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The acute effect of caffeine supplementation on strength, repetition sustainability and work volume of novice bodybuilders

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Abstract. Ergogenic effects of caffeine on anaerobic maximal and submaximal peak performance, especially in resistance exercise is not clear. According to this, the purpose of this study was to investigate the acute effect of moderate amounts of caffeine on maximal strength, repetition sustainability and work volume in the upper and lower body of novice body builders. In a randomized double blind study, 15 male body builders' athletes (age of 21.16±3.9 years, height of 174.42±6.12 cm and weight of 73.25±6.71 kg) were examined. Exercise protocol was to test one repetition maximum (1RM) in the bench press and leg press and repetition sustainability of bench press and leg press with 80% 1RM in 5 sets. These tests were performed, one hour after ingesting caffeine (6 mg/kg) and placebo, in two separate sessions as similar. Muscle strength, sustainability of repetitions and volume of work (load × the number of repetitions) of upper and lower body were measured. To examine the differences between the effects of caffeine and placebo, t-test was used. The results showed that caffeine causes a significant increase in the strength of the upper and lower body ($P<0.05$). The repetition sustainability of upper and lower body in the first, second and third sets did not change significantly, but decreased significantly in the fourth and fifth sets. In addition, volume of work at the first to fifth set with consumption of caffeine in the body was significantly more than placebo ($P<0.05$). However, in the first and second set of lower body exercise was not observed significantly difference and meaningful difference was only seen in the third to fifth set between caffeine and placebo conditions ($P<0.05$). It seems that acute consumption of caffeine supplementation with ergogenic effect on maximal strength, sustainability of repetitions and the training volume in resistance exercise improve performance and possibly stimulate muscle for its development.

Keywords. Caffeine, resistance exercise, maximum strength, repetition sustainability, work volume.

Introduction

The developing of sport- science research and new findings in sports, make amazing leaps records and the results of sports activities (Jeukendrup & Gleeson, 2009). Athletes use resistance training to achieve the highest level of performance (Saberi et al., 2008). Among these, body builders because of their field also use resistance training for increasing strength, endurance and muscular power and in this way, they use supplements and Ergogenic auxiliary materials for achieving superiority of physical, psychological and athletic success (Haghighi et al., 2012).

A variety of dietary supplements offered for Reinforcing physiological responses to enhance athletic performance and increasing adaptation of the training that includes a various of combination and substances such as vitamins, minerals, protein and carbohydrates supplements, phosphate, sodium bicarbonate, Sparta, alcohol and caffeine. In recent years one of the supplements that have attracted the attention of many athletes and coaches, is caffeine (Mcardle et al.,2005, Wong et al.,2008, Huffman et al., 2008).

Coffee is the most common form of caffeine that forms almost 54 percent of the caffeine consumption in the world. Tea 43 percent and Other substances containing caffeine (such as chocolate, sports beverages, drugs, etc.) make only 3 percent of the caffeine (Gilbert., 1984). These medicines use in various forms by people and regularly by athletes in activities for taking advantage of ergogenic properties (Wilmore & Costill., 2005). The prevalence of caffeine as ergogenic material has increased greatly due to lift the ban the combination of caffeine by the World Anti-Doping Committee (WADA) in strength and endurance athletes during the past three decades, especially after 2004.

Caffeine with a degree milder is similar to amphetamines and it is one of the weak ergogenic supplementation that uses equal amounts by aerobic and anaerobic athletes (Wilmore & Costill., 2005). Caffeine (1,3,7- three methyl xanthine) is a member of methyl xanthine drugs and its one of the most commonly used drugs in the world (Teery et al., 1996). It absorbed quickly through intestine and metabolized in the liver then turns three species of dimethyl (Paraxanthine, theophylline, theobromine) that, they are maintained longer period than the caffeine in the blood and then generated their corresponding signals (Wilmore & Costill., 2005, Beck et al., 2006). Xanthine, such as caffeine, inhibits the phosphodiesterase which plays an

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important role in the breakdown of cyclic adenosine 3 & 5- (cAMP) (Teery et al., 1996). By inhibiting phosphodiesterase, cAMP increases, thus the process of lipolysis and glycogen lysis are stimulating (Truitt et al., 1971), in addition, xanthine secreted and increases the releasing of catecholamines and so the permeability of calcium ions is affected in muscle tissue. Both of these changing (increased cAMP and calcium ion permeability) stimulate muscle contraction (MacCornak., 1977) and because using of fat as an energy source, cause saving glycogen consumption and delaying fatigue. Theobromine of caffeine metabolize is, relaxing blood vessels and increasing urine volume and theophylline bronchial smooth muscle relaxant (Russell., 2008).

Current consumption of caffeine often associated with high concentrations (4 to 9 mg per kg of body weight) and based on effectively and efficiently doses, but evidence supporting this subject is little and consumption habits and individual differences of this material is the cause of contradictory results in this regard (Schneiker et al., 2006). Caffeine is excreted in the urine and its peak concentration in urine is 1 to 3 hours after consumption (Woolf et al., 2009). National Olympic Committee has restricted using of caffeine, so that the amount of caffeine in the urine of athletes must be 12 micrograms per ml (Vandermerwe & Muller., 1996).

Researchers believe that consumption of caffeine increased free fatty acids and reduce glycolysis and lactate blood and by delaying the onset of fatigue increase athlete endurance in heavy and exhausting physical activity (Peker et al., 2005).

Research related ergogenic effects of caffeine often focused on endurance activities. So that the effects of caffeine on aerobic training such as skiing, cycling, rowing, running and swimming have been shown, While the potential ergogenic effects of caffeine on strenuous and short-term heavy activities, which may improve neuromuscular transmission is not clear (Wiliams., 1976). Due to the nature of strenuous and short-term activities, there are three main sites on the human body that caffeine influence effectively on them. The three sites are: central nervous system, neuromuscular transmission and muscle contraction process (Wiliams., 1976).

However, the results of the caffeine effects on intense and anaerobic muscle strength performance and resistance training volume are considered less and its results have been different.

Anselme and colleagues demonstrated that consumption of 250 mg caffeine increase anaerobic maximal performance by up to 7% in load-test speed (Saberi et al., 2008). Nevertheless, other studies have indicated that consumption of 250 mg caffeine had no effect on anaerobic maximal performance (Collomp et al., 1990) and also consumption of 5 mg caffeine had no effect on anaerobic supra-maximal performance (Collomp et al., 1991) on Kick bikes test. Greer and colleagues reported that the amount of caffeine supplementation 6 mg/kg reduce peak power and average power in the final stages of duplicate Wingate test (Greer & Graham., 1998).

Some studies have shown that caffeine improves short-term and power performance (Anselme et al., 1992, Beck et al., 2006), but some studies reported that this matter does not effect on the speed and power (Hendrix et al., 2010, Beck et al., 2006). In this context, Goldestein and colleagues (2010) examined the effects of caffeine (6mg / kg) one hour before training on endurance and strength upper body muscle in women with at least 6 months Precedent of resistance training and observed significant increase 1RM in the bench press (Goldestein et al., 2010). Green and colleagues (2007) showed that consumption of caffeine (mg / kg 6) one hour before training significantly increased leg press repetitions number, but it had no effect on bench press number repetitions (Green et al., 2007). Jacobs and colleagues (2003) showed that consumption of caffeine (4mg/kg) hadn't a significant effect on endurance and resistance muscular training in men (Jacobs et al., 2003). Astorino and colleagues (2008) also observed no significant effect (6mg/kg) on maximal strength and muscular endurance in trained males (Wilmore & Costill., 2005). Beck and colleagues (2006) reported that caffeine (4/2mg/kg) compared with placebo increases, maximal strength (Beck et al., 2006). In another study, they investigated the effects of caffeine (mg / kg 4/2) on maximal strength and exhaustion time on the treadmill and found no significant effect (Beck et al., 2008). An overall a review of previous studies, the effect of caffeine supplement on power-strength performance reports contradictory so that some studies have shown positive effect and some of them had no significant effect on performance.

However, Resistance training, especially strength development movements and muscle mass as a significant part of anaerobic activity is particularly important for bodybuilders and because of their activities nature, they be more willing to use supplement especially ergogenic supplement to impose more pressure on the muscles and neuromuscular stimulation for greater muscle size and strength. On the other hand, supplements should have the least side effects to the audience, including youth participants in resistance exercises not only the result that are not put at risk the health and risks. so, research on the effects of moderate doses of caffeine might be able to answer some ambiguities about ergogenic effects of caffeine on anaerobic performance especially popular field(sport) "bodybuilding". If the effect of ergogenic is proven, we can suggest caffeine to these athletes for using it before training or competition without any worries. Therefore, the present study aimed to investigate the acute effect of moderate amount of consumption of caffeine 6 mg per kg of body weight on maximal strength, repetition sustainability and training volume in the upper and lower body of novice body builders.

Methods

Subjects

Fifteen males' healthy novice body builder's athletes who had resistance training between 6 months to a year Participated voluntary in this study. Subject's characteristics are presented in table 1.

These individuals based on health questionnaires that were completed a week before the test, non-smokers and also lacks any disease affecting results of the study.

Table 1. Subjects characteristics.

Variables	Mean ± SD
Age (year)	21.16 ± 3.9
Height (cm)	174.42 ± 6.12
Weight (kg)	73.25 ± 6.71
BMI (kg/m^2)	23.86 ± 2.64

Procedure

After obtaining consent form, subjects in order to accustom, went to the gym one week before the test. 24 hours before the test, subjects were asked to avoid performing strenuous activity and eating food containing caffeine. On the day of the test, the subjects after 12 hours of fasting, randomized and double blind method, consumed caffeine (gelatin capsules containing 6mg/kg) and placebo (maltodextrin) with 200 ml of water. For reaching Plateau concentrations of caffeine in the blood, an hour before the test material was consumed by the subjects. Subjects performed special warm-up activities for 15 minutes. Then, they did one repetition maximum test (1RM) in bench press (as especial upper body exercise) and leg press (as original lower body exercise) with 3-minute rest intervals in the range of 3 to 5 attempts. After 5 minutes of rest, subjects carried out bench press and leg press 5 times with 80% of one repetition maximum with maximum possible repeat until exhaustion with 3 minutes' rest between sets. The test was repeated twice separated an interval of one week, both tests was done after 12 hours of fasting in the morning.

Statistical analysis

In order to describe the data, descriptive statistics were used to calculate the mean and standard deviation and also, to examine the data paired t- test, ANOVA with repeated measures and Bonferroni post hoc tests were used. Data analysis was performed by using SPSS version 22 and at least a significance level of $p<0.05$ was considered.

Results

Muscle Strength: Average muscle strength in the bench press and leg press in caffeine and placebo conditions are presented in Table 2. According to the t-test results, bench press and leg press muscle strength significantly increased in caffeine condition compared to placebo ($p<0.05$).

Table 2. Upper and lower body muscle strength (M±SD).

Exercises	Caffeine	Placebo
Bench Press (kg)	59.72 ± 7.28*	56.30 ± 6.49
Leg Press (kg)	194.09 ± 38.15*	187.46 ± 42.39

* Statistically significant compared to placebo at $p<0.05$

Repetition sustainability: The average numbers of bench press and leg press repetitions in caffeine and placebo conditions in five sets are presented in Table 3. According to the t-test results, the sustainability of bench press and leg press repetition in the first, second and third set in caffeine and placebo conditions were not significantly different ($P<0.05$). But the number of bench press and leg press repetitions in the fourth and fifth sets was significantly higher in caffeine compared to placebo conditions ($p<0.05$).

Table 3. Repetition sustainability from the first to the fifth (mean ± SD).

Set	Group	Bench Press (rep)	Leg Press (rep)
First	Placebo	10.35 ± 0.4	10.44 ± 0.7
	Caffeine	10.57 ± 0.6	10.55 ± 0.5
Second	Placebo	10.28 ± 0.5	10.36 ± 0.6
	Caffeine	10.41 ± 0.7	10.48 ± 0.9
Third	Placebo	9.20 ± 0.6	9.25 ± 1.02
	Caffeine	9.12 ± 0.9	9.56 ± 1.3
Forth	Placebo	7.19 ± 1.3	7.93 ± 2.1
	Caffeine	8.77 ± 1.6*	8.79 ± 2.8*
Fifth	Placebo	6.22 ± 1.5	7.10 ± 2.6
	Caffeine	7.4 ± 1.7*	8.55 ± 2.3*

* Statistically significant compared to placebo at $p<0.05$.

Table 4. Work volume from the first to the fifth (mean ± SD).

Set	Group	Bench Press (rep)	Leg Press (rep)
First	Placebo	572.44 ± 62.13	1992.51 ± 435.27
	Caffeine	*597.28 ± 61.77	1931.51 ± 429.56
Second	Placebo	569.29 ± 59.46	1914.63 ± 422.40
	Caffeine	*591.62 ± 60.25	1919.69 ± 440.18
Third	Placebo	554.19 ± 60.08	1706.47 ± 440.11
	Caffeine	*573.11 ± 62.38	*1723.25 ± 439±77
Forth	Placebo	517.30 ± 63.25	1552.29 ± 412.74
	Caffeine	*534.75 ± 60.09	*1569.51 ± 398.14
Fifth	Placebo	405.64 ± 57.73	1147.22 ± 452.27
	Caffeine	*421.16 ± 61.78	*1158.66 ± 409.20

* Statistically significant compared to placebo at $p<0.05$.

Work volume: The average of work volume in bench press and leg press exercise is presented in Table 4. The results of paired t-test showed, work volume of bench press in the first to fifth sets in caffeine compared with placebo conditions was significantly higher ($p<0.05$). But work volume of leg press in the first and second sets, in caffeine compared to placebo conditions did not change significantly, but work volume in caffeine conditions in third to fifth sets was significantly higher ($p<0.05$).

Discussion

The results showed that (6mg /kg) consumption of caffeine one hour before activity enhance the power of upper and lower body special movement as well as improving the ability of keeping repetition in the fourth and fifth sets of upper and lower body and increasing the volume of training in the upper body and also in the third to fifth sets of lower body at these movements in male bodybuilders.

Duncan et al. (2009) examined the Effect of consumption of Caffeine (5mg/kg) one hour before training in repetition to exhausting at 60% of one repetition maximum in the bench press at 13 trained men. The results showed that caffeine compared with placebo leads to more repetitions before to exhausting (Duncan et al., 2009). In a study, Hudson et al. (2008) examined the effect of moderate dose of caffeine (6mg/kg) on 12 repetition maximum leg extensions and biceps tests at 15 men with a history of 8 weeks of resistance training.

The results showed that a significant increase in the total occurrence of foot and there has been a significant increase in the first set of feet and hands repetitions, the results are consistent with the results of this study (Hudson et al., 2008). This result can be justified by saying that First, the subjects of this study were familiar with resistance training particularly with bench press training, secondly ergogenic effects of caffeine per day,2.5-7mg per kg of body weight is ideal for endurance, short and intense training.

In a study Astorino et al. (2011) examined the effect of caffeine (6mg/kg) one hour before training in repetition to exhausting by 70 to 80% of one repetition maximum of bench, shoulder and leg press and rowing at 14 trained males. Their results showed that caffeine compared with placebo has significant effect impact leg press, while it doesn't have effect on the upper body (Astorino et al., 2011). This result is inconsistent with the findings. Researchers reported the study subjects were consumer of caffeine, when they were asked to refrain consuming of caffeine, the side effects of kicking consumption include headaches and lethargy resulting underperformance, While the study subjects were not consumed caffeine permanently.

Goldstein et al. (2010) examined the effect of Caffeine (6mg/kg) on the performance of 15 women with a history of six months' resistance training. Examine Indicators were repetitions to exhausting at 60% of one repetition maximum in the bench press (Goldestein et al., 2010). The results showed a significant increase in one repetition maximum in bench press, while repetitions to exhausting was not affected by caffeine. This result with current study results is antithetic. The researchers noted that this result is, particularly, for untrained women and should not be used to compare and generalize it to men athletes. Of course, It is expressed cleansing caffeine from the body during training can be done more quickly in women than men which may explain the differences results.

Beck et al. (2006) studied the short-term effects of caffeine (4.2mg/kg) one hour before strength and endurance muscles tests in 37 trained males. Indicators included 1RM bench press and leg extension for the evaluation of strength, repetition to exhausting at 80% of 1RM in the bench press and leg extension were to assess muscular endurance (Beck et al., 2006). The results showed that caffeine significantly increased 1RM bench press, but compared with the placebo group, has no significant effect on other indicators. The results of this study are inconsistent with result of current study in strength and endurance of upper body and also strength of lower body. The researchers noted that caffeine might have different effects on the upper and lower extremities and also increasing cause of strength in upper body without an increase in lower body strength is for that. But in this study, caffeine has same effect on upper body and lower body strength.

Green et al. (2007) examined the effect of consumption of Caffeine (6mg/kg) on the 10 repetition

maximum bench press and leg press in the 17 active male with a history of two months' resistance training. The obtained result was not significant in the bench press, but in the final set of leg press, a significant increase was observed in number of repetitions with caffeine supplementation (Green et al., 2007). The results of the study are inconsistent with result of this study. Researchers argued that Ergogenic effects of caffeine on muscle may be limited, while the study also found no such restriction. Another study, Wolf et al. (2009) examined effect of Caffeine (5mg/kg) in repetitions to exhausting on the bench press in the 17-male footballer. Results showed no significant change in consumption of caffeine (Woolf et al., 2009). The result is inconsistent with this research results. Probably the type of subjects due to difference results, the reason for this difference can be the type of Participants who were body builders that they were familiar with resistance training.

In examining the difference effects of caffeine on the upper and lower extremities in this study it was observed that the maximum power of the upper and lower extremities, repetition sustainability and volume of training is a significant increase in both upper and lower extremities with caffeine.

These results are in favor of more effects of caffeine on lower and upper body strength training and upper and lower extremities endurance training. Beck el al. (2006) results focused on more impact of caffeine in the upper body. While Davis & Green (2009) reported that caffeine has little effect on upper body training. Therefore, none of these theories cannot be accepted or rejected; Because the difference in the type of subjects, the intensity and volume of training, supplementation and the presence or absence of control group has been effective on results and causes differences them. However, to clarify the matter and provide definitive feedback, more research is needed in this area. About the effects of caffeine on athletic performance three mechanisms has been expressed; CAMP increase and the its result is increasing in lipolysis, the mobilization of intracellular calcium sarcoplasmic reticulum and competitive antagonism of adenosine receptors in the central nervous system (Paasternak et al., 2006; Russell et al., 2008).

Caffeine increases fatty acid oxidation and stores muscle glycogen that this action especially during endurance training can increase performance but is said that in short and intense activities, such as activities that performed in this study is not limited by the available carbohydrate (Wong et al., 2008, Woolf et al., 2009). So, it seems that the effect of caffeine through this mechanism does not play a major role in these activities. Increasing release of calcium from the reticulum sarcoplasmic is also one of proposed mechanisms for ergogenic effects of caffeine on athletic performance. Of course, these effects occur at greater levels than physiological values that in this amounts detection toxic effects of caffeine are not unexpected Thus, it seems unlikely that this mechanism due to the used amounts in this study, have important role in improving performance (Davis & Green., 2008; Paasternak et al., 2006). However, suggested that the main and potential affecting caffeine mechanism, is caffeine acts as a competitive antagonism of adenosine in short-term and intense activities (Hudson et al., 2008). Caffeine by connecting to adenosine receptors in the CNS causes more motor units and also increases neuronal discharge that both of them increase voluntary contraction and force production (Beck et al., 2006). It is worth noting for effecting of caffeine through this mechanism is needed greater amounts than physiological amounts. For example, drinking two cups of coffee can cause these effects. Also, caffeine can through changing the perception training load, of a person's reaction time or mental state (Increasing alertness and peppy) enhance performance (Davis & Green, 2008; Paasternak et al., 2006). Overall, it seems that a combination of factors listed Can explain ergogenic effects of caffeine on athletic performance in intense and short-term activities, such as activities used in this study, Although, the role of caffeine as competitive antagonism of adenosine receptors in the CNS is more highlighted than other factors that is very important for bodybuilders due to the nature of their activities.

In summary, according to effective moderate consumption of caffeine on strength performance and muscle endurance in bodybuilders and minimal side effects of this supplement, it can be prescribed along with taking into considerations for bodybuilders. But, to ensure these findings further studies are necessary.

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