnson, K. D. (2019). The Effects of Whey vs. Pea Protein on Physical Adaptations Following 8-Weeks of High-Intensity Functional Training (HIFT): A Pilot Study. Sports (Basel), 7(1). doi:10.3390/sports7010012

Barbieri, J. F., Figueiredo, G. T. C., Castano, L. A. A., Guimarães, P. S., Ferreira, R. R., Ahmadi, S., Gaspari, A. F. & de Moraes, A. C. (2019). A comparison of cardiorespiratory responses between CrossFit® practitioners and recreationally trained individual. Journal of Physical Education and Sport, 19(3), 1606-1611.

Bartley, J. (2011). Breathing and temporomandibular joint disease. J Bodyw Mov Ther, 15(3), 291-297. doi:10.1016/j.jbmt.2010.06.002

Bellar, D., Hatchett, A., Judge, L. W., Breaux, M. E., & Marcus, L. (2015). The relationship of aerobic capacity, anaerobic peak power and experience to performance in CrossFit exercise. Biol Sport, 32(4), 315-320. doi:10.5604/20831862.1174771

Bonotto, D., Namba, E. L., Veiga, D. M., Wandembruck, F., Mussi, F., Afonso Cunali, P., . . . Azevedo-Alanis, L. R. (2016). Professional karate-do and mixed martial arts fighters present with a high prevalence of temporomandibular disorders. Dent Traumatol, 32(4), 281-285. doi:10.1111/edt.12238

Brown, D. D., Mucci, W. G., Hetzler, R. K., & Knowlton, R. G. (1989). Cardiovascular and ventilatory responses during formalized T'ai Chi Chuan exercise. Res Q Exerc Sport, 60(3), 246-250. doi:10.1080/02701367.1989.10607447

Burr, J. F., Beck, J. L., & Durocher, J. J. (2019). The relationship of high-intensity cross-training with arterial stiffness. J Sport Health Sci, 8(4), 370-375. doi:10.1016/j.jshs.2017.01.009

Claudino, J. G., Gabbett, T. J., Bourgeois, F., Souza, H. S., Miranda, R. C., Mezencio, B., . . . Serrao, J. C. (2018). CrossFit Overview: Systematic Review and Meta-analysis. Sports Med Open, 4(1), 11. doi:10.1186/s40798-018-0124-5

Conde, T.F., Silva, M.R.S., Caobianco, J., Robalino, J., Ferreira, J.C. (2022). Sensitivity of operational tests to training load in Crossfit® Journal of Physical Education and Sport, 22(6) 1493-1498.

Correia-Oliveira, C. R., Lopes-Silva, J. P., Bertuzzi, R., McConell, G. K., Bishop, D. J., Lima-Silva, A. E., & Kiss, M. (2017). Acidosis, but Not Alkalosis, Affects Anaerobic Metabolism and Performance in a 4-km Time Trial. Med Sci Sports Exerc, 49(9), 1899-1910. doi:10.1249/MSS.0000000000001295

Da Silva, J. B., Lima, V. P., De Castro, Juliana Brandão Pinto, Paz, G. A., Novaes, J. D. S., Nunes, R. D. A. M., & Vale, R. G. D. S. (2018). Analysis of myoelectric activity, blood lactate concentration and time under tension in repetitions maximum in the squat exercise. Journal of Physical Education and Sport, 18(4), 2478-2485.

de Almeida, R. L., Carvalho, V. G., & Ribeiro Neto, F. (2018). In Response to: Impact of CrossFit-Related Spinal Injuries. Clin J Sport Med. doi:10.1097/JSM.0000000000000583

Dexheimer, J. D., Schroeder, E. T., Sawyer, B. J., Pettitt, R. W., Aguinaldo, A. L., & Torrence, W. A. (2019). Physiological Performance Measures as Indicators of CrossFit((R)) Performance. Sports (Basel), 7(4). doi:10.3390/sports7040093

Driss, T., & Vandewalle, H. (2013). The measurement of maximal (anaerobic) power output on a cycle ergometer: a critical review. Biomed Res Int, 2013, 589361. doi:10.1155/2013/589361

Drum SN, Bellovary BN, Jensen RL, Moore MMT, & L., D. (2017). Perceived demands and post-exercise physical dysfunction in CrossFit® compared to an ACSM based training session. J Sports Med Phys Fitness, 57, 5.

Durkalec-Michalski, K., Nowaczyk, P. M., & Siedzik, K. (2019). Effect of a four-week ketogenic diet on exercise metabolism in CrossFit-trained athletes. J Int Soc Sports Nutr, 16(1), 16. doi:10.1186/s12970-019-0284-9

Durkalec-Michalski, K., Zawieja, E. E., Podgorski, T., Loniewski, I., Zawieja, B. E., Warzybok, M., & Jeszka, J. (2018). The effect of chronic progressive-dose sodium bicarbonate ingestion on CrossFit-like performance: A double-blind, randomized cross-over trial. PLoS One, 13(5), e0197480. doi:10.1371/journal.pone.0197480

Feito, Y., Burrows, E. K., & Tabb, L. P. (2018). A 4-Year Analysis of the Incidence of Injuries Among CrossFit-Trained Participants. Orthop J Sports Med, 6(10), 2325967118803100. doi:10.1177/2325967118803100

Feito, Y., Giardina, M. J., Butcher, S., & Mangine, G. T. (2019). Repeated anaerobic tests predict performance among a group of advanced CrossFit-trained athletes. Appl Physiol Nutr Metab, 44(7), 727-735. doi:10.1139/apnm-2018-0509

Fernández, J.F., Solana, R.S., Moya, D., Marin, J.M.S., Ramón, M.M. (2015). Acute physiological responses during Crossfit® workouts. Eur J Hum Mov, 35(7), 10.

Ferreira, I.C., Almeida, S.M., Miarka, B., Cardoso, R., Badaró, M., Brito, C., Barbosa, A.W.C. (2020). Interquartile differences in biomechanical parameters in CrossFit® athletes during deep squats with submaximal load until fatigue.J Sports Med Physic Fitness, 60(9), 1216-1222. doi: 10.23736/s0022-4707.20.10845-4

Harrell, W. E., Jr., Tatum, T., & Koslin, M. (2017). Is Centric Relation Always the Position of Choice for TMDs? Case Report of How TMD and Airway Dimension May Be Associated. Compend Contin Educ Dent, 38(4), e9-e12.

Herpich, C. M., Leal-Junior, E. C., Amaral, A. P., Tosato Jde, P., Gloria, I. P., Garcia, M. B., . . . Biasotto-Gonzalez, D. A. (2014). Effects of phototherapy on muscle activity and pain in individuals with temporomandibular disorder: a study protocol for a randomized controlled trial. Trials, 15, 491. doi:10.1186/1745-6215-15-491

Hopkins, B. S., Cloney, M. B., Kesavabhotla, K., Yamaguchi, J., Smith, Z. A., Koski, T. R., . . . Dahdaleh, N. S. (2017). Impact of CrossFit-Related Spinal Injuries. Clin J Sport Med. doi:10.1097/JSM.0000000000000553

Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. British Journal of Nutrition, 40(3), 497-504.

Johnson, R. W. (1996). Fitting percentage of body fat to simple body measurements. Journal of Statistics Education, 4(1), 1-8.

Karatzanos, E. (2020). Noninvasive Ventilation During Functional Electrical Stimulation Rowing in Spinal Cord Injury: An Add-on to Potentially Increase Benefits of Exercise Training. Chest, 157(5), 1058-1059. doi:10.1016/j.chest.2020.02.027

Laursen, P. B., Shing, C. M., Peake, J. M., Coombes, J. S., & Jenkins, D. G. (2002). Interval training program optimization in highly trained endurance cyclists. Medicine & Science in Sports & Exercise, 34(11), 1801-1807.

Martinez-Gomez, R., Valenzuela, P. L., Barranco-Gil, D., Moral-Gonzalez, S., Garcia-Gonzalez, A., & Lucia, A. (2019). Full-Squat as a Determinant of Performance in CrossFit. Int J Sports Med. doi:10.1055/a-0960-9717

Myrianthefs, P., & Baltopoulos, G. (2013). A higher tidal volume may be used for athletes according to measured FVC. ScientificWorldJournal, 2013, 526138. doi:10.1155/2013/526138

Qu, X., & Zhou, X. D. (2020). [Psychological intervention for patients with oral disease during the pandemic period of COVID-19]. Zhonghua Kou Qiang Yi Xue Za Zhi, 55(4), 235-240. doi:10.3760/cma.j.cn112144-20200213-00053

Sharma, V. K., Rattan, V., Rai, S., & Malhi, P. (2019). Quality of life assessment in temporomandibular joint ankylosis patients after interpositional arthroplasty: a prospective study. Int J Oral Maxillofac Surg, 48(11), 1448-1455. doi:10.1016/j.ijom.2019.04.017

TasanTay, D. K. L., & Pang, K. P. (2018). Clinical phenotype of South-East Asian temporomandibular disorder patients with upper airway resistance syndrome. J Oral Rehabil, 45(1), 25-33. doi:10.1111/joor.12551