

# EFFECTS OF DIFFERENT CONCURRENT TRAINING METHODS ON AEROBIC AND ANAEROBIC CAPACITY IN U 21 SOCCER PLAYERS

KHOUDJA YUCEF<sup>1,2</sup>, MIME MOKHTAR<sup>1,2</sup>, BELKADI ADEL<sup>1,2</sup>, BEBOUCHA WAHIB<sup>1</sup>

<sup>1</sup>Laboratory of Optimizing Research Programmes on Physical and Sports Activities, Institute of Physical Education and Sport, University of Abdelhamid Ibn Badis - Mostaganem, 27000 Algeria

<sup>2</sup>Training-University Research Projects (PRFU N° J00L02UN270120220003 Agreement: January 2022), 16000 Algeria

## Correspondence:

Belkadi Adel, Laboratory of Optimizing Research Programmes on Physical and Sports Activities, Institute of Physical Education and Sport, University of Abdelhamid Ibn Badis - Mostaganem, 27000 Algeria, adel.belkadi@univ-mosta.dz

**Abstract: Purpose:** The main aim of this study is to investigate the effect of the concurrent training method of muscular strength training or muscular endurance training combined with high-intensity interval training (HIIT) on the aerobic threshold (AerT) and anaerobic threshold (AT).

**Material and methods:** Twenty soccer player from the University team were recruited. Participants were divided into muscular strength training group (MS, N = 10) and the muscular endurance training group (ME, N = 10). All subjects sustained the regular specific training programs during the experimental period and had additional different concurrent training twice per week for twelve weeks. power output during the graded exercise test, peak power (PP), average power (AP), fatigue index (FI) during anaerobic power test were tested by graded exercise test on Wingate anaerobic power test. as well as one-repetition maximum (1-RM) of lower limbs and Romanian Deadlift (RDL) - Hamstring Leg Exercise were tested simultaneously before and after the experiment. Data were analysed by two-way mixed design ANOVA.

**Results:** After 12 weeks of training, the AT power output, 1-RM of half squat and the 1-RM of RDL were significantly higher than before training (MS: 407.12 ± 52.92 vs 431.78 ± 48.84 watt, 157.45 ± 35.66 vs 169.87 ± 47.31 kg, 120.16 ± 15.28 vs 122.56 ± 19.39 kg; ME: 411.11 ± 48.48 vs 429.16 ± 52.13 watt, 135.34 ± 26.27 vs 144.41 ± 35.78 kg, 96.93 ± 24.57 vs 103.46 ± 24.15 kg, p < .05) in MS group and ME group. Time to exhaustion of graded exercise test in ME group was significantly higher than before training (22.13 ± 7.73 vs 25.78 ± 8.74 min, 23.44 ± 7.73 vs 24.78 ± 8.74 p < .05). The AerT power output, PP, AP, and FI were no significant changes in both groups. Nevertheless, all dependent variables were no significant difference between groups before and after training.

**Conclusion:** Conducting the concurrent training method of muscular strength training or muscular endurance training combined with HIIT twice per week for twelve weeks increased soccer players' aerobic endurance as well as 1-RM of lower limbs. The concurrent training method of muscular endurance training combined with HIIT also promoted the performance of time to exhaustion. However, there were no significant difference between two training methods and minor significant benefits on anaerobic power.

**Keywords:** adapted physical activity, protocol, chronic low back pain.

## INTRODUCTION

There are many aspects to successful sports performance, including advanced technical preparation, strategy and physical fitness. soccer has clear physical requirements (Bloomfield, Polman, & O'Donoghue, 2007). Soccer Team sports need high levels of aerobic capacity (Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002), weightlifters need a high level of muscle strength (Krzysztofik, Wilk, Wojdała, & Golaś, 2019; Reggiani & Schiaffino, 2020). However, many sports require multiple physical abilities at the same time to achieve optimal performance (Mujika, Halson, Burke, Balagué, & Farrow, 2018). For example, in rugby, athletes need to have the acceleration and explosive power to surpass the opponent's crossing line, the muscle mass and muscle strength of the ball, long-distance movement and the aerobic ability to continuously intercept and tackle (Winter et al., 2016); soccer players need aerobic capacity, Repetitive sprint ability, maximum muscle strength and explosive power (Alemdaroğlu, 2012; Stojanovic, Ostojic, Calleja-González, Milosevic, & Mikic, 2012). Therefore, having both good aerobic and anaerobic abilities in most sports is the key to becoming a top athlete (Adel, Mokhtar, Abdelkader, Mohamed, & Othman, 2019; Buchheit, Mendez-Villanueva, Delhomel, Brughelli, & Ahmaidi, 2010). Aerobic endurance and anaerobic power are key

factors that determine the level of soccer players (Helgerud, Engen, Wisloff, & Hoff, 2001; Tumilty, 1993). Previous studies have found that soccer player has a higher aerobic power output in the incremental test to exhaustion (Dittrich, da Silva, Castagna, de Lucas, & Guglielmo, 2011; Impellizzeri, Rampinini, & Marcora, 2005), The peak power (PP) and average power (AP) measured by the Wingate anaerobic power test can predict the performance of soccer players (Al'Hazzaa, Almuzaini, Al-Refae, & Sulaiman, 2001). Therefore, increasing aerobic capacity and anaerobic power at the same time will help improve soccer skills performance (Amani-Shalamzari et al., 2019; Belkadi et al., 2015). Common ways to improve aerobic endurance include moderate continuous training and high intensity interval training (HIIT). Studies have confirmed that both continuous training and HIIT can improve aerobic endurance (Schaun, Pinto, Silva, Dolinski, & Alberton, 2018), but the time spent and training volume of HIIT are significantly lower than continuous training (Wen et al., 2019), and some studies have pointed out The effect of HIIT on aerobic endurance training is better than continuous training (Way, Sultana, Sabag, Baker, & Johnson, 2019; Wen et al., 2019). Anaerobic power can be improved through resistance training and power training (Helgerud et al., 2001; Impellizzeri et al., 2005). recent studies have pointed out that athletes can increase anaerobic power by increasing muscle strength or increasing the percentage of fast-twitch muscle fibers (Beboucha, Belkadi, Benchehida, & Bengoua, 2021; Lievens, Klass, Bex, & Derave, 2020). In addition to high training load and low training volume muscle strength training (V<sub>mst</sub>) can increase the maximum muscle strength (one-repetition maximum, 1-RM) (S. Benhammou, Mourot, Mokkedes, Bengoua, & Belkadi, 2021; Tillin & Folland, 2014), few studies have found that both adults and adolescents perform low training load and high training Extensive muscular endurance training can also achieve the benefits of 1-RM improvement (Farrell, Lantis, Ade, Cantrell, & Larson, 2018; Ferley, Scholten, & Vukovich, 2020). The integrated analysis of Stricker (2020) shows that resistance training for children and adolescents is beneficial in various aspects, including: muscle strength and explosive power, injury prevention and injury recovery, cardiopulmonary fitness, body composition, bone density (Stricker et al., 2020). Among them, by designing appropriate short-term resistance training, children and adolescents can increase their muscle strength by 30% (Behm, Faigenbaum, Falk, & Klentrou, 2008; Belkadi, Benchehida, Benbernou, & Sebbane, 2019). The integrated analysis of Cavar (2019) unifies the young athletes to conduct resistance training for at least 6 weeks (Cavar et al., 2019) with an average of  $2.6 \pm 0.9$  times per week, the range of training intensity and training volume There are multiple groups ( $60\text{-}80\%$  1-RM  $\times$  2-3 groups  $\times$  8-15 reps) from medium load to near maximum load, which can significantly improve muscle strength. endurance training and resistance training in different periods and on different days were usually needed to improve aerobic and anaerobic capacity at the same time (Kraemer & Ratamess, 2004). Force training is carried out. This training method is called concurrent training (Robineau, Lacombe, Piscione, Bigard, & Babault, 2017; Sousa et al., 2020). However, Hickson's (1980) research found that synchronized training produces a phenomenon called interference effect, which results in less muscle-lifting than resistance training alone (Hickson, 1980), muscle hypertrophy (Hickson, 1980; Kraemer & Ratamess, 2004) or explosive power (Mikkola, Rusko, Izquierdo, Gorostiaga, & Häkkinen, 2012). However, few recent studies have found that pairing with endurance training has little or no impact on the effectiveness of resistance training (B Alabinis, Psarakis, Moukas, V Assiliou, & Behrakis, 2003; McKay, Paterson, & Kowalchuk, 2009) Methenitis (2018) pointed out that low-volume and short-term HIIT or sprint interval training ,endurance training combined with resistance training has the lowest or no negative impact on the adaptation induced by resistance training (Lalia, Ali, Adel, Asli, & Othman, 2019; Methenitis, 2018). The resistance training part is often carried out by explosive force, strengthening, muscle strength and muscular endurance training, and endurance training is carried out by running, swimming, rowing or cycling. Continuous or intermittent endurance training (Gäbler, Prieske, Hortobágyi, & Granacher, 2018).

The study on adolescents has no interference effect compared to resistance training or endurance training alone, synchronized training may have the better training effect. This may be related to the fact that Gäbler et al. (2018) and Gäbler and Granacher (2019) mentioned that adolescents are different from adults in body measurement, physiological characteristics, and biomechanics, and therefore, synchronized training may be related to the different responses of adults (Gäbler & Granacher, 2019; yassin zenati, belkadi, & benbernou, 2021). In summary, both aerobic and anaerobic capacity are required by athletes in many sports. Moderate to mid-to-high intensity resistance training can increase the neuromuscular recruitment of young people to enhance muscle strength. If the target is adolescents and use HIIT's synchronized training, you can train for the two abilities on the same day, and avoid interference effects as much as possible. However, there is notable paucity been conducted to determine the possible effects of resistance

training with HIIT on aerobic endurance and anaerobic power by combining muscle strength or muscle endurance. Therefore, this study will conduct different synchronized training twice a week for 12 weeks to explore the changes in the aerobic and anaerobic capacity of adolescents after the intervention of the two training methods.

Purpose: of the study was To explore the aerobic threshold (AerT) power and anaerobic threshold (AT) power during aerobic exercise with the same HIIT for twelve-week muscle strength training or muscle endurance training for U21 soccer players; and explore the anaerobic exercise influence of peak power (PP), average power (AP), fatigue index (FI) and 1-RM of lower limbs.

## MATERIALS AND METHODS

### Participants

Twenty male soccer players from soccer university team were recruited in this study. The experimental participants had no chronic diseases such as heart disease and high blood pressure, and no serious bone and muscle injuries were reported within six months. Before the start of the experiment, the participants took various pre-tests and were matched-paired with AT scores. The participants were divided into muscle strength (MS) group and muscle endurance (ME) group. All experiment participants fill in personal information, health survey form and experiment participant consent form before the experiment. During the experiment, no extra strenuous exercise or resistance training was allowed except for normal soccer training and activities. During the experiment, participants were also required to eat and maintain daily habits, the study was conducted in accordance with the principles of the Helsinki Declaration and was approved by the Ethic Committee of the local physical and education sports Institute N°PRFU N° J00L02UN270120220003.

*Table 1. Baseline characteristics of participants. Mean ± SD*

Variable	Groups	
	MS group N=10	ME group N=10
Age	19.50 ± 1 .50	19.95±0.25
Height (cm)	168 .89±6.33	170.11±4 .85
Weight(kg)	69.36±3 .85	70.36±4 .85
BMI (kg/m2)	26.60±2 .60	25.80±2 .80
Training experience (years)	7.00±2.50	8.50±3.50

*BMI = body mass index; MS = muscle strength; ME = muscle endurance*

### Experimental design

Participants in the experiment took the Incremental soccer test (**Footeval**), Wingate anaerobic power test, and 1-RM estimation test for lower limbs before the experiment. After two days of rest, they began to perform simultaneous training twice a week for 12 weeks. Resistance training was performed with low load and high repetitions, while resistance training was performed with low load and high repetitions in the ME group. The two trainings were separated by at least 48 hours; during the two groups of experimental participation. Participants will carry out special soccer training normally; after the 12th week, 48 hours later, the participants' Incremental soccer test (Footeval), Wingate anaerobic power test, and lower limb 1-RM estimated test performance will be measured again to evaluate 12 weeks benefits of resistance training, the experimental framework is shown in Figure 1.

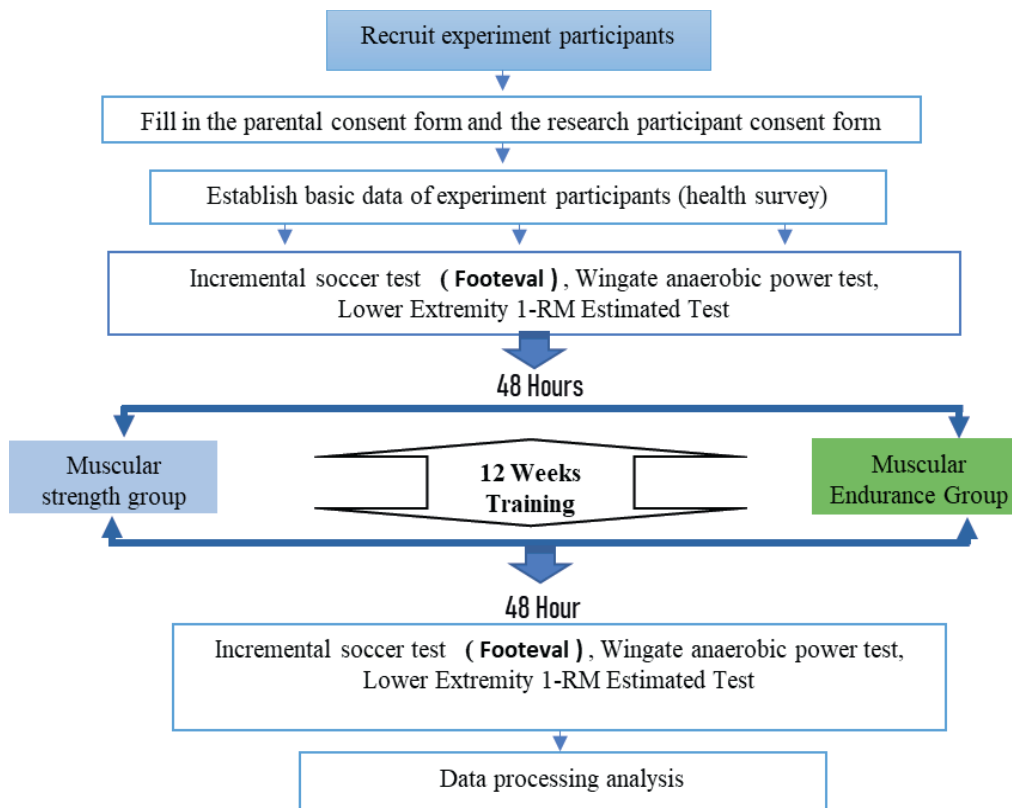


Figure 1. Experimental framework

Table 2. Training schedule

		1_ 4 weeks		
Training content		load	Number of Rep/sets.sc	Rest
MS group	Lift actions exercise	85% 1_RM	2 sets /6Rep	3mn
	Auxiliary actions	75% 1_RM	3 sets /10 rep	1mn
	Body Plank exercise	own weight	10 sets /10s	10mn
	HITT	90% AEROBIC	8 sets /60s	60s
ME group	Lift actions exercise	67%1_RM	2 sets /12Rep	30sc
	Auxiliary actions	67%1_RM	2 sets /12Rep	30sc
	Body Plank exercise	own weight	8 sets /10s	10sc
	HITT	90% AEROBIC	8 sets /60s	60sc
		5_ 8 weeks		
Training content		load	Number of rep/sets.sc	Rest
MS group	Lift actions exercise	85% 1_RM	4 Sets /6Rep	3mn
	Auxiliary actions	75% 1_RM	5 Sets/10 Rep	1mn
	Body Plank exercise	own weight	10 sets/10 s	10mn
	HITT	90% AEROBIC	10 Sets/60 s	60s
ME group	Lift actions exercise	67%1_RM	3 Sets /15Rep	30sc
	Auxiliary action	67%1_RM	3 Sets /15Rep	30sc
	Body Plank exercise	own weight	10 Sets/10 s	10sc
	HITT	90% AEROBIC	10 Sets/60 s	60sc
		9_ 12 weeks		
Training content		load	Number of rep/sets.sc	Rest
MS group	Lift actions exercise	85% 1_RM	5Sets /6Rep	3mn
	Auxiliary actions	75% 1_RM	5 Sets/10 Rep	1mn

	Body Plank exercise	own weight	10 Sets/10 s	10mn
	HITT	90% AEROBIC	10 Sets/60 s	60s
ME group	Lift actions exercise	67%1_RM	3 Sets /18Rep	30sc
	Auxiliary actions	67%1_RM	3 Sets /18Rep	30sc
	Body Plank exercise	own weight	12 Sets/10 s	10sc
	HITT	90% AEROBIC	12 Sets/60s	60sc

Note: Lift actions exercise: half squat, Romanian deadlift, auxiliary actions: one-foot leg push, Standing Hip Flexion with Cable, lift Heel, toe lift, Body Plank exercise, HIIT: high intensity Interval training



Figure 2. Training action exercise

The experimental process:

- Experimental participants completed the Incremental soccer test (Footeval), the Wingate anaerobic power test, and the lower limb 1-RM estimation test in sequence on three different days before the experiment. The interval between each experiment was at least 24 hours so that the experimental participants could Complete with best effort in each test.
- Two days after the pre-test was completed, the two groups of experimental participants began to perform twice a week for 12 weeks, each time the muscular strength or muscular endurance of the 7 movements are combined with endurance training. The two trainings are separated by at least 48 hours. The two groups of experimental participants normally conduct special training.
- The two resistance training schedules are based on Haff and Triplett (2015) in the NSCA book(G. Haff & Triplett, 2015). Resistance training principles and youth resistance training principles, balanced development of adolescents’ front and rear muscle groups, including core exercises: half squats, Romanian dead lift (RDL), auxiliary exercises: single leg push, standing and single foot Hip flexion, heel lift, toe lift and joint actions: stick pose, and refer to the research and design training content of (Hill-Haas, Bishop, Dawson, Goodman, & Edge, 2007)) training volume adjustment for adolescent muscle strength training and refer to the research (Ignjatovic, Radovanovic, Stankovic, Marković, & Kocic, 2011)Adjust the training volume for adolescent

muscle endurance training, and calculate the total training volume of the two groups in the way of load × number of groups × times.

- The specific content is shown in Table 2, and the training action diagram is shown in Figure 2-1-to Figure2-6.
- The endurance training schedule uses a stationary bicycle to perform HIIT and adjusts the intensity according to (McKay et al., 2009). During the training, the revolutions per minute (rpm) of the bicycle must be maintained above 100 rpm.
- 48 hours after the 12th week of the training period, the incremental soccer test (Footeval), Wingate anaerobic power test, and lower limb 1-RM estimation test will be performed again on different days.

**Tests items and methods:**

**Wingate Anaerobic Test**

Wingate anaerobic with stationary bicycle (Bar-Or, 1987). The test is used to determine peak anaerobic power and anaerobic capacity. Anaerobic power is the ability to produce energy by the ATP-PC energy pathway. Anaerobic capacity is the combined ability of both anaerobic pathways to produce energy and so is shown as the average power output during the test.

**The Footeval Test**

Is an incremental and intermittent football (soccer) specific test designed by (Manouvrier, Cassirame, & Ahmaidi, 2016)The test is based on the 20m shuttle test, though it incorporates dribbling of a soccer ball and 30 second rest periods after every minute. With the aim to measure aerobic fitness and skill in soccer players.

Equipment required: 30m x 10m grassed field area, measuring tape, marker cones, soccer balls, soccer goal, portable barrier for reflecting the kicked ball, audio track and audio player as shown in the figure 3.

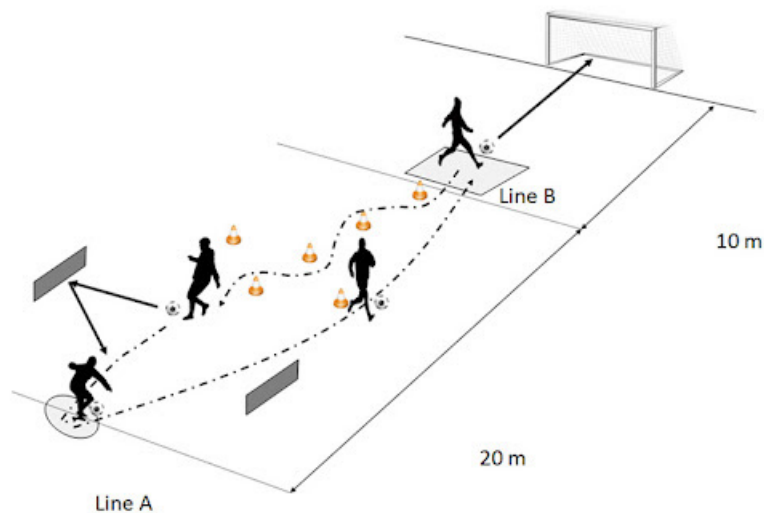


Figure 3. (Footeval) Test intermittent (soccer) specific test

**One-Repetition Maximum or 1-RM test:**

Repetition maximum is often expressed as 1RM or one-repetition maximum. This indicates the heaviest weight you can lift with maximum effort in a single repetition. A 1RM is your personal weightlifting record for a squat, deadlift, or any other weightlifting exercise.

The 1RM measurement is a standard in weight training for marking improvement(Seo et al., 2012), By establishing your 1RM and tracking it, you are able to observe your progress. According to (Gregory & Travis, 2015)1-RM test process adjusted to 6-RM test process, the entire test must measure the weight of 6-RM within 5 times, and use (G. G. Haff & Triplett, 2015) The table “Estimated 1-RM and Load Weight” estimates the weight of 1-RM.

**Statistical Analysis**

Statistical analysis was performed using the using SPSS software (version 22) and Significance levels were set at  $p \leq 0.05$ . Shapiro- Wilk test was used to evaluate normal distribution of the conformity of continuous variables. The t-test for normally distributed variables. Comparison by two-way ANOVA, mixed design Between and within

AerT power, AT power, PP, AP, FI and squat, RDL. To detect the sub-group differences, the rate % of change of the pre- and post-test values between each group, and compare the difference in the rate of change between groups by independent sample t test. A p value of <0.05 was considered statistically significant. the effect size of the pre- and post-measurement values between each group. Judgment of the amount of effect: Very small (trivial): <0.20, small (small): 0.20-0.49, medium (moderate): 0.50-0.79, large:> 0.80 (Hedges & Schauer, 2019)

**RESULTS**

The results shown in Table 3 referred to the influence of twelve weeks of different synchronized training on aerobic endurance, the AerT power of the two groups was not significantly different, before training the AT power of the second group was significantly better than before training (p <.05); only the ME group had significantly better time to exhaustion than before training (p <.05), There is no significant difference between the two groups before and after the test group.

The effect of AT power in the MS group and ME group were 0.48 and 0.36, respectively; the effect of exhaustion time in the ME group was 0.24, which was a small effect.

*Table 3. Aerobic threshold power and anaerobic threshold power*

	MS group	ME group
	<b>(AerT) power (watt)</b>	
Before training	160.44 ± 53.73	164.00 ± 64.44
After training.	176.22 ± 33.50	179.57 ± 45.70
Change rate ( %)	49.85 ± 61.54	40.04 ± 67.12
	<b>(AT) power(watt)</b>	
Before training	407.12 ± 52.92	411.11 ± 48.48
After training.	431.78± 48.84*	429.16 ± 52.13*
Change rate ( %)	13.15 ± 7.17	08.60 ± 4.50
	<b>exhaustion Time(min)</b>	
Before training	22.13 ± 7.37	23.44 ± 7.73
After training.	25.22 ± 8.24	24.78 ± 8.74*
Change rate ( %)	11.57 ± 18.61	12.63 ± 10.13

*Note: MS group: muscular strength group, ME group: muscular endurance group, AerT: aerobic threshold, AT: anaerobic threshold Values are expressed as mean ± standard deviation, each group n = 10*

*\* Significant difference compared with previous test (p <.05).*

The results shown in Table 3,4 and 5 referred to the influence of twelve weeks of different synchronized training on anaerobic performance, twelve weeks later, the weight of the muscle strength group was 73.91 ± 6.64 kg, and the weight of the muscle endurance group was 72.13 ± 7.45kg. The results of PP, relative PP, AP, relative AP and FI of the muscle strength group and muscle endurance group before and after the test are shown in Table 4. There was no significant difference between the two groups of PP, relative PP, AP, relative AP and FI after twelve weeks of training, and there was no significant difference between the two groups before and after the test.

*Table 4. Peak power average and fatigue index*

	MS group	ME group
	<b>PP (watt)</b>	
before training	710.57 ± 172.12	716.89 ± 210.15
after training.	744.82 ± 206.38	729.19 ± 225.56
Change rate ( %)	4.53 ± 11.03	1.32 ± 6.80
	<b>Relative pp (watt)kg/w</b>	
before training	13.00 ± 1.35	13.22 ± 2.19

after training.	13.43 ± 1.62	13.28 ± 2.39
Change rate ( %)	3.60 ± 10.18	0.32 ± 6.76
<b>Ap (watt)</b>		
before training	441.28 ± 132.45	446.45 ± 141.43
after training.	448.22 ± 128.45	444.92 ± 143.72
Change rate ( %)	1.82 ± 4.39	-0.53 ± 0.27
<b>Relative Ap (watt) kg/w</b>		
before training	8.00 ± 1.14	8.19 ± 1.39
after training.	8.07 ± 1.11	8.07 ± 1.44
Change rate ( %)	0.97 ± 4.15	-1.48 ± 5.74
<b>FI (%)</b>		
before training	64.33 ± 10.38	66.51 ± 10.85
after training.	66.09 ± 8.74	58.68 ± 12.10

Note: MS group: muscular strength group, ME group: muscular endurance group, PP: peak power, AP: average power, FI: fatigue index. Values are expressed as mean ± standard deviation, each group n = 10

**Table 5. Maximum muscle strength of lower limbs**

	MS group	ME group
<b>Half squat (kg)</b>		
before training	157.45 ± 35.66	135.34 ± 26.27
after training	169.87 ± 47.31*	144.41 ± 35.78*
Change rate (%)	12.83 ± 10.34	10.69 ± 8.82
<b>relative to squat (kg/kg/w)</b>		
before training	2.34 ± 0.40	2.16 ± 0.29
after training	2.52 ± 0.49*	2.37 ± 0.38*
Rate of change	7.92 ± 10.07	9.65 ± 9.49
<b>(%) Romanian deadlift (kg)</b>		
before training	120.16 ± 15.28	96.93 ± 24.57
after training	122.56 ± 19.39*	103.46 ± 24.15*
Rate of change	9.05 ± 9.44	8.41 ± 9.44
<b>(%) vs. Romanian deadlift (kg/kgw)</b>		
before taking	1.71 ± 0.26	1.61 ± 0.26
after training	1.85 ± 0.29*	1.72 ± 0.29*
Change rate (%)	8.06 ± 7.99	7.28 ± 8.33

Note: MS group: muscular strength group, ME group: muscular endurance group, AerT: aerobic threshold, AT: anaerobic threshold Values are expressed as mean ± standard deviation, each group n = 10

\* Significant difference compared with previous test (p < .05)

## DISCUSSION

The main study was conducted to evaluate the effect of twelve weeks of different synchronized training on the aerobic endurance of U21 soccer players, In this study, after 12 weeks of muscle strength and muscle endurance training with the same HIIT, the AerT power and AT power after the two types of training have a tendency to increase, and the AT power of the two groups has improved significantly, and the effect is small (ES: 0.36-0.48 ), the result of AT power increase is in line with our expected result. In the previous studies of synchronized training, most of the aerobic endurance indicators used  $\dot{V}O_{2max}$  (Dittrich et al., 2011; Farrell et al., 2018; Impellizzeri et al., 2005; McKay et al., 2009; Wen et al., 2019); however, AT and endurance sports performance are also highly correlated (Gharazibaei, 2021), and predict the performance of soccer players or long-distance runners by analyzing AT (Hoff et al., 2002;



Impellizzeri et al., 2005; Messonnier et al., 2022; Schaun et al., 2018). Speed or power Higher output means that athletes can maintain higher speed or power output during long-term exercise (Izquierdo, Häkkinen, Gonzalez-Badillo, Ibáñez, & Gorostiaga, 2002; Mohammed, Bachir, Eddine, & Adel, 2018). The change of AT may be Resynthesis of creatine acid, supplementation of glucose and oxygen, and elimination of lactic acid are related to positive adaptation (Benchehida et al., 2021; Kendrick et al., 2008; McKay et al., 2009; Schumann, Yli-Peltola, Abbiss, & Häkkinen, 2015). Therefore, the results of this study show that the two groups of different forms of synchronized training have significantly increased the power output of AT, and it can be inferred that the aerobic endurance performance of the two groups of athletes has improved significantly. However, the AerT power did not change significantly in the results of this study. Skovgaard (2018) believe that the load corresponding to AerT is the upper limit of pure aerobic metabolism (Hill-Haas et al., 2007; Skovgaard et al., 2018; Messonnier et al., 2022). Previous studies have pointed out that resistance training can increase the running economy of well-trained long-distance runners by 8% (Gorostiaga, Izquierdo, Iturrealde, Ruesta, & Ibáñez, 1999; Kraemer, Ratamess, & French, 2002; Krzysztofik et al., 2019). HIIT can improve neuromuscular characteristics and then manifest in muscle strength and work economy (Mikkola et al., 2012; Tillin & Folland, 2014; García-Pinillos, Cámara-Pérez, Soto-Hermoso, & Latorre-Román, 2017), while improving anaerobic metabolism (Ziemann et al., 2011). The training program designed in this study did not train for aerobic metabolism, so it could not improve AerT power. the use of resistance training combined with HIIT synchronized training found that the power output of AT has been significantly improved after training (Petré, Löfving, & Psilander, 2018), which are the same as the results presented in this study; if the order of resistance training and endurance training is reversed (HIIT first, then resistance training), the power output of AT is not significantly different from before training (Fyfe, Bartlett, Hanson, Stepto, & Bishop, 2016; Ignjatovic et al., 2011; Saddek et al., 2020). However, a study of healthy adults with moderate activity points out that regardless of the order of resistance exercise and endurance exercise, the power of AT can be significantly increased (Lee et al., 2020). The results of this study showed that only the ME group made significant progress in exhaustion time in the wingate test. In the past, synchronized training was used to improve individual endurance performance (Hickson, 1980; Mujika et al., 2018; Petré et al., 2018; Winter et al., 2016), but high-intensity training will increase more type II Muscle fibers, not aerobic type I muscle fibers (García-Pinillos et al., 2017; Lievens et al., 2020; Mikkola et al., 2012; Mokhtar et al., 2019; Reggiani & Schiaffino, 2020) High-volume resistance training may improve monocarboxylate transporter proteins MCT1 and MCT4, thereby increasing lactate clearance and increasing the load corresponding to AT (Adel, Abdelkader, et al., 2019; Mohamed, Mohamed, Mohammed, Mokrani, & Belkadi, 2019). Lantis, Farrell III, Cantrell, & Larson (2017) proved that high-volume resistance training can delay the appearance of 4 mmol·L<sup>-1</sup> and increase leg muscle strength for experimental participants with endurance training experience (Farrell et al., 2018). Therefore, it can be inferred that the ME group increased the lactic acid clearance rate after training, and the exhaustion time in the wingate test was longer than before the training. However, the current research on synchronized training for young players is limited compared with adults, and the synchronized training research that allows young athletes to use HIIT as an endurance training method focuses on actual sports performance and the impact of  $\dot{V}O_2$  (Buchheit et al., 2010; Karahan, 2020; Wen et al., 2019), there is a limited research to explore the change of aerobic capacity through [la<sup>-</sup>] calculating AerT and AT.

After 12 weeks of muscle strength and endurance training with the same HIIT, there was no significant difference between PP and AP after the two trainings and before training, and the FI showed an increasing trend; however, the half squats and RDL 1-RM of the two groups As well as the relative half squat, RDL, 1-RM has been significantly improved after training, and the effect is small to medium (ES: 0.27-0.62). This result is in line with our expectation that by improving the 1-RM of the lower limbs. Previous studies with adults found that synchronized training did not only significantly improved the 1-RM of the upper or lower limbs, but also significantly enhanced the PP of the upper or lower limbs (Hartono, Martin-Arrowsmith, Peeters, & Churchward-Venne, 2022; Murlasits, Kneffel, & Thalib, 2018; Parastesh, Saremi, Hashemi, Ramezani, & Shavandi, 2022). However, some studies have found that although the 1-RM of the lower limbs is significantly increased compared to before training, there is no significant change in PP (Adel, Abdelkader, et al., 2019; Adel, Alia, & Mohammed, 2020). The study of (Jones et al., 2021) divided 08 men with casual exercise habits into resistance training group, HIIT + resistance training group, and medium-intensity continuous training + resistance training group, for 8 weeks, 3 times a week training intervention. The results showed that 1-RM, CMJ in the resistance training group the performance training effect is significantly better than the other

two groups. The author pointed out that although synchronized training significantly improves 1-RM, resistance training has a more significant improvement in 1-RM training effect than synchronized training. Therefore, it may be related to the interference effect of synchronized training, which affects the development of 1-RM. There is no significant improvement in the PP that makes the reverse jump. In addition, HIIT can improve the aerobic and anaerobic capacity, physical fitness and performance of time to exhaustion of well-trained athletes (Gäbler et al., 2018; Kraemer et al., 2002; Lee et al., 2020). (Schumann et al., 2015) let men and women with leisure sports habits use the Wingate test (do their best) to perform HIIT. The results show that after training, PP, AP and FI are significantly better than the previous test. (Adel, Abdelkader, et al., 2019) compare the difference between HIIT (85~100% HRmax) and high-intensity continuous running (85% HRmax). The results show that only PP and AP improved significantly after training in the HIIT group. The common point of the above studies is that they all use the maximum training intensity for HIIT, while the twelve-week HIIT in this study maintained the same training intensity, only increasing the training volume after the 4th and 8th weeks. It is speculated that the factors that did not improve anaerobic power may be related to the insufficient training intensity of HIIT. In many synchronized training studies targeting teenagers in the past, the use of moderate to medium-to-high intensity resistance training (60-85% 1-RM) combined with endurance training can significantly improve the 1-RM of ordinary teenagers and young athletes (García-Pinillos et al., 2017; Lee et al., 2020; Robineau et al., 2017). Such results are usually attributed to increased neuromuscular activation rather than muscle hypertrophy (Reggiani & Schiaffino, 2020). In this study, the two types of simultaneous training with 67-85% 1-RM training load improved the 1-RM of the lower limbs of young soccer players, supporting the results of previous studies. It can be inferred that athletes at this stage do not need to use maximum load for resistance training to improve 1-RM performance. The study of (Saddek Benhammou et al., 2021) used elite male long-distance runners to compare the performance differences between 12-week muscle strength training and endurance training on teams. The results showed that the 1-RM, running economy, and peak speed of the two training methods were significantly improved after training, but  $\dot{V}O_{2max}$  and HRmax did not improve significantly. The author believes that because the experimental participants are high-level athletes, the trainability of aerobic capacity is limited; on the other hand, the addition of resistance training does not have a negative impact on  $\dot{V}O_{2max}$ . This result can explain the difference between resistance training and endurance training. They do not interfere with each other, but have the concept of additional benefits (Izquierdo et al., 2002). The same as this study is that they all improve 1-RM, but it may be due to the relationship between different levels, different dependent variables of the test, and different exercise patterns. The aerobic capacity (AT) of this study has improved, and the anaerobic capacity (PP) There is no difference.

## CONCLUSIONS

This study is divided into two types of synchronized training for 12 weeks, two training interventions per week, namely muscle strength training with HIIT and muscle endurance training with HIIT, and their effects on aerobic endurance, anaerobic power and 1-RM. Conclusion In order to improve the AT power of young athletes under normal soccer training conditions, both types of synchronized training can also improve 1-RM of the lower limbs. In this study, PP, AP, and FI have not changed. It is recommended that if young athletes are allowed to perform HIIT endurance training in future studies, attention should be paid to the adjustment of training intensity. This study originally expected that the various indicators of the muscle strength group after training were significantly higher than the muscle endurance group, but the results of the two groups were not significantly different in each variable. Therefore, it can be inferred that regardless of whether the synchronized training is carried out by muscle strength or muscle endurance, resistance training loads at medium to medium-to-high intensity (67-85% 1-RM) can improve aerobic endurance and 1-RM effect, it is recommended that the coach can follow the exercise. The training status and development situation of the staff choose a suitable training method. Finally, the standard deviation of each variable in the results of this study is very large. It is speculated that athletes at this stage (junior high school, high school) have large differences in abilities, and gender may also be one of the factors. It is recommended that the ethnic conditions of experimental participants in future studies are as large as possible Similarity, to avoid inconsistencies in the abilities of various experimental participants, resulting in unclear training effects.

## Acknowledgments

*We thank the Algerian General Directorate for Scientific Research and Technological Development (DGRSDT-MESRS) for their co-operation and help in setting up the study. also for maintaining and supporting finances and quality of research.*

## REFERENCES

- Adel, B., Abdelkader, B., Alia, C., Othman, B., Mohamed, S., & Houcin, A. (2019). The Effect of High-Intensity Exercise on Changes of Blood Concentration Components in Algerian National Judo Athletes. *Acta Facultatis Educationis Physicae Universitatis Comenianae*, 59(2), 148-160. doi: 10.2478/afepuc-2019-0013
- Adel, B., Alia, C., & Mohammed, Z. (2020). Algerian Judo Competition Modality and its Impacts on Upper and Lower Limbs Strength Perseverance and Limitations. *Orthopedics and Sports Medicine: Open Access Journal*, 3(4), 293-299. doi: 10.32474/OSMOAJ.2020.03.000168
- Adel, B., Mokhtar, M., Abdelkader, B., Mohamed, S., & Othman, B. (2019). Effects of tow protocol cold water immersion on the post match recovery and physical performance in youth handball players. *International Journal of Sport Culture and Science*, 7(2), 1-12.
- Alemdaroglu, U. (2012). The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. *Journal of human kinetics*, 31(2012), 149-158.
- Al'Hazzaa, H. M., Almuzaini, K. S., Al-Reface, S. A., & Sulaiman, M. A. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness*, 41(1), 54.
- Amani-Shalamzari, S., Khoshghadam, E., Donyaei, A., Parnow, A., Bayati, M., & Clemente, F. M. (2019). Generic vs. Small-sided game training in futsal : Effects on aerobic capacity, anaerobic power and agility. *Physiology & behavior*, 204, 347-354.
- B Alabinis, C. P., Psarakis, C. H., Moukas, M., V Assiliou, M. P., & Behrakis, P. K. (2003). Early Phase Changes by Concurrent Endurance and Strength Training. *The Journal of Strength & Conditioning Research*, 17(2), 393-401.
- Bar-Or, O. (1987). The Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Medicine (Auckland, N.Z.)*, 4(6), 381-394. doi: 10.2165/00007256-198704060-00001
- Beboucha, W., Belkadi, A., Benchehida, A., & Bengoua, A. (2021). The anthropometric and physiological characteristics of young algerian soccer players. *Acta Facultatis Educationis Physicae Universitatis Comenianae*, 61(1).
- Behm, D. G., Faigenbaum, A. D., Falk, B., & Klentrou, P. (2008). Canadian Society for Exercise Physiology position paper : Resistance training in children and adolescents. *Applied Physiology, Nutrition, and Metabolism*, 33(3), 547-561. doi: 10.1139/H08-020
- Belkadi, A., Benchehida, A., Benbernou, O., & Sebbane, M. (2019). Competencies and training needs and its impact on determining the professional skills of Algerian elite coaches. *International Journal of Physical Education, Fitness and Sports*, 8(3), 51-61. doi: 10.26524/ijpefs1936
- Belkadi, A., Othman, B., Mohamed, S., M, B. H., Gleyse, J., Adel, B., ... Gleyse, J. (2015). Contribution to the Identification of the Professional Skills Profile of Coaches in the Algerian Sport Judo System. *International Journal of Sports Science*, 5(4), 145-150.
- Benchehida, A., Belkadi, A., Zenati, Y., Benbernou, O., Cherara, L., & Sebbane, M. (2021). Implementation of An Adapted Physical Activity Therapy Protocol for Patients with Low Back Pain. *GYMNASIUM*, 22(1), 83-96.
- Benhammou, S., Mourou, L., Mokkedes, M. I., Bengoua, A., & Belkadi, A. (2021). Assessment of maximal aerobic speed in runners with different performance levels : Interest of a new intermittent running test. *Science & Sports*. doi: 10.1016/j.scispo.2020.10.002
- Benhammou, Saddek, Mourou, L., Coquart, J., Belkadi, A., Mokkedes, M. I., & Bengoua, A. (2021). The 180/20 intermittent athletic test : A new intermittent track test to assess the maximal aerobic speed in middle-distance runners. *Revista Andaluza de Medicina Del Deporte*. doi: 10.33155/j.ramd.2021.08.001
- Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical Demands of Different Positions in FA Premier League Soccer. *Journal of Sports Science & Medicine*, 6(1), 63-70.
- Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players : Repeated shuttle sprints vs. Explosive strength training. *The Journal of Strength & Conditioning Research*, 24(10), 2715-2722.
- Cavar, M., Marsic, T., Corluca, M., Culjak, Z., Zovko, I. C., Müller, A., ... Hofmann, P. (2019). Effects of 6 weeks of different high-intensity interval and moderate continuous training on aerobic and anaerobic performance. *The Journal of Strength & Conditioning Research*, 33(1), 44-56.
- Dittrich, N., da Silva, J. F., Castagna, C., de Lucas, R. D., & Guglielmo, L. G. A. (2011). Validity of Carminatti's test to determine physiological indices of aerobic power and capacity in soccer and futsal players. *The Journal of Strength & Conditioning Research*, 25(11), 3099-3106.
- Farrell, J. W. I., Lantis, D. J., Ade, C. J., Cantrell, G. S., & Larson, R. D. (2018). Aerobic Exercise Supplemented With Muscular Endurance Training Improves Onset of Blood Lactate Accumulation. *The Journal of Strength & Conditioning Research*, 32(5), 1376-1382. doi: 10.1519/JSC.0000000000001981
- Ferley, D. D., Scholten, S., & Vukovich, M. D. (2020). Combined Sprint Interval, Plyometric, and Strength Training in Adolescent Soccer Players : Effects on Measures of Speed, Strength, Power, Change of Direction, and Anaerobic Capacity. *The Journal of Strength & Conditioning Research*, 34(4), 957-968. doi: 10.1519/JSC.0000000000003476
- Fyfe, J. J., Bartlett, J. D., Hanson, E. D., Stepto, N. K., & Bishop, D. J. (2016). Endurance Training Intensity Does Not Mediate Interference to Maximal Lower-Body Strength Gain during Short-Term Concurrent Training. *Frontiers in Physiology*, 7. Consulté à l'adresse <https://www.frontiersin.org/article/10.3389/fphys.2016.00487>
- Gäbler, M., & Granacher, U. (2019). Concurrent Training in Children and Adolescents. In M. Schumann & B. R. Rønnestad (Éds.), *Concurrent Aerobic and Strength Training : Scientific Basics and Practical Applications* (p. 255-275). Cham: Springer International Publishing. doi: 10.1007/978-3-319-75547-2\_17
- Gäbler, M., Prieske, O., Hortobágyi, T., & Granacher, U. (2018). The Effects of Concurrent Strength and Endurance Training on Physical Fitness and Athletic Performance in Youth : A Systematic Review and Meta-Analysis. *Frontiers in Physiology*, 9. Consulté à l'adresse <https://www.frontiersin.org/article/10.3389/fphys.2018.01057>
- García-Pinillos, F., Cámara-Pérez, J. C., Soto-Hermoso, V. M., & Latorre-Román, P. Á. (2017). A High Intensity Interval Training (HIIT)-Based Running Plan Improves Athletic Performance by Improving Muscle Power. *The Journal of Strength & Conditioning Research*, 31(1), 146-153. doi: 10.1519/JSC.0000000000001473
- Gharazibaei, R. (2021). An Evaluation of the Effectiveness of Exercise Training-Based Cardiac Rehabilitation to Improve Aerobic Fitness.

*Undergraduate Student Research Internships Conference*. Consulté à l'adresse <https://ir.lib.uwo.ca/usri/usri2021/researchoutputshowcase/206>

- Gorostiaga, E. M., Izquierdo, M., Iturralde, P., Ruesta, M., & Ibáñez, J. (1999). Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *European Journal of Applied Physiology and Occupational Physiology*, 80(5), 485-493. doi: 10.1007/s004210050622
- Gregory, H. G., & Travis, T. N. (2015). *Essentials of Strength Training and Conditioning 4th Edition*. Human Kinetics.
- Haff, G. G., & Triplett, N. T. (2015). *Essentials of strength training and conditioning 4th edition*. Human kinetics.
- Haff, G., & Triplett, N. (2015). Essentials of strength training and conditioning. *Research outputs 2014 to 2021*. Consulté à l'adresse <https://ro.ecu.edu.au/ecuworkspost2013/1882>
- Hartono, F. A., Martin-Arrowsmith, P. W., Peeters, W. M., & Churchward-Venne, T. A. (2022). The Effects of Dietary Protein Supplementation on Acute Changes in Muscle Protein Synthesis and Longer-Term Changes in Muscle Mass, Strength, and Aerobic Capacity in Response to Concurrent Resistance and Endurance Exercise in Healthy Adults : A Systematic Review. *Sports Medicine*. doi: 10.1007/s40279-021-01620-9
- Hedges, L. V., & Schauer, J. M. (2019). Statistical analyses for studying replication : Meta-analytic perspectives. *Psychological Methods*, 24(5), 557.
- Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. A. N. (2001). Aerobic endurance training improves soccer performance. *Medicine and science in sports and exercise*, 33(11), 1925-1931.
- Hickson, R. C. (1980). Interference of strength development by simultaneously training for strength and endurance. *European Journal of Applied Physiology and Occupational Physiology*, 45(2), 255-263. doi: 10.1007/BF00421333
- Hill-Haas, S., Bishop, D., Dawson, B., Goodman, C., & Edge, J. (2007). Effects of rest interval during high-repetition resistance training on strength, aerobic fitness, and repeated-sprint ability. *Journal of Sports Sciences*, 25(6), 619-628. doi: 10.1080/02640410600874849
- Hoff, J., Wisloff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine*, 36(3), 218-221. doi: 10.1136/bjism.36.3.218
- Ignjatovic, A., Radovanovic, D., Stankovic, R., Marković, Z., & Kocic, J. (2011). Influence of resistance training on cardiorespiratory endurance and muscle power and strength in young athletes. *Acta Physiologica Hungarica*, 98(3), 305-312. doi: 10.1556/aphysiol.98.2011.3.7
- Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of sports sciences*, 23(6), 583-592.
- Izquierdo, M., Häkkinen, K., Gonzalez-Badillo, J. J., Ibáñez, J., & Gorostiaga, E. M. (2002). Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology*, 87(3), 264-271. doi: 10.1007/s00421-002-0628-y
- Jones, T. W., Eddens, L., Kupusarevic, J., Simoes, D. C. M., Furber, M. J. W., van Someren, K. A., & Howatson, G. (2021). Aerobic exercise intensity does not affect the anabolic signaling following resistance exercise in endurance athletes. *Scientific Reports*, 11(1), 10785. doi: 10.1038/s41598-021-90274-8
- Karahan, M. (2020). Effect of skill-based training vs. Small-sided games on physical performance improvement in young soccer players. *Biology of Sport*, 37(3), 305.
- Kendrick, I. P., Harris, R. C., Kim, H. J., Kim, C. K., Dang, V. H., Lam, T. Q., ... Wise, J. A. (2008). The effects of 10 weeks of resistance training combined with  $\beta$ -alanine supplementation on whole body strength, force production, muscular endurance and body composition. *Amino Acids*, 34(4), 547-554. doi: 10.1007/s00726-007-0008-3
- Kraemer, W. J., & Ratamess, N. A. (2004). Fundamentals of resistance training : Progression and exercise prescription. *Medicine and Science in Sports and Exercise*, 36(4), 674-688. doi: 10.1249/01.mss.0000121945.36635.61
- Kraemer, W. J., Ratamess, N. A., & French, D. N. (2002). Resistance training for health and performance. *Current Sports Medicine Reports*, 1(3), 165-171. doi: 10.1007/s11932-002-0017-7
- Krzysztofik, M., Wilk, M., Wojdała, G., & Golaś, A. (2019). Maximizing Muscle Hypertrophy : A Systematic Review of Advanced Resistance Training Techniques and Methods. *International Journal of Environmental Research and Public Health*, 16(24), 4897. doi: 10.3390/ijerph16244897
- Lalia, C., Ali, A. R., Adel, B., Asli, H., & Othman, B. (2019). Effects of caloric restriction on anthropometrical and specific performance in highly-trained university judo athletes. *Physical education of students*, 23(1), 30-36.
- Lee, M. J.-C., Ballantyne, J. K., Chagolla, J., Hopkins, W. G., Fyfe, J. J., Phillips, S. M., ... Bartlett, J. D. (2020). Order of same-day concurrent training influences some indices of power development, but not strength, lean mass, or aerobic fitness in healthy, moderately-active men after 9 weeks of training. *PLOS ONE*, 15(5), e0233134. doi: 10.1371/journal.pone.0233134
- Lievens, E., Klass, M., Bex, T., & Derave, W. (2020). Muscle fiber typology substantially influences time to recover from high-intensity exercise. *Journal of Applied Physiology*, 128(3), 648-659.
- Manouvrier, C., Cassirame, J., & Ahmaidi, S. (2016). Proposal for a Specific Aerobic Test for Football Players : The "Footeval". *Journal of Sports Science & Medicine*, 15(4), 670-677.
- McKay, B. R., Paterson, D. H., & Kowalchuk, J. M. (2009). Effect of short-term high-intensity interval training vs. Continuous training on O2 uptake kinetics, muscle deoxygenation, and exercise performance. *Journal of Applied Physiology (Bethesda, Md., 107(1))*, 128-138. doi: 10.1152/jappphysiol.90828.2008
- Messonnier, L. A., Oyono-Enguélé, S., Vincent, L., Dubouchaud, H., Chatel, B., Sanchez, H., ... Féasson, L. (2022). Lower Muscle and Blood Lactate Accumulation in Sick Cell Trait Carriers in Response to Short High-Intensity Exercise. *Nutrients*, 14(3), 501. doi: 10.3390/nu14030501
- Methenitis, S. (2018). A Brief Review on Concurrent Training : From Laboratory to the Field. *Sports (Basel, Switzerland)*, 6(4), E127. doi: 10.3390/sports6040127
- Mikkola, J., Rusko, H., Izquierdo, M., Gorostiaga, E. M., & Häkkinen, K. (2012). Neuromuscular and Cardiovascular Adaptations During Concurrent Strength and Endurance Training in Untrained Men. *International Journal of Sports Medicine*, 33(9), 702-710. doi: 10.1055/s-0031-1295475

- Mohamed, K. S., Mohamed, K., Mohammed, S., Mokrani, D., & Belkadi, A. (2019). The Effect of Heavy Weight Training on Physiological Abilities of Soccer Players Under the Age 21 Years Old. *Acta Facultatis Educationis Physicae Universitatis Comenianae*, 59(1), 33-43. doi: 10.2478/afepuc-2019-0004
- Mohammed, B., Bachir, K., Eddine, S. N., & Adel, B. (2018). Study of LDH adaptations associated with the development of Speed endurance in basketball players U19. *International Journal of Applied Exercise Physiology*, 7(3), 35-43.
- Mokhtar, M., Adel, B., Wahib, B., Hocine, A., Othman, B., & Mohamed, S. (2019). The effects of tow protocol cold water immersion on the post match recovery and physical performance in well-trained handball players. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 23(6), 288-295.
- Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International journal of sports physiology and performance*, 13(5), 538-561.
- Murlasits, Z., Kneffel, Z., & Thalib, L. (2018). The physiological effects of concurrent strength and endurance training sequence : A systematic review and meta-analysis. *Journal of sports sciences*, 36(11), 1212-1219.
- Parastesh, M., Saremi, A., Hashemi, Y., Ramezani, S., & Shavandi, N. (2022). The effect of concurrent endurance-resistance training on serum testosterone levels, body composition, muscular strength and international index of erectile function in older men. *Advances in Rehabilitation*, 36(1).
- Petré, H., Löfving, P., & Psilander, N. (2018). The Effect of Two Different Concurrent Training Programs on Strength and Power Gains in Highly-Trained Individuals. *Journal of Sports Science & Medicine*, 17(2), 167-173.
- Reggiani, C., & Schiaffino, S. (2020). Muscle hypertrophy and muscle strength : Dependent or independent variables? A provocative review. *European Journal of Translational Myology*, 30(3), 9311. doi: 10.4081/ejtm.2020.9311
- Robineau, J., Lacombe, M., Piscione, J., Bigard, X., & Babault, N. (2017). Concurrent Training in Rugby Sevens : Effects of High-Intensity Interval Exercises. *International Journal of Sports Physiology and Performance*, 12(3), 336-344. doi: 10.1123/ijsp.2015-0370
- Saddek, B., Coquart, J. B. J., Mourot, L., Adel, B., Idriss, M. M., Ali, B., & Djamel, M. (2020). Comparison of Two Tests to Determine the Maximal Aerobic Speed. *Acta Facultatis Educationis Physicae Universitatis Comenianae*, 60(2), 241-251. doi: 10.2478/afepuc-2020-0020
- Schaun, G. Z., Pinto, S. S., Silva, M. R., Dolinski, D. B., & Alberton, C. L. (2018). Whole-body high-intensity interval training induce similar cardiorespiratory adaptations compared with traditional high-intensity interval training and moderate-intensity continuous training in healthy men. *The Journal of Strength & Conditioning Research*, 32(10), 2730-2742.
- Schumann, M., Yli-Peltola, K., Abbiss, C. R., & Häkkinen, K. (2015). Cardiorespiratory Adaptations during Concurrent Aerobic and Strength Training in Men and Women. *PLOS ONE*, 10(9), e0139279. doi: 10.1371/journal.pone.0139279
- Seo, D., Kim, E., Fahs, C. A., Rossow, L., Young, K., Ferguson, S. L., ... So, W.-Y. (2012). Reliability of the One-Repetition Maximum Test Based on Muscle Group and Gender. *Journal of Sports Science & Medicine*, 11(2), 221-225.
- Skovgaard, C., Christiansen, D., Christensen, P. M., Almquist, N. W., Thomassen, M., & Bangsbo, J. (2018). Effect of speed endurance training and reduced training volume on running economy and single muscle fiber adaptations in trained runners. *Physiological reports*, 6(3), e13601.
- Sousa, A. C., Neiva, H. P., Izquierdo, M., Alves, A. R., Duarte-Mendes, P., Ramalho, A. G., ... Marinho, D. A. (2020). Concurrent Training Intensities : A Practical Approach for Program Design. *Strength & Conditioning Journal*, 42(2), 38-44. doi: 10.1519/SSC.0000000000000520
- Stojanovic, M. D., Ostojic, S. M., Calleja-González, J., Milosevic, Z., & Mikic, M. (2012). Correlation between explosive strength, aerobic power and repeated sprint ability in elite basketball players. *Journal of Sports Medicine and Physical Fitness*, 52(4), 375.
- Stricker, P. R., Faigenbaum, A. D., McCambridge, T. M., Fitness, C. on S. M. A., LaBella, C. R., Brooks, M. A., ... Peterson, A. R. (2020). Resistance Training for Children and Adolescents. *Pediatrics*, 145(6). doi: 10.1542/peds.2020-1011
- Tillin, N. A., & Folland, J. P. (2014). Maximal and explosive strength training elicit distinct neuromuscular adaptations, specific to the training stimulus. *European Journal of Applied Physiology*, 114(2), 365-374. doi: 10.1007/s00421-013-2781-x
- Tumilty, D. (1993). Physiological characteristics of elite soccer players. *Sports medicine*, 16(2), 80-96.
- Way, K. L., Sultana, R. N., Sabag, A., Baker, M. K., & Johnson, N. A. (2019). The effect of high Intensity interval training versus moderate intensity continuous training on arterial stiffness and 24 h blood pressure responses : A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 22(4), 385-391.
- Wen, D., Utesch, T., Wu, J., Robertson, S., Liu, J., Hu, G., & Chen, H. (2019). Effects of different protocols of high intensity interval training for VO2max improvements in adults : A meta-analysis of randomised controlled trials. *Journal of Science and Medicine in Sport*, 22(8), 941-947.
- Winter, E. M., Abt, G., Brookes, F. B. C., Challis, J. H., Fowler, N. E., Knudson, D. V., ... Yeadon, M. R. (2016). Misuse of “Power” and Other Mechanical Terms in Sport and Exercise Science Research. *The Journal of Strength & Conditioning Research*, 30(1), 292. doi: 10.1519/JSC.0000000000001101
- Yassin Zenati, Belkadi, Adel, & Benbernou, Othman. (2021). Functional Movement Screening as a Predictor of Injury in Highly Trained Female’s Martial Arts Athletes. *Polish Hyperbaric Research*, 71(2), 67-74. doi: 10.2478/phr-2020-0012
- Ziemann, E., Grzywacz, T., Luszczuk, M., Laskowski, R., Olek, R. A., & Gibson, A. L. (2011). Aerobic and Anaerobic Changes with High-Intensity Interval Training in Active College-Aged Men. *The Journal of Strength & Conditioning Research*, 25(4), 1104-1112. doi: 10.1519/JSC.0b013e3181d09ec9

Primljen: 10. april 2022. / Received: April 10, 2022  
Prihvaćen: 09. jun 2022. / Accepted: June 09, 2022

