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Effects of caffeine on near vision of healthy subjects in Benin metropolis

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ABSTRACT: To determine the effect of oral consumption of different concentrations of caffeine on near vision, thirty (30) healthy volunteers consisting of fifteen males and fifteen females were used for the study. The subjects were aged between 19-30 years with a mean age of 24.2±2.9 years. They were all non-habitual consumers of coffee and non-smokers of cigarettes. The subjects were all emmetropes and had no history of any systemic or ocular pathologies. For the purpose of the study, the subjects were divided into 2 groups (A and B) of 15 subjects each, to which 2 different concentrations of caffeine (100mg and 200mg) was administered. The near vision was assessed by measuring the amplitude of accommodation (A of A) and near point of convergence (NPC) of the subjects using the Royal Airforce (RAF) rule. The measurements were taken before, and then, after 30, 60 and 90minutes of oral consumption of 100mg and 200mg concentrations of caffeine solutions respectively. Statistical analysis of the data was carried out using ANOVA and T-test, where it was discovered that the consumption of the two concentrations of caffeine caused a significant change in the mean A of A and NPC ($P<0.05$). Thus the consumption of certain concentration of caffeine has the capacity to adversely affect near vision.

Keyword: Caffeine; Amplitude of accommodation; Near point of convergence.

Introduction

The word caffeine was derived from the Italian term for coffee, i.e. 'cafe'. It is an organic compound which has a stimulating effect on the Central Nervous System (CNS)[1]. It is derived from various natural sources e.g. leaves and beans of the coffee plant, tea, guarana berries, kolanut, and cocoa. Caffeine is contained in various drinks and beverages consumed worldwide, making it the world's most widely consumed psychoactive substance. In its isolated form, caffeine is a white alkaloid with an intensely bitter taste and has been made in tablet and capsule forms. It increases mental alertness and improves on the general coordination of body tissues[2,3]. It is sometimes combined with antihistamines to counteract the drowsy effect of these drugs including the treatment of other conditions like difficulty in breathing in newborn babies. People who are used to the consumption of large amount of caffeine over a long period tend to build up tolerance to it such that, they have to consumme more quantities of caffeine daily to get same effect, etc.[3,4,5].

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Caffeine is metabolized in the liver, completely absorbed by the stomach and small intestine within 30 minutes of ingestion, after which it is distributed throughout all the tissues of the body. It therefore takes less than an hour for caffeine to have full effect on the body system. Caffeine acts on receptors and channels in the cell membrane, as well as intracellular action on calcium and cAMP pathways[5,6]. Like alcohol, nicotine and antidepressants, caffeine readily crosses the blood brain barrier. And once in the brain, its principal mode of action is that of an antagonist of adenosine receptors found in the brain. The caffeine molecule is structurally similar to adenosine, and binds to adenosine receptors on the surface of cells thereby acting as adenosine inhibitor. The reduction in the activity of adenosine results in increased activity of the neurotransmitter, dopamine, which largely accounts for the stimulatory effects of caffeine[2,4]. Thus, acute usage of caffeine would result in increased levels of serotonin, because adenosine is known to constrict the afferent arterioles of the glomerulus. Its inhibition may therefore cause vasodilatation, with an increase in renal blood flow (RBF) and glomerular filtration rate (GFR). This effect, called competitive inhibition, will interrupt the pathway that regulates nerve conduction by suppressing post-synaptic potentials. This will result in increase in the level of epinephrine and nor-epinephrine released via the hypothalamic- pituitary-adrenal axis[3,8,9].

Accommodation is the ability of the eye to change the refractive power of the lens to enable it focus on an object at any given distance. It is a complex combination of sensory, neuromuscular and biophysical phenomena by which the refracting power of the eye changes rapidly to produce distinct image of objects at different viewing distances clearly on to the retina [5,10]. Accommodation reflex involves: pupil contraction, increased lens convexity, and convergence of the eye. The stimulus to accommodation is retinal blur which elicites nervous impulse that is transmitted via efferent pathway to area 17 of the brain. This is innervated by the oculomotor nerve (CN_3) with majority of the fibres being relayed through the ciliary ganglion cells from the midbrain nucleus[11,12]. The ciliary muscles (smooth muscles) regulates the ability of the eye to focus and this is measured in two forms: near point of accommodation (or punctum proximum); and far point of accommodation (or punctum remotum). The distance between the far point and near point is referred to as 'range of accommodation'. The maximum amount of accommodation that the ocular system can produce is called amplitude of accommodation (A of A). It decreases from childhood uptill about the age of 60 years [10,12,13].

Convergence can be defined as the movement of the two eyes towards the midline to maintain a clear and comfortable vision at near. It is stimulated by the presence of retinal blur. The process of convergence is brought about by the action of the medial rectii muscles also innervated by the oculomotor nerve (i.e.CN_3). The measurement of convergence is by the determination of the nearest point at which the eye can maintain a single, clear, binocular vision which is usually termed the 'near point of convergence' (NPC)[11,13]. Convergence can be measured in the clinic by determing the strongest base-out prism that can be used without inducing diplopia (act of seeing double). It can also be determined by the use of RAF rule which will indicate the distance at which the target would appear double or blurred[10,13,14].

Materials and Methods

The study was carried out in the Optometry Clinic of University of Benin, Ugbowo, Benin City in Edo State of Nigeria. The study population was made up of a sample size of 30 healthy subjects between the ages of 19 and 30 years with mean age of 24.2±2.9 years, comprising of 15 males and 15 female with each subject serving as his/her own control. They were randomly selected from seventy volunteers who were students of the University of Beinn.

The subjects who were all emmetropes, had an average body weight of 70kg and had no history of any ocular or systemic pathologies. Neither were they on any form of medication. Their visual acuity assessment was carried out with Snellen's charts; general eye-health was assessed with penlight and direct ophthalmoscope; NPC & A of A and measurement were carried out with the RAF rule. The study began at 8.00am each day before breakfast where the NPC & A of A of each of the subjects was determined. Thereafter, a 100mg weight of Nestle caffeinated coffee was dissolved in 200ml of hot water and was administered on each of the subjects before breakfast. The NPC & A of A were measured again after the administration of the coffee at intervals of 30 minutes, 60minutes and 90 minutes respectively for all the 30 subjects. The mean value for the readings obtained at the three intervals for each subject was recorded by simple conversion to dioptres directly from the RAF rule. The period for the experiment each day was

between 8.00am and 12 noon without breakfast. And it took two days to administer the 100mg concentration on all the subjects. After an interval of two days, the subjects were reassembled for the ingestion of the second concentration of coffee i.e. 200mg in 200ml of hot water. Their NPC & A of A were measured as usual before thee administration of this second concentration of coffee. After the administration of the coffee, the measurement was repeated three times at an interval of 30 minutes for all the 30 subjects and the mean was recorded for each of them.

Results

The result presented in Table 1 show that the mean NPC decreased in value after the ingestion of 100gm weight of coffee solution in both males and females. However, the mean A of A increased in value after the ingestion of coffee. Statistically, there is a significant difference in mean NPC and A of A before and after the in-take of coffee solution at intervals of 30, 60 & 90minutes, in both males and females, using the one way analysis of variance (ANOVA $F=146.893$ $P<0.05$: $F=111.392$, $P<0.05$: $F=192.59$, $P<0.05$). Also the Post Hoc and Duncan Multiple Range test showed that the mean difference in NPC and A of A before and after ingestion of coffee over a period of 30, 60 & 90minutes were not statistically significant. However, the mean difference before and after 30mins were different statistically from mean difference between 60 and 90mins after the ingestion of coffee.

Table 1: Gender distribution of mean NPC & A of A before and after ingestion of 100 gm weight of Coffee

TIME INTERVAL	**MEAN NPC**		**MEAN A of A**	
	Males	**Females**	**Males**	**Females**
Before	8.00±0.00	7.86±0.36	11.46±1.09	11.67±0.617
30 mins	7.80±0.41	7.79±0.43	12.63±1.75	12.40±0.63
60 mins	6.53±0.52	6.93±0.62	14.38±2.29	10.57±0.52
90 mins	6.07±0.41	6.29±0.47	14.81±2.14	14.53±0.52

Table 2 shows that the mean NPC decreased in value after the ingestion of 200gm weight of coffee solution in both males and females wile the mean A of A increased in value after the ingestion of coffee. Statistically, there was a significant difference before and 30mins, 60mins & 90mins after the ingestion in mean NPC and A of A in both males and females using the one way analysis of variance (ANOVA $F=146.893$ $P<0.05$: $F=131.82$, $P<0.05$: $F=221$, $P<0.05$). Also Post Hoc and Duncan Multiple Range test showed that the mean difference in NPC and A of A before and after ingestion of coffee for the period of 30mins, 60mins & 90mins after the ingestion of coffee were not significantly different. However, the mean difference before and after 30mins were different statistically from mean difference between 60 and 90mins after the ingestion of coffee. The result also showed that in both males and females the most significant effect on NPC was after 90mins of ingestion of coffee; while the least significant effect was after 30mins of ingestion of coffee. The effect of coffee on A of A was most significant after 30mins of ingestion.

Table 2: Gender distribution of mean NPC & A of A before & after ingestion of 200 gm weight of Coffee

TIME INTERVAL	MEAN NPC		MEAN A of A	
	Males	Females	Males	Females
Before	8.00±0.00	7.86±0.36	11.44±1.08	11.67±0.62
30 mins	7.07±0.80	7.2±0.70	13.69±1.96	13.27±0.96
60 mins	5.86±0.64	6.214±0.58	15.81±0.83	14.60±0.74
90 mins	5.40±0.51	5.57±0.51	16.50±2.92	16.07±0,96

Discussion

Table 1 showed that the mean NPC and A of A before ingestion of coffee were 7.93±0.25cm and 11.67D ±0.61 respectively while after the ingestion of 100mg of coffee the mean NPC decreased (i.e.better convergence) while that of A of A increased with increasing time. The reason is that with stimulation of the innervations to the medial rectus muscle there is increase in the inward pull of the muscles resulting in the decrease in the NPC value. On the other hand, the reason for the increase in A of A was as a result of greater stimulation of the ciliary innervations brings about increase in the accommodative activity of the ciliary muscles and consequent increase in accommodation[10,14,15]. The mean A of A and NPC before and 30mins, 60mins and 90 mins after ingestion of 100mg of coffee, was statistically significant using one way analysis of variance (ANOVA: $F = 114.79, p < 0.05$) with NPC decreasing systematically by a mean difference of 0.13 cm (7.80±0.41 cm) within 30 mins for the 100 mg group. Also, the difference in mean A of A before and 30mins, 60mins and 90 mins after 100 mg caffeine ingestion was statistically significant (ANOVA: $F = 111.99$, $p<0.05$) increasing systematically within 30mins by 0.9 D (12.57±0.94 D) for the 100 mg group.

Table 2 also showed that the mean NPC decreased from the baseline value of 7.93±0.25cm and 11.67 ±0.61D after the ingestion of 200mg coffee. Also, the mean NPC & A of A before and 30mins, 60mins and 90 mins after ingestion of 200mg of coffee, was statistically significant using one way analysis of variance (ANOVA: $F = 121.88, p < 0.05$) with NPC decreasing systematically by a mean difference of 0.13 cm (7.80±0.41 cm) value and that of A of A increased after ingestion of 200mg of coffee. Also, the mean A of A and NPC before and 30mins, 60mins and 90 mins after ingestion of 200mg of coffee, was statistically significant using one way analysis of variance (ANOVA: $F = 159.97, p < 0.05$) with NPC decreasing systematically by a mean difference of 0.13 cm (7.80±0.41cm) . This implied an improvement in the value of NPC in all the subjects and A of A with ingestion of 200mg of coffee. This was in line with the studies by earlier reseachers.

The reason for this was probably because; caffeine readily crosses the blood-brain barrier and acts primarily on the receptor cells within the brain. This stimulates the activities of excitatory nervous pathways which decreases the activities of inhibitory nerve pathways. Since caffeine has similar structure as adenosine receptors in the brain, it binds to these receptors and thereby inhibiting their activities[16,17,18]. This effect, called competitive inhibition of adenosine receptors, interrupts the pathway that normally serves to regulate nerve conduction by suppressing post-synaptic potentials. The result is an increase in the levels of epinephrine and nor-epinephrine that are released via the hypothalamic- pituitary-adrenal axis. Epinephrine, the natural endocrine response to a perceived threat, stimulates the sympathetic nervous system, leading to an increased heart rate and therefore increased blood pressure[11,13,19,20]. This stimulates the nerves innervating the ciliary muscle and consequently the suspensory ligament which holds the crystalline lens in place causing it to relax and release the tension on the lens. This leads to the increase in the anterior-posterior diameter of the lens and consequently results in increase in accommodation. Convergence is brought about by the stimulation of the oculomotor nerve (CN_3) that innervates the medial

rectus and the inhibition of the 6th cranial nerve that innervates the lateral rectus muscle causing it to be pulled inward. This effect was dose dependent because acute usage increases the level of neurotransmitter secreted in the blood thereby increasing accommodative activities[10,14,21,22].

The NPC also showed a systematic decrease in mean between the two concentrations of caffeine and this difference is statistically significant after 30mins, 60mins, & 90mins, using the paired t-test ($t=3.50$, $p<0.05$: $t=6.68$, $p<0.05$: $t=7.17$, $p<0.05$. On the contrary, the A of A showed a systematic increase in mean difference which is also statistically significant after 30mins, 60mins, & 90mins of ingestion of coffee using the paired t-test ($t=-6.12$, $p<0.05$: $t=-5.28$, $p<0.05$:$t= 12.42$, $p<0.05$).

Thus there is a decrease in NPC break value with increased dosage of coffee; and there is an increase in A of A value with increased dosage of coffee thereby improving both NPC and A of A. The result also showed that the mean decrease in NPC and mean increase in A of A is slighty higher in males than females. This was because of the physiological differences in males and females, which is in agreement with earlier experimental studies[22,24,25].

This increase in A of A and the improvement in convergence would prevent symptoms of asthenopia usually associated with near work in early presbyopes. On the other hand, a young adult whose A of A is normal or in excess may experience further increase in value of A of A after ingestion of caffeine. This may lead to convergence excess or divergence insufficiency with associated symptoms of headaches[10,11,13,14].

Conclusion

The study revealed that the ingestion of caffeine has a significant positive effect on NPC and A of A. And the effect is dose dependent and gender related. Thus the stimulating effect of caffeine might enable an individual with convergence insufficiency to overcome symptoms of asthenopia at near, especially in early presbyopes[10,22,26]. Also, the positive impact of caffeine on NPC could be exploited in the management of convergence insufficiency, a common phenomenon among elderly patients which tend to require higher reading additions for near work [9,17,20].

The study also brought out the need for eye-care practitioners to take detail history of their patients so that they would always be conscious of these effects in counselling their patients who may be regular consumers of caffeine. This is because, patients who have high-blood concentration of caffeine may end up with inaccurate results in subjective refraction, especially patients who are already in the presbyopic age-bracket.

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