Investigation of the effect of 6-week CrossFit exercises on anaerobic endurance and anaerobic strength in male basketball players

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ABSTRACT

The aim of this study was to investigate the effect of 6-week CrossFit exercises on anaerobic endurance and anaerobic strength in male basketball players. The sample of the study was composed of 24 male basketball players; 12 in the test group (20.17 ± 2.65 years, 183.67 ± 7.21 cm, 78.17 ± 10.54 kg, 22.96 ± 2.39 kg/cm^2) and 12 in the control group (21.67 ± 3.62 years, 184.75 ± 5.20 cm, 77.08 ± 8.57 kg, 22.57 ± 2.28 kg/cm^2). Anthropometric measurements of all the basketball players participating in the study were obtained and they were applied a 20-minute warm-up program before the measurements including a 5-minute jogging and 15-minute dynamic stretching movements. Following the warm-up, MyJump vertical jump test was applied for anaerobic strength measurement by using the 240 Hz high-speed video shooting feature of IPhone 6S smartphone, and Lewis formula was used for anaerobic strength measurement. In determining anaerobic endurance, 6×35 meter Repeated Sprint Test (R.S.T.) was applied with 10-second rest intervals. After the measurements, the participants were divided into two groups as the test group and the control group. While the test group basketball players participated in the CrossFit training program 3 times a week for a period of 6 weeks in addition to their basketball trainings, the control group basketball players only performed their basketball trainings. At the end of the 6-week period, the test protocol was repeated for both groups. In data analysis, SPSS 20.0 package program was used. According to the results of the statistical analysis; it was determined that there was no significant difference in between-groups pre-test results of the test group and control group, and in the pre-test/post-test results of the control group. However, in the post-test results, it was revealed that there was a statistically significant difference between the pre-test/post-test results of the test group in the Repeated Sprint Test Mean (R.S.T.M.), Fatigue Index (FI) and Anaerobic Strength (AS); and that there was also a statistically significant difference between the two groups in R.S.T.M. and A.S. ($p < 0.05$). In conclusion, it can be said that the 6-week CrossFit exercises have improved anaerobic endurance and anaerobic strength in male basketball players. Therefore, it is suggested that basketball coaches can use CrossFit exercises as an alternative in order to improve their players' anaerobic endurance and anaerobic strength.

Keywords: Anaerobic endurance, anaerobic strength, CrossFit.

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INTRODUCTION

CrossFit is a training model which involves high intensity and repetitive functional movements (Butcher et al., 2015). CrossFit training, which has gained great popularity today, was introduced to the world by Glassman from California in 1995 and this training model keeps spreading rapidly (Goins, 2014; Dilber and Doğru, 2018). CrossFit trainings, which include various sports movements, are basically composed of Olympic lifts such as squat, deadlift, clean, snatch and overhead, gymnastics such as parallel bar, ring, pull up, and exercises improving aerobics such as swimming, running and rowing, and the training of the day is programmed as

"work out of the day" (Meyer et al., 2017; Claudino et al., 2018). Some of CrossFit unit trainings are based on the principle of "repeating as many rounds as possible in one round" (AMRAP) (Smith et al., 2013). CrossFit trainings aim to develop strength and endurance. These trainings are thought to improve the aerobic capacity and anaerobic capacity of the individual thanks to the trainings performed with high intensity movement combinations. Together with the fact that CrossFit trainings affect the positive development in aerobic capacity, muscle endurance and body composition, it also requires high technical capacity in the implementation of the movements (Moran et al., 2017).

In CrossFit exercises, the principle of doing the movements by the athletes as fast as they can within the given time indicates that they affect the anaerobic energy system, which is one of the energy systems (Escobar et al., 2017; Paine et al., 2010). In addition to this, it can increase aerobic performance capacity by enhancing max VO_2 together with the increase in stroke volume in high intensity movement practices. These different and intense training programs have enabled CrossFit to be a preferred training method; and the reasons of this ideal also depend on the physical and physiological development. In some studies conducted, it was observed that the trainings positively affected the athletes' maximal strength and maximal anaerobic capacity (Borras et al., 2017). CrossFit trainings performed with many repetitions, short time and just a few rest intervals with the aim of cardiovascular system and strength development, are performed at a level close to the maximum pulse of the individual. Athletes reach high speed in the trainings aiming to reach a limited number of targeted movements (Murawska-Cialowicz et al., 2015). The fact that the physical and physiological competencies of basketball players are high enables them to perform in-game offensive and defense organizations effectively. Basic requirements such as shooting, dribbling and passing, which are among the offense organizations, affect the success in basketball and these features can be improved through trainings that enhance anaerobic features (Abdullah and Gencer, 2019). The shorter the elapsed time for the heart rate to be returned to normal during the competition, the more successful interventions or successful shots will be achieved within the game. It is thought that CrossFit can be an ideal alternative training method for basketball in which various movement practices are performed sequentially, and anaerobic endurance and strength are important components in performance.

Along with the fact that there were a limited number of studies conducted on CrossFit when the literature was examined, no studies have been found regarding the effect of CrossFit trainings on anaerobic performance in basketball players. For this reason, the aim of this study was to investigate the effect of 6-week CrossFit exercises on anaerobic endurance and anaerobic strength in male basketball players.

MATERIALS AND METHODS

In this study, a total of 24 male basketball players, 12 in the test group (20.17 ± 2.65 years, 183.67 ± 7.21 cm, 78.17 ± 10.54 kg, 22.96 ± 2.39 kg/cm^2) and 12 in the control group (21.67 ± 3.62 years, 184.75 ± 5.20 cm, 77.08 ± 8.57 kg, 22.57 ± 2.28 kg/cm^2), competing in Turkish Major Male Basketball League participated voluntarily. The study was launched after the approval of Aydın Adnan Menderes University, Faculty of Medicine Ethics Committee, numbered 53043469-050.04.04 and the decision numbered 29. Prior to the start of the study, all the participants were asked to sign voluntary consent forms explaining the purpose of the research and possible risks. The measurements of the athletes were carried out in the facilities of Faculty of Sport Sciences, Aydın Adnan Menderes University. First of all, anthropometric measurements of all the participants were obtained and then, the athletes performed a 20-minute warm-up program which was composed of a 5-minute jogging and 15-minute dynamic stretching exercises. The performance tests applied to the athletes were performed immediately after the warm-up. In order to determine anaerobic endurance of the athletes, Repeated Sprint Test (R.S.T.) was used, and in order to determine their anaerobic strength, MyJump vertical jump test was used. Following the measurements, the participants were randomly divided into two as the test group and the control group. While the test group basketball players participated in the CrossFit training program in addition to their basketball trainings, the control group basketball players only performed their basketball trainings. At the end of the 6-week period, the test protocol was repeated for both groups.

Anthropometric measurements

Height measurements of the athletes were performed barefoot and wearing only sports equipment, by using Seca brand stadiometer, standing in an upright position and adjusting the sliding caliper on the scale so that it touches the head of the athlete, with a precision of 1 mm for height. The body weight measurements of the athletes were performed barefoot and wearing only sports equipment, standing in an upright position and adjusting so that the soles of the athletes' feet fully touch the metal part of the scale.

Repeated sprint test

Repeated Sprint Test (R.S.T.), which was developed by Draper and Whyte (1997) in order to determine the

athletes' anaerobic endurance and which was stated to have similar mean values with the Wingate anaerobic strength test, was utilized in the research. In Repeated Sprint Test (R.S.T.), the athletes ran a distance of 35 meters with 6 maximal repetitions, with recovery intervals less than 10 seconds. The durations at the time of the tests were recorded as intermediate tours through photocell. Funnels were used so as to determine the 35-meter distance. The athletes launched the beginning of the tests when they felt ready for the tests (Draper et al., 1997). The best time, worst time, average time and fatigue time values of the athletes were calculated with the formula developed by Harman (1991), mentioned below.

Strength = kg × distance^2/time^3
Fatigue index = (peak power − minimum power output) / peak power × 100
S = Sprint time
Average time = [S1 + S2 + S3 + S4 + S5 + S6]/6

Vertical jump test

MyJump vertical jump test was used to determine anaerobic strength of the athletes. The athletes performed the vertical jump test with hands on their waist, in a static standing position and their feet straight. All the jumps were recorded synchronously by using the 240 Hz high-speed video shooting feature of IPhone 6S (Apple Inc., USA) smartphone. Video shootings were performed on the frontal plane by focusing on the toes of the participant jumping at a 1-meter distance. The videos recorded were analyzed using the *MyJump* (AppStore) smartphone application. By using this application, the time when the toes of the participants rose up from the ground and touched down again during the jump was determined manually and their time during the jump was calculated (Turgut et al., 2018).

CrossFit workouts

CrossFit trainings of the basketball players forming the test group were performed at Spor-In Wellness Club and Aydın Adnan Menderes University sports facilities between 11.00 and 12.00 in the morning, 3 times a week, and for a 6-week period. CrossFit trainings determined were designed similar to the studies of Murawska-Cialowicz et al. (2015) and Bellar et al. (2015). CrossFit training program applied in addition to basketball trainings is given in Table 1.

Statistical analysis

SPSS 20.0 package program was used in the statistical analysis of the research data. First of all, it was analyzed whether the data showed normal distribution. For the data with normal distribution; Paired Samples t-test was used in in-group evaluations to determine the differences between the 6-week pre-test and post-test values of the basketball players, and Independent Samples t-test was used to evaluate the differences between the pre-test and post-test measurements of the test group and control group. In the tests performed, the significance level was determined as $p < 0.05$.

FINDINGS

In this study, which aimed to investigate the effect of 6-week CrossFit exercises on anaerobic endurance and anaerobic strength in male basketball players, a total of 24 male basketball players, 12 in the test group and 12 in the control group, participated. The demographic characteristics of the basketball players participating in the study are given in Table 2.

When Table 2 was examined, it could be seen that there was not a statistically significant difference between the age, height, body weight and body mass indexes of the test group and control group.

Repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants in the test group and control group obtained before and after the 6-week CrossFit trainings, and the differences between them are given in Table 3.

When Table 3 was examined, it could be seen that there was not a statistically significant difference in the pre-test results of the test group and control group, whereas there was a statistically significant difference according to the post-test results in R.S.T. and A.S. ($p < 0.05$); it could also be revealed that there was not a statistically significant difference in F.I. of the basketball players ($p > 0.05$). According to the results of the statistical analysis, it could be said that the participants in the test group displayed positive improvement.

Body weight, repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants in the test group obtained before and after the 6-week CrossFit trainings, and the differences between them are given in Table 4.

When Table 4 was examined, it could be seen that there was a statistically significant difference between the body weight, R.S.T., F.I. and A.S. mean values of the participants in the test group ($p < 0.05$). It was revealed that the body weight, R.S.T. and F.I. of the participants in the test group decreased as a result of the 6-week CrossFit trainings, whereas their A.S. increased ($p > 0.05$).

Body weight, repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants in the control group obtained before and after the 6-week CrossFit trainings, and the differences between them are given in Table 5.

Table 1. CrossFit training program.

	Monday	Wednesday	Friday
1. Week	Deadlift (3×5) (60-70-80%) AMRAP (30 min) 20 Air squat 10 Box jump 100 Rope jump 20 Jumping jack 100 Rope jump 10 Box jump 20 Air squat	Back Squat (3×5) (60-70-80%) Every 45 sec. for 30 min. (minimum) (10 repeats) 45 sec. 10 push up 45 sec. 10 KB swing 45 sec. KB front squat 45 sec. rest	Thruster (3×5) (60-70-80%) EMOM (every minute on the minute) (12 min) METCON 10 kettlebell (KB) swing 10 Hip thruster
2. Week	Hand release × Push up max. Repeat 30 sec. practice - 30 sec. rest (5 sets) KB power clean Wall ball KB swing Squat jump	Front squat (3×5) (60-70-80%) (3 sets) (20 min) 10 dB snatch 10 burpee 10 wall ball	Deadlift (3×5) (60-70-80%) (20 min) 20 lunge 100 rope jump 20 air squat 100 rope jump 20 air squat 100 rope jump 20 lunge
3. Week	Thruster (3×5) (60-70-80%) AMRAP (minimum 10 min.) 21 dB snatch 21 wall ball 15 dB snatch 15 wall ball 5 dB snatch 5 wall ball	Deadlift (3×5) (60-70-80%) AMRAP 3 sets 10 push press 10 kb snatch 10 box jump 10 wall ball	Back Squat (3×5) (60-70-80%) AMRAP 3 sets 50 rope jump 10 exes hand squat 10 burpee 10 push up
4. Week	Thruster (3×5) (60-70-80%) 12 min. 5 sumo deadlift high pull 5 push up 5 bent over row	Chin up 10 min. AMRAP (30 min) 100 body weight air squat 100 sit up 100 push up 100 pull up	Hand release push up (10 min) AMRAP (20 min) 21 kb swing 21 jump squat 15 kb swing 15 jump squat 5 kb swing 5 jump squat
5. Week	Front squat (3×5) (60-70-80%) (3 set) (20 min) 10 dB snatch 10 burpee 10 wall ball	Hand release × Push up max. Repeat 30 sec. practice - 30 sec. rest (5 sets) KB power clean Wall ball KBS Squat jump	Deadlift (3×5) (60-70-80%) (20 min) 20 lunge 100 rope jump 20 air squat 100 rope jump 20 air squat 100 rope jump 20 lunge
6. Week	Thruster (3×5) (60-70-80%) AMRAP (minimum 10 min.) 21 dB snatch 21 wall ball 15 dB snatch 15 wall ball 5 dB snatch 5 wall ball	Deadlift (3×5) (60-70-80%) AMRAP 3 sets 10 push press 10 kb snatch 10 box jump 10 wall ball	Back Squat (3×5) (60-70-80%) AMRAP 3 sets 50 rope jump 10 exes hand squat 10 burpee 10 push up

Table 2. The demographic characteristics of the participants.

Values	Test group (n = 12)	Control group (n = 12)	p
Age (year)	20.17 ± 2.65	21.67 ± 3.62	0.26
Height (cm)	183.67 ± 7.21	184.75 ± 5.20	0.67
Body Weight (kg)	78.17 ± 10.54	77.08 ± 8.57	0.78
B.M.I. (kg/m^2)	22.96 ± 2.34	22.57 ± 2.28	0.68

p < 0.05.

Table 3. Repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants, and the differences among them.

Values	Test group Pre-test (n = 12)	Control group Pre-test (n = 12)	p	Test group Post-test (n = 12)	Control group Post-test (n = 12)	p
R.S.T. (sec)	5.71±0.63	5.63±0.36	0.60	4.84±0.45	5.63±0.38	0.00*
F.I.	1.62±0.75	1.51±0.55	0.67	1.06±0.34	1.30±0.44	0.29
A.S. (watt)	450.33±136.09	457.42±130.69	0.89	608.92±152.88	418.08±158.57	0.07*

p < 0.05.

Table 4. Body weight, repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants in the test group, and the differences among them.

Parameter	Test group pre-test	Test group post-test	p
Body weight (kg)	78.17 ± 10.54	75.42 ± 7.20	0.04*
R.S.T.(sec.)	5.71 ± 0.36	4.84 ± 0.45	0.00*
F.I.	1.62 ± 0.75	1.06 ± 0.34	0.00*
A.S. (watt)	450.33 ± 136.09	608.92 ± 152.88	0.00*

p < 0.05.

Table 5. Body weight, repeated sprint test (R.S.T.), fatigue index (F.I.) and anaerobic strength (A.S.) pre-test and post-test mean values of the participants in the control group, and the differences among them.

Values	Control group pre-test	Control group post-test	p
Body weight (kg)	77.08 ± 2.47	77.08 ± 2.47	0.78
R.S.T.(sec.)	5.63 ± 0.36	5.63 ± 0.38	0.51
F.I.	1.51 ± 0.55	1.30 ± 0.44	0.36
A.S. (watt)	457.42 ± 130.69	418.08 ± 158.57	0.19

p < 0.05.

When Table 5 was examined, it could be revealed that there was not a statistically significant difference between the body weight, repeated sprint test (R.S.T.), fatigue index (F.I.), anaerobic strength (A.S.) mean values of the participants in the control group (p > 0.05).

DISCUSSION

In this study, it was aimed to investigate the effect of 6-week CrossFit exercises on anaerobic endurance and anaerobic strength in male basketball players. CrossFit trainings, which were programmed by Glassman in the early 2000s, have reached an increasing mass of people in the world and gained popularity (Lichtenstein and Jensen, 2016). CrossFit trainings, which had been primarily developed for American soldiers and police officers, begun to be performed by the individuals engaged in recreational sports and the athletes doing individual sports (Meyer et al., 2017). It was also reported that CrossFit trainings improved both aerobic and anaerobic performance by being performed for various

periods and intensity levels (Glassman, 2010). Despite the effect stated, it can be noted that the number of studies in the literature regarding CrossFit trainings are limited.

According to the findings of this study, it was revealed that there was a statistically significant difference in the basketball players as a result of the 6-week CrossFit trainings in terms of body weight, repeated sprint test (R.S.T.), anaerobic strength (A.S.) and fatigue index (F.I.) mean values. When the literature was examined, it was found that there were studies parallel to the findings of this study. In their study which examined the effect of the 8-week CrossFit trainings on the vertical jump features of male wrestlers, Yüksel et al. (2018) found that there was a significant difference in the squat jump heights of the wrestlers' CrossFit trainings as a result of the pre-tests and post-tests. They revealed that CrossFit trainings increased jumping and strength output. In their 10-week "Circuit vs CrossFit" study, Wessel et al. (2015) found that there was a statistically significant and positive difference in the vertical jump features of female athletes before and after the trainings. In their study on 32 healthy males, Bellar et al. (2015) stated that CrossFit positively affected anaerobic performance. Sousa et al. (2016) found in their study comparing endurance and CrossFit trainings that there was a statistically significant increase in the vertical jump heights of the 13 male participants forming the test group after CrossFit trainings. Schultz et al. (2016) revealed in their study published as a pilot study on 16 male participants that in the heart rate, blood pressure, body composition, 1 repeat maximal bench press/squat and wingate anaerobic strength tests of the 8-week CrossFit trainings, there was a significant difference in body composition. They also stated that body fat ratio decreased and body composition improved. However, they noted that further studies were required regarding the data obtained. In the study of Goins (2014) conducted on 12 participants, it was found that the 6-week CrossFit trainings had an impact on aerobic capacity, anaerobic capacity and some performance values. In the same study, it was also stated that the participants did not participate in any exercise programs other than CrossFit and that CrossFit training programs improved 3 energy systems used for aerobic capacity, anaerobic capacity and performance (Goins, 2014).

CrossFit trainings are the training programs planned with the aim of developing 3 energy systems (phosphagen system, glycolytic system, and oxidative system). The trainings are formed upon the features of cardiovascular endurance, strength, speed, coordination, agility, balance and muscle endurance. The studies conducted regarding the fact that CrossFit trainings are activating all 3 energy systems, though limited, have been focused on aerobic endurance. Dexheimer et al. (2019) stated that in CrossFit trainings, the effect will be enhanced with the development of lower extremity strength, anaerobic strength and anaerobic performance.

In the study conducted in order to reveal the effect of CrossFit trainings on body composition and aerobic endurance, Smith et al. (2013) found that the 10-week trainings improved maxVO$_2$ capacity and body composition. In their study with 10 healthy males examining the effect of CrossFit trainings on maximum heart rate and max VO$_2$ level, Fernandez-Fernandez et al. (2015) found that there was a statistically significant increase in max VO$_2$ level. In their study on young females and males, Murawska-Cialowicz (2015) revealed that the 3-month CrossFit trainings positively affected max VO$_2$ values and decreased the fat rate in females more than males. In the study conducted with young students, Borras et al. (2017) found that CrossFit trainings improved aerobic capacity in the test group. All these studies mentioned above show that CrossFit trainings improve aerobic capacity, and therefore, enhances working capacity and positively affects maximal oxygen consumption capacity.

Unlike the studies mentioned above; Butcher et al. (2015) revealed in their study examining the effect of CrossFit trainings performed in 4 different protocols (Fran, Grace, Cindy and CrossFit Total) that there was not a statistically significant difference in CrossFit (Fran, Grace and Cindy) training programs in terms of anaerobic strength.

In conclusion, despite the fact that there is a scarce number of studies examining the effect of CrossFit trainings on anaerobic strength and anaerobic endurance, the studies conducted have exhibited that these trainings have an effect on physical fitness, aerobic impact and anaerobic strength. In this study, it was concluded that the 6-week CrossFit trainings affected anaerobic endurance and anaerobic strength in male basketball players. Accordingly, it can be said that basketball players and coaches can use CrossFit trainings to improve their anaerobic strength and anaerobic endurance as an alternative to other training methods they use in their training plans. Furthermore, it is stated that CrossFit trainings, which are not widely used in team sports during the season or mid-season period on certain days, may affect the cardiovascular system, and the improvement of aerobic and anaerobic capacity, but may cause injuries unless enough attention is drawn on the movements requiring high technique (Buthcer et al., 2015; Claudino et al., 2018). For this reason, while performing CrossFit trainings, necessary attention should be paid in terms of the athletes' injury risks and being fully rested. This study is the first study planned with the aim of determining the effect of 6-week CrossFit trainings on anaerobic endurance and anaerobic strength in male basketball players. Further studies are needed regarding the effect of CrossFit trainings on performance in different sports branches in addition to basketball. Therefore, it is thought that this study will shed light on future CrossFit studies and contribute to the training plans of basketball coaches.

REFERENCES

Abdullah, R. R., and **Gencer**, Y. G. (**2019**). Basketbolda Dinamik Dengenin Şut İsabetine Etkisinin İncelenmesi. Uluslararası Toplum Araştırmaları Dergisi, 9(10): 1478-1494.

Bellar, D. M., Hatchett, A., Judge, W. L., and Marcus, L. R. (**2015**). The relationship of aerobic capacity, anaerobic peak power and experience to performance in HIT exercise. Biology of Sport, 32(4): 315-320.

Borras, A. P., Herrera, J., and Ponseti, J. F. (**2017**). Effects of CrossFit lessons in physical education on the aerobic capacity of young students. Journal of Physical Education and Health, 6(10): 5.

Butcher, S. J., Neyedly, T. J., Horvey, K. J., and Benko, C. R. (**2015**). Do physiological measures predict selected CrossFit benchmark perforamance? Journal of Sports Medicine, 6: 241-245.

Claudino, G. J., Gabbett, J. T., Bourgeois, F., Souza Sa de, H., Miranda, C. R., Mezencio, B., Soncin, R., Filho, C. A. C., Bottaro, M., Hernandez, J. A., Amadio, C. A., and Serrao, C. J. (**2018**). CrossFit overview: Systematic review and meta-analysis. Sports Medicine, 4(11): 1-14.

Dexheimer, J. D., Schroeder, T. E., Sawyer, J. B., Pettitt, W. R., Aguinaldo, L. R., and Torrence, W. A. (**2019**). Physiological performance measures as indicators of CrossFit performance. Sports, 7(4): 93.

Dilber, A., and **Doğru**, Y. (**2018**). The effect of high intensity functional exercise on anthropometric and physiological characteristics in sedantery. International Journal of Sports Exercise and Training Science, 4(2): 64-69.

Draper, N., and **Whyte**, G. (**1997**). Anaerobic Performance Testing. https://www.researchgate.net/publication/256097681_Anaerobic_Perf ormance_Testing.

Escobar, K. A., Morales, J., and VanDusseldorp, T. A. (**2017**). Metabolic profile of a CrossFit training bout. Journal of Human Sport and Exercise, 4(12): 1248-1255.

Fernandez-Fernandez, J., Sabido-Solana, R., Moya, D., Sarabia, M.J., and Moya, M. (**2015**). Acuta Physiological Responses During CrossFit Workouts. European Journal of Human Movement, 35: 114-124.

Glassman, G. (**2010**). CrossFit Training Guide. CrossFit Journal, 1-115.

Goins, J. M. (**2014**). Physiological and Performance Effects of CrossFit. Master Thesis. The University of Alabama. 26-28.

Harman, E. A., Rosenstein, M. T., Frykman, P. N., Rosenstein, R. M., and Kraemer, W. J. (**1991**). Estimation of Human Power Output From Vertical Jump. Journal of Applied Sport Science Research, 5(3): 116-120.

Lichtenstein, M. B., and **Jensen**, T. T. (**2016**). Exercise addiction in CrossFit: Prevalence and psychometric properties of the exercise addiciton inventory. Addictive Behaviors Reports, 3(33): 7.

Meyer, J., Morrison, J., and Zuniga, J. (**2017**). The benefits and risks of CrossFit. Continuing Education, 65(12): 612-618.

Moran, S., Booker, H., Staines, J., and Williams, S. (**2017**). Rates and risk factors of injury in CrossFit: a prospective cohort study. Journal of Sports Medicine and Physical Fitness, 57(9): 1147-1153.

Murawska-Cialowicz, E., Wojna, J., and Zuwala-Jagiello, J. (**2015**). CrossFit training changes brain- derived neurotrophic factor and irisin levels at rest, after wingate and progressive tests, and improves aerobic capacity and body composition of young physically active men and women. Journal of Physiology and Pharmacology, 66(6): 811-821.

Schultz, J. T., Parker, A., Curtis, D., Daniel, J., and Huang, H.H. (**2016**). The physiological and psyiological benefits of CrossFit training - A pilot study. International Journal of Exercise Science, 2(8): 1.

Smith, M., Sommer, M., Starkoff, A. J., and Devor, S. T. (**2013**). CrossFit-based high intensity power training improves maximal aerobic fitness and body composititon. Journal of Strength and Conditioning Research, 27(11): 3159-3172.

Sousa, A., Del Rosso, S., and Boullosa, A. D. (**2016**). Differences in physical fitness between recreational CrossFit and resistance trained individuals. Journal of Exercise Physiology Online, 19(5): 112-122.

Turgut, A., Çoban, Ö. G., and Gelen, E. (**2018**). Dikey Sıçrama Performansının Belirlenmesinde Akıllı Telefon Uygulaması Kullanılabilir Mi? International Journal of Sports Exercise and Training Science, 4(2): 79-83.

Wessel, P., Imman, C., Stone, W., Arnett, S., Schafer, M., Lyons T. S., Maples, J., Crandall, J., and Callahan, Z. (**2015**). CrossFit vs. circuit training: Effects of a ten-week training program on muscular strength and endurance. Medicine and Science in Sports and Exercise. 47(55): 800.

Yüksel, O., Gündüz, B., and Kayhan, M. (**2018**). Effect of CrossFit training on jump and strength. Journal of Education and Training Studies, 7(1): 121-124.