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Acute and Continuous Effects of Caffeine Consumption with Anaerobic Training on Anaerobic Performance, Body Composition and Serum Lactate Levels in Active Men

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***Abstract*— the purpose of this study was to compare acute and continuous effects of caffeine consumption with a four-week anaerobic training on anaerobic performance, serum lactate levels and body composition values in active men. The study design was a quasi-experimental one. Experimental and control groups were compared in the phases of pre-test and two post-tests. Thirty-two active male students performed a 400m-run and blood samples were collected 2 minutes later. Next day, Wingate test was conducted to assess anaerobic power. Then, all subjects were randomly divided into 2 groups: caffeine consumption (Experimental group) and placebo (Control group), performing a 4-week anaerobic exercise. Finally, blood samples have been collected like before; then, each group was divided into 2 subgroups (caffeine or placebo consumption for one day) and blood samples have been collected after a 400m-run again. Subjects also consumed either caffeine or placebo at a dose of 5 mg/kg of body weight. T-tests were used to analyze data, at a significance level of P<0.05. Four weeks Anaerobic training with and without caffeine consumption decreased the time of 400m-run and elevated serum lactate levels (p=0.001) (higher differences were observed in caffeine group), but had no significant effect on Wingate test results. Weight value only increased in Experimental group. Acute consumption of caffeine in placebo group also decreased the time of 400m-run and elevated lactate levels (p=0.001). Acute and continuous consumption of caffeine along with anaerobic exercise improved anaerobic performance; while increased serum lactate levels in active men.**

***Keywords*— Anaerobic training, Caffeine, Anaerobic performance, Lactate**

I. INTRODUCTION

The study of issues affecting sport performance is one of the most important tasks and concerns of researchers in the field of sports sciences. The issue of sport supplements is one of the most important concerns that demands attention in our country more than the past due to their effect on performance, widespread use by athletes and increased awareness among instructors. Caffeine is a quasi-crystalline, white and bitter tasted substance chemically called 1,3,7-trimethyl xanthine with the formula $C_8H_{10}N_4O_2$, which is one of the supplements that is used today in sports activities prevalently, and is found in a variety of beverages especially coffee, tea and chocolate with cacao [1]. In the past, consumption of caffeine before the tournament was considered to be doping; however, the World Anti-Doping Agency recently eliminated caffeine from the list of banned substances. So far, some of the studies that have been carried out on this supplement abroad have pointed to the positive effects of caffeine consumption on long-term activities, but its impact on anaerobic performance and sprint training led to contradictory findings [2, 3]. The mechanism of caffeine effectiveness is that it initially stimulates adrenaline secretion, which causes a) the release of fatty acids, b) Storage of muscle glycogen, c) Stimulation of the central nervous system and increase in mental arousal, d) Increase in the formation of cross bridges [4]. Also, caffeine leads to placement of calcium through the plasma and the endoplasmic membrane in the endoplasmic network of the heart muscle cells and skeletal muscle which reduces the potential of the threshold to stimulate and extension of the contraction time [5]. However, numerous articles have been presented by various researchers, including Davis (2009), Turley (2015) and Andre (2015) that caffeine consumption can affect anaerobic performance in the short-term and high intensity activities, including repetitive Wingate tests, handgrip test, as well as sports such as soccer, hockey and rugby that are largely reliant on anaerobic system [6-8], and acts as an ergogenic substance. For instance, taking 5 mg of caffeine per kilogram of body weight in female athletes can reduce lactate production during intense sportive activities [9]. There are reasons for the possibility of a positive effect of caffeine consumption on anaerobic performance; caffeine may indirectly change the sodium to potassium ratio by altering the concentration of calcium ion, and cause more stability in the intercellular environment, and subsequently improve the conditions for the development of force [5, 10], also it can facilitate the release of calcium from its storage location in muscle cells. This effect increases muscle strength and power for a short period in the high intensity activities [11]. According to conducted researches on the effect of caffeine consumption on anaerobic performance, it seems that the consumption time and amount of caffeine consumed before physical activity can directly affect the performance of athletes. On the other hand, in a study by Woolf *et al*. (2009), participants who had very low caffeine consumption record did not report any differences in Rating of Perceived Exertion (RPE) after a 30-second Wingate test [12]. This study was performed on 18 male athletes, in which experimental group consumed 5 mg of caffeine per kg body weight, and after an hour, their anaerobic performance was evaluated during the Wingate test. Hence, it is suggested that caffeine consumption responses may be different in individuals with continuous intake and consumers with low intake of caffeine [12]. It can also be expected that continuous and acute consumption of caffeine will provide different responses both in terms of performance and biochemical markers in athletes [12]. According to the research history, it seems there is a need for more study on the effect of caffeine consumption in various people with high and/or low intake of caffeine, as well as the effect of continuous intake comparing to acute consumption of caffeine on anaerobic performance and serum lactate.

As stated before, various studies have been done on the effect of caffeine consumption on the anaerobic performance of athletes; however, less as the present study, the effect of continuous and acute consumption of this substance on anaerobic function and serum lactate level and comparison of both of these types of caffeine consumptions have been considered in active people. Plus, in previous studies, we observed the subjects who were caffeine-deprived and were fed with acute intake of caffeine; and it was not found any study containing a period of anaerobic training along with a certain amount of caffeine consumption. Thus, in the first phase of the present study, we investigated the effect of caffeine or placebo along with 4 weeks of anaerobic training on anaerobic performance, body composition factors and serum lactate level in active men who had low and high intake of caffeine. In the second phase, we examined the effect of cessation of supplementation on before-mentioned factors in caffeine consumers and also, the effect of acute supplementation in consumers with low intake of caffeine. Hopefully, according to the findings of the current study, coaches and athletes could be helped to improve anaerobic performance.

II. Methodology

The method of this study was a quasi-experimental one. Experimental and control groups were compared in the phases of pre-test and two post-tests. The statistical population of this study was Kharazmi University's physical education students aged 19-22 years. Among them 32 students with mean age (21.2 ± 52.33 years), height (175.03 ± 05.8 cm) and weight (67.08 ± 02.35kg) were selected as the statistical sample by random sampling. Subjects were divided into Two groups (each group n=16) of caffeine consumers as experimental group and placebo or control group. They were asked to fill out a questionnaire containing information on the history of caffeine consumption. The subjects consuming a maximum of one cup of tea daily were put in the control group, and those who were consuming 5 cups of tea or a cup of coffee daily were placed in the experimental group. Both groups performed anaerobic training; experimental group received caffeine while, control group received placebo. In this research, active male students were participating in physical education classes during the week and regularly had at least one hour of physical activity per day. In the pre-test phase, body composition test was conducted. In two consecutive days following the same meal at 18 o'clock, a 400-meter run test was performed and after 2 minutes, 5cc of venous blood was taken from subjects to assess the level of lactate. The next day, a 30-second Wingate test was done to assess the anaerobic power [9].

Then, each day at 17 o’clock, the experimental group has received caffeine-containing capsules, and placebo group received starch-containing capsules for four weeks. Both of groups have performed anaerobic exercise during four weeks. In the next stage and after four weeks of anaerobic training, the first post-test phase including a 400-m run, blood sampling, body composition assessment, and 30-second Wingate test, were conducted similar to the pre-test phase. Then, each group was divided into two equal and homogeneous subgroups. On the next day at 17 o'clock, one of the subgroups of the experimental group, received placebo and the other subgroup received caffeine like before. Subgroups of the control group also received placebo or caffeine (acute intake of supplement was examined here). Then, at 18:00 o’clock the same day, all the subgroups performed a 400-m run test, and after 2 minutes, 5cc of venous blood was collected again [9]. The 400-m run test records were measured by two chronometers and the average of records were registered as the final record of each subject. During the intervention period, subjects in both groups have performed anaerobic exercise for four weeks and three sessions a week. Plus, since the most desirable adaptations are reported at least within 4 weeks, the duration of training in this study was also considered as 4 weeks [13]. The exercise program was designed with the simulation of exercise program of Thomas *et al*., (sprint runs) [14]. Anaerobic training protocol can be seen in Table 1.

Caffeine was prepared as a powder with 98% purity from the al-Hawi Pharmaceutical Company. Next, gel capsules were filled with 5 mg of caffeine/starch per kg of subjects’ body weight. Access to the subjects was easy for the researcher due to their residence in the campus. Caffeine/placebo capsules which were prepared according to the weight of each subject have been consumed every day at 17 o'clock.

Data were analyzed by SPSS software version 15. The normal distribution of data and the homogeneity of variances were assessed by the Kolmogorov-Smirnov test (KS), and the

Levene's test, respectively. Then, t-student test was used to compare the differences within and between groups. Significance level was considered at P values <0.05.

TABLE1. Training Protocol

Session	First week	Second week	Third week	Fourth week
First	➢ 10-minute warm up ➢ 100m sprint and then 300m slow running (2 times) ➢ 10-minute cool down	➢ 10-minute warm up ➢ 200m sprint and then 600m slow running (2 times) ➢ 10-minute cool down	➢ 10-minute warm up ➢ 300m sprint and then 500m slow running (2 times) ➢ 10-minute cool down	➢ 10-minute warm up ➢ 400m sprint and then 5 minutes active rest (3 times) ➢ 10-minute cool down
Second	Repeating the first session (3 times)	Repeating the first session (3 times)	Repeating the first session (3 times)	Repeating the first session (4 times)
Third	Repeating the first session (4 times)	Repeating the first session (4 times)	Repeating the first session (4 times)	Repeating the first session (4 times)

III. RESULTS

The results showed that the mean of subjects' traits including age, height and weight in experimental group were (21.96 ± 2.41 years), (176.6 ± 2.2 cm) and (66.26 ± 9.7 kg); and in control group were (21.2±2.01 years), (173.5 ± 4.5 cm) and (67.9 ± 8.2 kg), respectively (Total average: 21.52 ± 2.33 years, 175.05± 3.8 cm and 67.02±8.35 kg). Also, the results of the Kolmogorov-Smirnov test and Levene's test showed that the distribution of data in both the experimental and control groups were normal and there was a consistency in the data variance; in the other words, there was no significant difference in baseline status between the two groups. Meanwhile, in the stage of second post-test, the sample size in the experimental group was reduced to 15 due to the absence of one subject; therefore, the records of this subject were discarded.

Table 2 indicates the differences within and between groups of 400-m run and serum lactate level before and after the intervention (pre-test and first post-test). After four weeks of anaerobic training, it was observed a decrease of 6.52% and 2.68%, in the time of 400-m run, and an increase of 23.26% and 13.98% in serum lactate levels in both caffeine consumers (experimental) and placebo consumers (control), respectively. In both groups, the post-test changes compared to the pre-test ones were significant (P <0.05). Also, the differences between groups show that there are significant differences between experimental and control groups in the 400-m run and serum lactate level (P = 0.001), which is approximately 2 times higher in experimental group. Table 3 represents the differences between groups of Wingate test results and body composition before and after the intervention (pre-test and first post-test). There was no significant difference in none of the performance indicators of the 30-second Wingate test in two groups (P>0.05); while, it was seen a significant difference in weight value between two groups (p=0.035).

Comparison of the first and second post-test data in the subgroups of control group (placebo) in Table 4 show that there are significant differences in the 400-m run performance and serum lactate level between acute consumption of caffeine and no caffeine intake after a period of anaerobic exercise (p =0.001).

Comparison of the first and second post-test data in the subgroups of experimental group (caffeine) in Table 5 indicates that there are significant differences in the 400-m run performance and serum lactate level between continuous consumption of caffeine and no caffeine intake after a period of anaerobic exercise (p =0.001).

TABLE2. Differences within and between groups of 400m sprint and serum lactate level before and after the intervention (pre-test and first post-test)

Variables	Groups	Stages		Pre and post Difference*	P value &	P value $
		Pre-test*	First Post-test*			
400m sprint ¥	Experimental	74.86±7.80	69.98±7.12	-4.88±1.41	0.001†	0.001†
	Control	75.3±8.21	73.28±6.36	-2.02±1.24	0.006†	
Lactate €	Experimental	10.66±1.41	13.14±1.4	2.47±0.58	0.001†	0.001†

Control	10.44±1	11.9±1.1	1.46±0.8	0.001†

Both Experimental (caffeine) and Control (placebo) groups performed a four-week anaerobic training; * The numbers are expressed as mean ± standard deviation; & Significance at the level of P<0.05 for the differences within groups; $ significance level at P<0.05 for the differences between groups; ¥ by second; € by mmol/L; † accepted significance level: P<0.05

TABLE3. Differences between groups of Wingate test results and body composition before and after the intervention (pre-test and first post-test)

Variables		Groups	Stages		Pre and post Difference*	t value	P value
			Pre-test*	First Post-test*			
30-second Wingate	Peak power $	Experimental	9.93±1.74	12.06±1.17	2.13±1.11	-0.41	0.686
		Control	9.63±1.34	11.49±1.34	1.86±1.81		
	Mean power $	Experimental	4.82±0.75	5.80±0.67	0.97±0.68	-1.51	0.147
		Control	5.20±0.77	5.78±0.81	0.57±0.48		
	Min Power $	Experimental	1.75±0.38	1.93±0.57	0.18±0.84	-0.14	0.89
		Control	2.06±0.56	2.22±0.65	0.13±0.49		
	Power loss percentage	Experimental	84.74±7.44	83±5.60	-1.73±11.74	1.05	0.305
		Control	82.62±9.73	86.2±13.72	3.57±10.68		
Body composition	Weight &	Experimental	66.26±9.7	66.75±9.4	0.49±0.66	-2.27	0.035 #
		Control	67.9±8.2	67.6±8.3	-0.3±0.96		
	Fat-free mass &	Experimental	55.6±6.8	55.8±6.5	0.2±1.2	-0.64	0.534
		Control	55.24±5.5	55.2±5.5	-0.04±0.51		
	Muscle mass &	Experimental	52.6±6.5	52.8±6.3	0.2±1.13	-0.66	0.51
		Control	52.24±5.2	52.2±5.2	-0.04±0.48		
	Body fluid	Experimental	38.5±4.7	37.7±4.6	0.2±0.81	-0.64	0.53
		Control	38.3±3.8	38.2±3.8	-0.1±0.35		

* Numbers are expressed as mean ± standard deviation; $ Watts per kilogram of body weight; & by kilogram; # Significance at the level of P<0.05.

TABLE4. Comparison of the first and second post-test control subgroups in 400m sprint and serum lactate levels

Variables	Groups	Subgroups	Stages		First and Second post Difference*	t value	P value #
			First post-test*	Second Post-test*			
400m sprint $	Control or Placebo	Caffeine (acute intake)	73.11±7.20	70.29±7.60	-2.82±1.05	-4.75	0.001 †
		placebo	73.45±6.72	73.16±6.41	-0.29±0.78		
Lactate &	Control or Placebo	Caffeine (acute intake)	12.17±1.51	13.18±1.35	-1.02±0.86	-3.14	0.001 †
		placebo	11.58±0.51	11.45±0.43	-0.13±0.23		

* The numbers are expressed as mean ± standard deviation; # Significance at the level of P<0.05 for the differences between groups; $ by second; & by mmol/L; † accepted significance level: P<0.05.

TABLE5. Comparison of the first and second post-test experimental subgroups in 400m sprint and serum lactate levels

Variables	Groups	Subgroups	Stages		First and Second post Difference*	t value	P value #
			First post-test*	Second Post-test*			
400m sprint $	Experimental	Caffeine (continuous intake)	70.27±8.19	70.93±8.9	0.65±0.63	6.46	0.001†
		placebo	69.87±8.67	73.22±8.1	3.34±0.73		
Lactate &	Experimental	Caffeine (continuous intake)	14.04±1.41	13.98±1.77	0.06±0.53	-2.56	0.03†
		placebo	12.52±1.4	11.88±1.45	0.63±0.13		

* The numbers are expressed as mean ± standard deviation; # Significance at the level of P<0.05 for the differences between groups; $ by second; & by mmol/L; † accepted significance level: P<0.05.

IV. Discussion

The results of the body composition in the present study showed that the difference in mean body weight in the subjects of the caffeine group was significantly higher than that of the placebo group, but other indicators of body composition, such as muscle mass, free-fat mass and total body fluid were not significantly affected. Significant increase in the mean body weight of the caffeine group compared to placebo group may be due to an increase in lean mass and especially increased muscle mass as well as an increase in total body fluid (however, these indicators alone did not change significantly). Astrup *et al*. examined the effect of caffeine and ephedrine (200 mg and 20 mg, respectively), on energy expenditure and body composition in 40 obese women. It was not observed any significant difference in total weight after eight weeks in both placebo and caffeine along with ephedrine groups; however, the subjects of caffeine and ephedrine group lost 2.8 kg of their free fat mass. In this study, the amount of fat in the experimental group reduced more compared to the placebo group, but was not significant [15]. It seems that if the duration of the study was greater than 4 weeks, this decreased fat mass in the experimental group became significant. Given that the number of studies on the effect of caffeine on body compositions is very small, more research is needed to comment on this.

In our study, there was no significant difference in any of the performance indicators of 30-second Wingate test. The previous studies on the performance indicators of the Wingate test have often examined the acute consumption of caffeine. Davis and Green (2009) showed that caffeine has little effect on the performance of Wingate anaerobic test [6]. Williams *et al*. (2008) investigated the effect of caffeine and ephedrine on the peak power and muscle strength in trained athletes and the 30-second Wingate test was performed in order to determine the peak power, mean power and fatigue index. There was no significant difference between muscle strength, muscular endurance and peak power before and after the consumption of caffeine and ephedrine [16]. Woolf *et al*. (2008) also examined the anaerobic performance of subjects during a Wingate test. Their results showed that higher peak power was obtained during Wingate test after caffeine intake, but it was not reported no significant difference in the mean power, the minimum power and power loss values between caffeine and placebo groups [12]. In a study conducted by Greer *et al*. (2006), 18 male students participating in recreational activities performed 30-second Wingate test after taking placebo or caffeine. They declared that caffeine did not affect power efficiency in 30 seconds of high intensity cycling [17]. These results are consistent with ours. It should be noted that caffeine consumption on the performance of Wingate test had positive effect in some studies but it was not significant. In this study, we also observed a positive effect of caffeine on peak power, mean power, minimum power, and percentage of power loss which was not significant. Our findings demonstrated that four-week anaerobic exercise improved 400-m run performance in both caffeine and placebo groups, significantly. Plus, it was observed a significant difference between groups in 400-m run record. Since all subjects in the pre-test stage were nearly homogeneous, it seems that the decrease of 400-m run record in the placebo group was probably because of anaerobic exercise, and a further decrease in the record of 400-m run in the caffeine group was due to the effect of caffeine which enhanced positive effect of anaerobic training. Caffeine stimulates sarcoplasmic networks and releases more calcium. Calcium ions play a major role in the process of muscle contraction. It binds to the troponin molecule and activates actin, and eventually muscle contraction occurs. The higher the calcium ions release, the longer the contraction will occur [5]. Thus, it is expected that anyone consuming caffeine, can exercise more quickly and longer.

The findings of the current study showed that either continuous or acute consumption of caffeine has a significant impact on the performance of 400-m run and serum lactate concentration. Since the studies investigating the effect of caffeine on the performance of 400-m run are very few; this research were compared to those estimating the effect of caffeine on anaerobic tests whose performance time was similar to 400-m run time. Anslem *et al*. (1992) reported that the consumption of caffeine (250 mg) increased maximum anaerobic power and blood lactate levels, and improved the maximum strength in sprint runners; however, did not affect the Wingate test results. It seems that caffeine has an energetic effect in activities lasting less than 60 seconds [9]. Wiles *et al.* (2006) measured the performance of eight trained cyclists in a 1-kilometer cycling test on an ergometric bike and showed that consuming 5 mg of caffeine resulted in a 1.3% improvement in the performance time [18]. Crowe *et al*. (2006) investigated reaction-time tests and a 60-second cycling effort, 90 minutes after taking 6 mg caffeine or placebo and suggested that caffeine increased the blood lactate concentration compared to the placebo and control group, significantly; more, the peak power has been reached sooner in caffeine group than placebo and control group during 60 seconds cycling effort. However, peak power, work efficiency, rating of perceived exertion and maximum heart rate did not change significantly [19]. Recently, Davis and Green (2009), in a study on trained subjects, conducted special tests as intermittent sports activities. The results showed that the anaerobic function of the subjects in the caffeine group was significantly improved. According to the results of this study, caffeine consumption appears to be energetic for activities lasting from 60-180 seconds [6]. According to the results of Collomp *et al*, caffeine elevated the speed of elite swimmers in a 100-m swimming, but did not affect the amateur swimmers speed [20, 21]. With regard to the research findings, caffeine seems to have a positive effect on anaerobic activity which lasts from 60 seconds to 90 seconds. The results of this study were consistent with above-mentioned studies. In our study, there was no significant difference between the effect of continuous and acute consumption of caffeine on 400-m run performance as well as serum lactate level. We observed useful results in both acute and continuous caffeine consumption. To justify this, we can consider the benefits related to caffeine ingestion including elevated mean power output, stimulation of motor activity and increase in alertness and ability to concentrate as well as reduced sensation of pain and exertion, delayed feeling of fatigue and increased fatty acid oxidation. Plus, it was reported that the inhibition of adenosine receptor, especially in the central nervous system, is probably a mediator of caffeine's ergogenic properties. Caffeine is able to counteract many of the inhibitory effect of adenosine on neuroexitability, neurotransmitter release, and arousal by binding adenosine receptors [23].

More, in our study, cessation in caffeine use resulted in loss of performance in 400-m run and decreased blood lactate level. It should be mentioned that caffeine reduces the rate of perceived exertion and labor pressure during exercise. This phenomenon has beneficial effects on maximum neural firing rate and the transmission of neural impulses to the motor unit which allow for more sustained and stronger muscle contractions [5]. Caffeine is also very similar to adenosine molecules and therefore, it can be attached to the adenosine receptors, and inhibits the messages for resting phase [5, 22]. Caffeine also stimulates sarcoplasmic network and higher calcium is released. Then, the prolonged contractions are occurred due to high concentration of calcium [13]. In the end, the results of this study showed that consumption of caffeine with anaerobic training, compared with the same exercise but without caffeine consumption had a significant effect on anaerobic function at 400-m run and serum lactate levels which confirmed the useful effect of caffeine on anaerobic performance.

V. CONCLUSION

Anaerobic training for 4 weeks with and without caffeine consumption decreased the time of 400m-run and elevated serum lactate levels (higher differences were observed in caffeine group); whereas, had no significant effect on Wingate test results and body composition values. Acute consumption of caffeine in placebo group also decreased the time of 400m-run and elevated serum lactate levels. Totally, acute and continuous consumption of caffeine along with anaerobic exercise improved anaerobic performance; while increased serum lactate levels in active men.

VI. ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted in accordance with the ethical guidelines of the Kharazmi University, Tehran, Iran.

VII. HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

VIII. CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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