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RESEARCH ARTICLE

ENHANCEMENT OF PHYSICAL PERFORMANCE IN MEDICAL STUDENTS OF RURAL INDIA-THE ROLE OF CAFFEINE

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ABSTRACT

Caffeine (1, 3, 7-Trimethylxanthine) is a habitual substance present in a wide variety of beverages and in choclate based foods. It is also used as adjuvants in some drugs. There have been numerous reports that caffeine is an ergogenic aid, ingestion of the drug has been shown to increase endurance, particularly in prolonged exercise lasting 30 -120 minutes. The present study was undertaken to study the effects of caffeine in coffee on endurance exercise in young healthy adult males. Twenty young males participated in this single blind study. Participants underwent two testing sessions seperated by 7days. The testing sessions consisted of handgrip strength test, Rate of percieved exertion scale (RPE) test and an incremental test to exhaustion on treadmill. Paired "t" test revealed significant difference in handgrip strength test, RPE scale, exhaustion time, maximal oxyzen uptake(VO2 max) and heart rate($p>0.05$) before and after caffeine exhaustion. The present study indicates that caffeine consumed 60 minutes before exercise can enhance exercise performance by increasing the total time to fatigue.

INTRODUCTION

Caffeine is probably the most frequently ingested pharmacologically active substance in the world. It is found in common beverages (coffee, tea, soft drinks), in products containing cocoa, or chocolate, and in medications. Caffeine an alkaloid of the methylxanthine family is a naturally occurring substance found in the leaves, seeds or fruits of over 63 plant species worldwide (Wanyika *et al*., 2010). In its pure state, it is an intensely bitter powder. Its chemical formula is C8H10N402, and its systematic name is 1,3,5-trimethylxanthine (Aurnaud, 1987). Caffeine is a pharmacologically active substance and depending on the dose , can be a mild central nervous system stimulant. Caffeine does not accumulate in the body over the course of time and is normally excreted withen several hours of consumption (Barone, 1996). Other naturally occurring methylxanthines include theobromine and theophyline. Methylation of theobromine forms caffeine (Wanyika *et al*., 2010). Caffeine is used as an ergogenic aid because multiple well- controlled experiments have found that moderate doses of caffeine (3-6 mg/kg) can improve performance in atheletes (Graham, 2001; Flinn *et al*., 1990). Its use by atheletes is actually favoured since it has been removed on the 1st January 2004 by the World Anti- Doping Agency(WADA) from its list of banned substances (World Anti-Doping Agen, 2008).

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The mechanism for the caffeine -improved performance is not clear but several possibilities have been proposed such as the antagonism of adenosine receptors (Davis *et al*., 2003), the attentuation of effort perception or reduction of muscle pain (Doherty, 2004; O'connor *et al*., 2004) and the increase in catecholamine release (Greer *et al*., 2000; Graham *et al*., 2000; Jackman *et al*., 1996**;** Van Soeren, 1998). There have been numerous reports that caffeine is an ergogenic aid, ingestion of the drug have been shown to increase endurance, particularly in prolonged exercise lasting 30- 20 minutes (Reilly *et al*., 1997; Graham *et al*., 1994; Graham, 1991). Coffee is certainly the most common mode of caffeine ingestion , and it also provides caffeine in a more concentrated form than do other foodstuffs (Garattini, 1993; 17,18). Caffeine and coffee ingestion have been shown to result in similar hemodynamic responses in resting participants (Casiglia, 1991). The aim of the present study was to study the effects of caffeine in coffee on physical performance, exercise intensity and muscle strength in young healthy adults.

MATERIALS AND METHODS

Participants in this case control study were 20 young healthy males aged between 17-24 years studying in 1st MBBS. They were non atheletes, non regular users of caffeine, non smokers and apparently healthy. Males with history of smoking ,asthma, hypertension, congenital heart disease, allergy, diabetes were excluded from the study.

The study was carried out in the Exercise Physiology Unit of department of Physiology, Jawaharlal Nehru Medical College, Sawangi (Meghe), Wardha, Maharashtra in the month of January. The participants were informed both verbally and in writing about the nature of the experiments and the protocol was approved by the Ethics Committee of the Institution.

Experimental protocol

Each participant reported to the Exercise unit on three occasions. On the first occasion they performed an incremental $V0_2$ max test on a treadmill (RMS Polyrite, Chandigarh). Subsequently, on a separate day, the participants performed a practice trial consisting of 20-30 min running on the treadmill at a workload predicted to require 80% of the V02 max. On the same day the basic parameters of participants such as age, weight, height, body mass index and heart rate maximum (HRmax) were recorded as given in Table (Wanyika *et al*., 2010). Maximal voluntary isometric arm flexion strength was measured by handgrip dynamometer and the best result of three readings was recorded. Rate of perceived exertion by Borg's 10 point scale (Borg, 1982) was recorded at 3 min intervals throughout the exercise and exhaustion time was recorded on treadmill .Time to exhaustion was determined on a treadmill (the time that the subject could no longer maintain exercise intensity or reached volitional exhaustion).

The participants were instructed to refrain from consuming caffeine for 48 h prior to each testing session. A list of food and beverages containing caffeine was provided to each participant in order to inform them of what products, they should avoid. Participants were also asked to keep a diary documenting their diet 24 h prior to the first testing session and to replicate this diet before next visit. The participants arrived at the laboratory on all the occasions at the same time (7:30 or 8:15 AM). When the participants reported to the Exercise unit after seven days they were given filter coffee with desired amount of caffeine needed (5mg/kg) dissolved in 200ml warm water and added artificial sweetner (sugar free gold i.e aspartane). The dose of 5.0 $mg.kg^1$ was selected based on previous studies that used this dose and reported performance benefits (Graham *et al*., 1998). Participants relaxed for 60 min, followed by an active warm up they were instructed to run on the treadmill at a speed and slope calculated to require 80% of VO_2 max until voluntary exhaustion. Endurance i.e exhaustion time, rate of perceived exertion, handgrip strength test and HRmax was recorded as done previously.

Table 1. Descriptive statistics for age, height, weight and BMI

Parameters	Mean	SD	Minimum	Maximum
Age(yrs)	18.65	0.74	18.00	20.00
Height(cm)	70.15	3.09	65.00	75.00
Weight(kg)	173.95	4.58	166.00	182.00
BMI(kg/m2)	23.25	0.67	21.80	24.20

All values are in mean-SD

Estimation of VO2 max

V02 max was calculated by following equation,

VO2 max = resting component (1MET {3.5 ml 02/kg/min} + Horizontal component {(speed(m/min) x oxygen consumption of vertical movement}) (William *et al*., ?).

Statistical Analysis

All results are expressed as means ± SD. Students Paired’t’ test was applied and the level of significance was set at $P < 0.05$.

RESULTS

All results refer to 20 subjects, unless otherwise indicated. Statistical analysis pertains to results obtained in 20 subjects. There was a significant difference in all the parameters before and after caffeine ingestion. All the results are shown in Table 2.

Exhaustion time and VO2 max

Ingestion of caffeine significantly increased the time to exhaustion in all subjects (545.10 sec ± 3.50 SD to 608 ± 42.01 SD) with $p < 0.05$. There was also a significant difference in VO_2 max after caffeine ingestion (35.36 ± 4.01 SD to 40.33 ± 3.70, $p < 0.05$).

Handgrip and RPE scale

There was a significant difference in the isometric muscle strength by handgrip dynamometer and in the rate of perceived exertion before and after caffeine ingestion (86.25±3.50 SD to 88.25 ± 3.11 SD with p<.05 and 4.45 ± 0.51 to 6.85 ± 0.87, p < .05) respectively. There was also a significant difference in the HR max after caffeine ingestion (176.50 ± 6.01 to 179.40 ± 5.95) with $p < 0.05$.

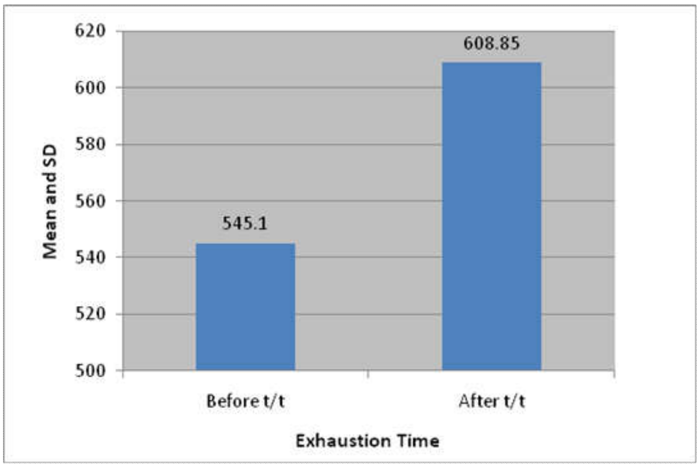
DISCUSSION

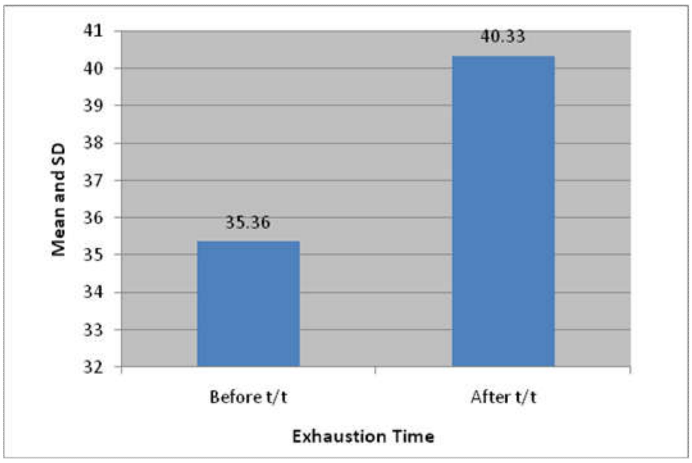
Research on the physiological effects of caffeine as it relates to athletic performance is extensive. Caffeine research in specific areas of interest, such as endurance, strength, team sport, recovery, and hydration is vast and at times, conflicting (Erica, 2010). Therefore the present study was undertaken to study the effects of caffeine in coffee on exhaustion time, VO2 uptake , muscle strength, rate of perceived exertion and hear rate maximum in 20 young healthy adult males studying in first MBBS. Overall, results from this study showed that caffeine in coffee resulted in significant increases in all the parameters examined. Borg (1982) demonstrated that the general perception of physical exertion comes from the integration of different symptoms arising from active muscles, cardiovascular and respiratory systems, joints, perspiration, possible pain, dizziness etc. The Borg CR-10 scale is a category scale with ratio properties consisting of numbers related to verbal expressions, which allows rate comparison between intensities as well as a determination of intensity levels. It has been used for more than two decades (Borg and Kaijser,2006; Neely *et al*., 1992). The use of this scale is relatively simple and cost effective. In our study we used this scale which demonstrated that the rate of perception of physical exertion increased after caffeine ingestion. There are studies that have failed to detect statistically significant changes in the perceptual response to exercise following caffeine ingestion, for example, both Tarnopolsky *et al*. (1989) and Trice *et al*. (1995) found that caffeine ingestion reduced RPE by approximately 16% and 6% in comparison to placebo when six and eight subjects ran and cycled between 70% and 90% VO2max, respectively.

Table 2. Comparison of data before and after ingestion of coffee

	Mean		N		Std. Error Mean	
	Before	After	Before	After	Before	After
Handgrip	86.25±3.50	88.25 ±3.118*	20	20	0.78	0.69
RPE scale	4.45±0.51	6.85 ±3.70*	20	20	0.11	0.19
VO2 max	35.36 ±4.01	40.33±3.70*	20	20	0.89	0.82
HRmax	176.50±6.01	179.40±5.95*	20	20	1.34	1.33
Exhaustion time	545.10 ±40.58	608.85±42.01*	20	20	9.07	9.39

All the values are in mean ± SD,*indicates a significant difference with $p<0.05$.





A meta-analytic study done by M. Doherty and P. M. Smith (2005) quantifies suggestions in the literature that caffeine has a noticeable effect on RPE, which is in support of findings in our study. Caffeine ingestion resulted in augmented exercise performance as indicated by a significantly higher time to exhaustion and maximal O_2 consumption as seen in our study. These results are consistent with those reported by other authors (Doherty and Smith, 2004; Flinn *et al*., 1990; Guillermo J. Olcina *et al*., 2006). Multiple mechanisms have been proposed to explain the effects of caffeine supplementation on sport performance. However, several extensive reviews have stated that the most significant mechanism is that caffeine acts to compete with adenosine at its receptor sites (Fredholm *et al*., 1999; Sokmen *et al*., 2008; Spriet, 2004). Another possible mechanism through which caffeine may improve endurance performance is by increasing the secretion of β-endorphins. Laurent *et al*. (2000) demonstrated that when compared to the placebo group caffeine consumption (6 mg/kg) significantly increased plasma β-endorphin concentrations following two hours of cycling at 65% VO_2 peak and a subsequent bout of high intensity sprint activity. It has been established that plasma endorphin concentrations are enhanced during exercise and their analgesic properties may lead to a decrease in pain perception (Grossman, 1985). Research has also demonstrated that caffeine may result in alterations of neuromuscular function and/or skeletal muscular contraction (Kalmar, 1999; Lopes*et al*., 1983). Kalmar and Cafarelli (Kalmar, 1999) indicated a moderate dose of caffeine (6 mg/kg) significantly enhanced both isometric leg extension strength as well as the time to fatigue during a submaximal isometric leg extension. Whatever caffeine's mechanism of action, one consistent outcome of caffeine ingestion during exercise testing, regardless of mode, intensity, or duration of exercise, is an alteration in participants perceptual response. This alteration has been manifest as either an increase in work output at a given rating of perceived exertion (RPE) or effort sense (Ivy *et al*., 1979; Cole *et al*., 1996; Plaskett, 2001) or, more typically, a reduced RPE at a constant exercise (Costill, 1978; Giles, 1984; Casal, 1985; Macintosh, 1995).

Various methods of caffeine supplementation have been explored and results have provided considerable insight into appropriate form and dosage of the compound. One of the most acknowledged studies, published by Graham *et al*. (1998) demonstrated a range of effects when caffeine (at 4.45 mg/kg) was consumed in varying forms. In their study, aerobically conditioned runners performed five treadmill runs to exhaustion at approximately 85% $V0_2$max after receiving one of the following treatments 60 minutes prior: caffeine capsules plus water, regular coffee, decaffeinated coffee, decaffeinated coffee plus caffeine in capsule form, and placebo. Caffeine in capsule form significantly increased work capacity allowing them to run an additional 2-3 km (Graham *et al*., 1998), as compared to the four other treatments.

As such, McLellan and Bell (McLellan, 2004) examined whether a morning cup of coffee just prior to anhydrous caffeine supplementation would have any negative impact on the compound's ergogenic effect. Subjects were physically active and considered to be moderate-to-high daily consumers of caffeine. The results of their study indicated that caffeine supplementation significantly increased exercise time to exhaustion regardless of whether caffeine in anhydrous form was consumed after a cup of regular or decaffeinated coffee (McLellan, 2004). McNaughton *et al*. (2008) reported the effects of a moderate dose of caffeine (6 mg/kg) on 1-hour time trial performance. This investigation was unique to the research because, while continuous, the protocol also included a number of hill simulations to best represent the maximal work undertaken by a cyclist during daily training. The caffeine condition resulted in the cyclists riding significantly further during the hour-long time trial, as compared to placebo and control. The time trial performance was improved 4-5% by the caffeine treatment over the other two treatments (McNaughton *et al*., 2008). Demura *et al*. (2007) examined the effect of coffee, which contained a moderate dose of caffeine at 6 mg/kg, on submaximal cycling. Subjects consumed either caffeinated or decaffeinated coffee 60 min prior to exercise. The only significant finding was a decreased RPE for the caffeinated coffee as compared to the decaffeinated treatment (Demura *et al*., 2007).

Coffee contains multiple biologically active compounds; however, it is unknown if these compounds are of benefit to human performance (Natella, 2002). However, it is apparent that consuming an anhydrous form of caffeine, as compared to coffee, prior to athletic competition would be more advantageous for enhancing sport performance. Nevertheless, the form of supplementation is not the only factor to consider as appropriate dosage is also a necessary variable. Reviews of the physiological effects of caffeine commonly give an approximate equivalent of various food items such as coffee, tea, colas, etc. The implication would appear to be that ingesting the same amount of caffeine via a food source is as effective as ingesting pure caffeine (Graham *et al*., 1998).

Conclusion

The results of this study support the use of coffee with an adequate dose of caffeine (5mg/kg BW) before exercise can help to improve physical performance in physically active adults. Competing with adenosine to its receptor site , secretion of β 3-endorphins or alterations of neuromuscular function and/or skeletal muscular contraction could be the several possible mechanisms that may account for this improvement . Further research is required to support the same.

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