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ORIGINAL ARTICLE

Effect of Visual Function on Consumption of Dark Chocolate

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Abstract

Objective: To study the effect of visual and cognitive function on the consumption of dark chocolate in young Myopes. **Methods**: A total of 30 myopic subjects (median age: 20) participated in the study. After obtaining informed consent from the participants, procedures such as Visual acuity, contrast sensitivity, reaction time, and Intra Ocular Pressure (IOP) were measured before and after consumption of Dark chocolate with and without refractive correction. All the tests were taken with an interval of 2 hours of intake of 50g of dark chocolate and compared with the Pre-Test values. **Findings:** A total of 30 participants were assessed for changes in visual acuity, contrast sensitivity, reaction time, and IOP. Among the 30 participants 24 were female and 6 were Male. Statistically significant improvements were seen in visual acuity, contrast sensitivity, and reaction time. (p value < 0.05) While statistically significant reductions in IOP were seen in the left eye of myopic individuals (p value < 0.05), but there were no statistically significant changes noted in the right eye of myopic individuals (p value > 0.05). **Novelty:** Consumption of dark chocolate shows a sudden temporary improvement in visual acuity, contrast sensitivity, and reaction within 2 hours of eating as well novel reduction in IOP was observed indicating positive ocular and neuro-visual perception benefits of dark chocolate intake.

Keywords: Visual acuity; Contrast sensitivity; Reaction time; Dark chocolate; Cocoa; Flavanols

1 Introduction

Dark chocolate is a nutritious, rich food that possesses lots of benefits for human health. It consists of a large amount of cocoa solids that are derived from *Theobroma cacao*. The increased percentage of cocoa contains more nutrients and antioxidants.[(1)]

Cocoa is enveloped in Polyphenols, particularly flavanols, and has been associated with numerous health benefits been linked to biological mechanisms, like antioxidant, anti-inflammatory, and anti-allergic activities due to these natural compounds that are present in Polyphenols.[(2)] Consumption of cocoa has positive effects on visual functions, cognitive and skin functions.[(2)],[(3)]

Endothelial function:

The cocoa flavanols could influence a nitric oxide- mediated pathway, that results in nitric oxide production through Ca (2+) which is independent endothelial Nitric oxide synthase (eNOS) activation or phosphorylation.[4]

Thus, endothelial function is improved along with increased plasma epicatechin concentrations after the consumption of flavonoid rich dark chocolate in adults. Enhanced flow-mediated dilation, driven by endothelium-derived vasodilators like Nitric oxide and prostanoids, boosts vascular function[5] Hence, cocoa flavanols can increase peripheral and central blood flow by hemodynamics, supporting better visual and cognitive performance.[6] Experiment have shown that the participants who inhaled air with a higher percentage of CO2 has induced mild hypercapnia, which resulted in vasodilation and increased ocular blood flow thus improving the contrast sensitivity and reducing Intraocular pressure.[7] Thus we hypothesized same vasodilatation effect is created by endothelium driven Nitric oxide and prostanoids by dark chocolate might help in improved contrast acuity and reduced IOP.

Effects of flavanols on vision and visual functions:

Flavonoids have multiple effects on the visual system, that is focused on the retina, which performs the initial neural processing in the brain that results in visual perception.[8] Due to the antioxidant property of flavonoids, it protects against cell degeneration, which is important in the contribution for vision as there is a high metabolic rate in the retina, which is highly susceptible to oxidative injury.[9]

Cocoa flavonoids action:

Flavanols are subgrouped into Catechin, Epicatechin (monomers), and proanthocyanidin oligomers based on their structural characteristics.[10],[11]

Due to the increased absorption of epicatechins, which is identified in the plasma of individuals 2 hours after consumption of dark chocolate and have a relative clearance time of 2-4 hours.[8] Thus Consumption of flavanol-rich cocoa resulted in increased cerebral blood flow which peaked after 2hours of intake. Hence, we have studied the dark chocolate post consumption effect after 2hours of eating.

Study by Rabin JC et al proved that the intake of dark chocolate will have a positive short-term effect on visual acuity and contrast sensitivity when compared with milk chocolate bar[12]. To the best of our knowledge, most studies to date have been conducted in healthy young emmetropic (no refractive power) adults. Also, very few have studied the entire visual function test together. Thus, we aim to study the effect of dark chocolate in visual functions like, visual acuity with and without spectacle correction, contrast acuity with and without spectacle power, Intra ocular pressure and cognitive function with reaction time in myopic adults.

2 Methodology

The Prospective cross-sectional study was carried out with 30 myopic subjects with median age of 20. The Prospective cross-sectional study was carried out with approval from the institutional research and ethics committee with the reference number REF: CSP/23/APR/126/308. Prior to informed consent, each subject was briefed on the procedure of the study and voluntary willingness for the consumption of 50 grams of dark chocolate was confirmed. Subjects were informed that they will be evaluated with standard visual assessment, which would take approximately 20-25 minutes for each Pre - and post consumption of dark chocolate to compare its effects on Visual performance. Subjects were asked to refrain from consuming dairy products and carbonated drinks before and on the day of examination, as they could act as potential confounding factors. After getting informed consent from the participants, the study was initiated. The following procedures were done in the study: A General History was taken to determine if the subject has any ocular co-morbidities. Major histories like complaints regarding vision, history of spectacle usage, general health status, current medications, and family history were taken, and the Subjects were asked if they had an allergic history to any food. The Best corrected distance and near visual acuity were assessed. After the assessment of visual status, the procedure was initiated. Baseline measurements like vision with LogMAR visual acuity chart, contrast sensitivity with pelli robson chart, reaction time with hit the dot[13], and IOP were assessed. The Subjects were asked to consume 50grams of dark chocolate. Repeated measurements of Visual acuity, contrast sensitivity, Reaction time, and IOP were carried out after a 2 hour's consumption of dark chocolate.

Test for Visual Acuity:

LogMAR: Logarithm of the Minimum Angle of Resolution (LogMAR) chart is a visual acuity testing tool which consists of uniform progressive letter size, the legibility of letters in LogMAR are comparatively better than Snellen visual acuity chart. LogMAR consists of Equal number of letters on each row and uses a Sloan font which makes the letter more accurate than Snellen. The test was performed under normal illumination. The participants were asked to read the letters from the top of the chart and the visual acuity was recorded. This test was assessed monocularly. Both aided and unaided visual acuity was assessed on pre -and post consumption of dark chocolate.

Test for Contrast Sensitivity:

Pelli Robson chart: Pelli- Robson contrast sensitivity chart consists of a single large letter size with varying contrast across each group of letters. Each line of the chart consists of 6 letters which are arranged in groups and the first three letters on the left has an increase in contrast compared to the 3 letters on the right. Participants were instructed to read the letters horizontally initiating with the higher to lower contrast letters, which is performed monocularly. This test was performed at 1 meter distance. Both aided and unaided contrast sensitivity was examined on pre- and post-consumption of dark chocolate.

Test for Reaction Time:

Reaction time test: Amount of time required to react, typically by pressing a mouse button by the participants to the sudden appearance or change of a visual stimulus**.** Participants were asked to react by pressing the mouse button while the spot of dots appears in a grid spontaneously as soon as they can spot the dot which appeared on the screen over the time course of 30 seconds. This test would determine the spontaneous response of the subjects to the random dot in the grid. Reaction score was recorded on pre- and post-consumption of dark chocolate.

Test for Intra Ocular Pressure:

Non-Contact Tonometer: The Non-contact tonometer (NCT) is an instrument which is used to measure Intraocular pressure [IOP]. During this procedure, no anesthetic is required. A small puff of air is exhibited which would flatten the center area of the cornea. The examiner first manually replicates how the instrument works by having the subject placing a finger in front of the nozzle and actuating the puff of air by pressing the control button. With the participants seated at the instrument, the examiner centers the nozzle a few millimeters in front of the participants cornea and further adjusts the position of the nozzle until a small green target is in sharp focus in the center of a circle. The participants were instructed to watch the green target and not to move; the examiner then pressing the button and actuated the puff of air. An average of three readings was taken monocular. Readings were taken on pre- and post-consumption of dark chocolate.

3 Results and Discussion

A total of thirty Myopic participants with a median age of 20 in which 24 (80%) were female and 6 male (20%).The Median Refractive power of participants are -2.00 DS (-2.75 -1.00) in OD and -1.50 DS (-2.75 -1.00) in OS.

All thirty participants were assessed Visual acuity, contrast sensitivity, reaction time, and IOP on pre and post consumption of dark chocolate. Each subject was given 50 grams of dark chocolate to consume. The post-test assessment was identical to the pre-test. All 30 participants completed the study. The Wilcoxon signed rank test was used for comparing the difference between pre and post consumption. Statistical analysis of these subject's data revealed an overall improvement after the consumption of dark chocolate. Therefore, the analyzed data of all participants are illustrated below.

Unaided visual acuity of Pre and post consumption of dark chocolate is illustrated in the Table 1.

Table 1. Median (IQR) of Unaided visual acuity (Log MAR)

Unaided visual acuity	Group	Median (IQR)	P-Value
OD	Pre-consumption	0.70 (0.47-0.80)	0.000
	Post-consumption	0.60 (0.37-0.70)	
OS	Pre-consumption	0.65 (0.50-0.80)	0.000
	Post-consumption	0.55 (0.30-0.70)	

The unaided LogMAR visual acuity in pre- consumption of dark chocolate was 0.7 (0.4-0.8) which shows one line improvement with post consumption of dark chocolate as 0.6 (0.3-0.7) in OD, with statistical significance of (p= 0.00) and in OS unaided visual acuity in Pre- consumption was 0.6 (0.5-0.8) and post consumption was 0.5 (0.3-0.7) shows a statistical significance of p= 0.00. Under pre consumption of dark chocolate aided LogMAR visual acuity was 0.0(-0.1-0.0) that shows an improvement on post consumption of dark chocolate as -0.1(-0.1- 0.0) with a significance of p =0.00 in OD, similarly for OS pre consumption value was 0.0(-0.1- 0.0) and post consumption was -0.1(-0.1–0.1) shows a statistical significance of p=0.00 which is illustrated in Table 2.

For unaided contrast sensitivity pre- consumption of dark chocolate was 0.75 (0.45-0.90) which shows one line improvement with post consumption of dark chocolate as 0.90 (0.75-1.05) in OD, with statistically significance p=0.00. For OS pre-consumption value was 0.75 (0.60-0.90), which shows an improvement on post consumption of dark chocolate as 0.90 (0.75-1.05) with a statistical significance of p=0.00 which is illustrated in Figure 1.

For aided contrast sensitivity pre consumption value was 1.05(1.05-1.05) which shows an improvement on post consumption of dark chocolate as 1.20 (1.05-1.20) with a significance of p=0.00 in OU which is illustrated in Figure 2.

Table 2. Median (IQR) of aided visual acuity (Log MAR)

Aided Visual acuity	Group	Median (IQR)	P-Value
OD	Pre consumption	0.00 (-0.10-0.00)	0.000
	Post consumption	-0.10 (-0.10–0.07)	
OS	Pre consumption	0.00 (-0.10-0.00)	0.000
	Post consumption	-0.10 (-0.10–0.10)	

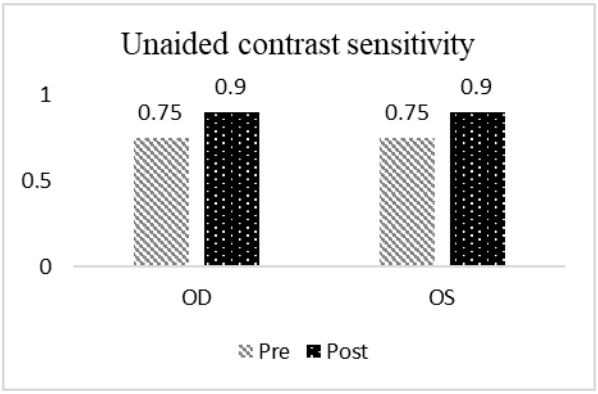

Fig 1. Comparing pre and post unaided contrast sensitivity

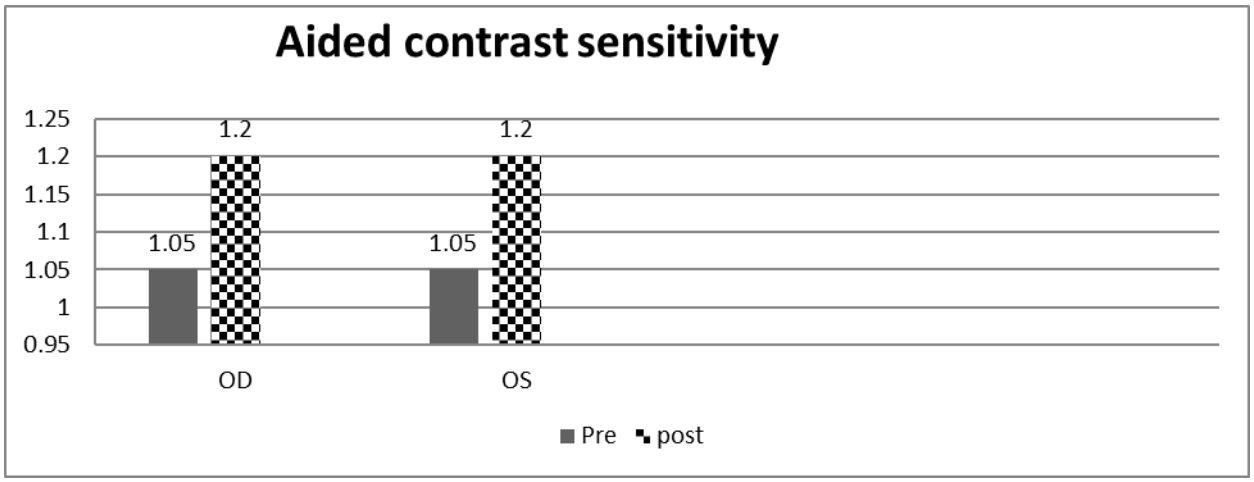

Fig 2. Comparing pre and post aided contrast sensitivity

The median of the participants during the reaction time task was faster in post- consumption 14.5 (13-16) than pre consumption 12.5 (11-14) which shows statistically significance of p = 0.00 in OD which is illustrated in the Figure 3, and for OS similarly, post consumption was faster 16 (14-17) than the pre consumption 14 (12.7-16.2) which shows significance p =0.00. There was a statistically improved effect on the measures of reaction time tasks.

Intraocular pressure was evaluated and found to be reduced in the OS, 2 hours after consuming dark chocolate by 11.5 (9-14) compared to the pre- consumption intraocular- pressure value of 13 (11-16), as illustrated in Table 3, which shows statistically significant value p=0.03. Though OD Intraocular pressure was found to be not significant statistically p= 0.18. Clinically significant difference was noted with reduction of pressure in the post consumption median as 12 (10-13.2) than in pre consumption 13 (12-14.2).

This is a prospective cross sectional study, which was conducted among 30 college students under the median age of 20. Our study was done to observe if there is an improvement in visual acuity, contrast sensitivity, reaction time, and IOP after the intake of 50g of dark chocolate. Studies have reported to have an improvement in these factors after the flavanol- rich consumption of

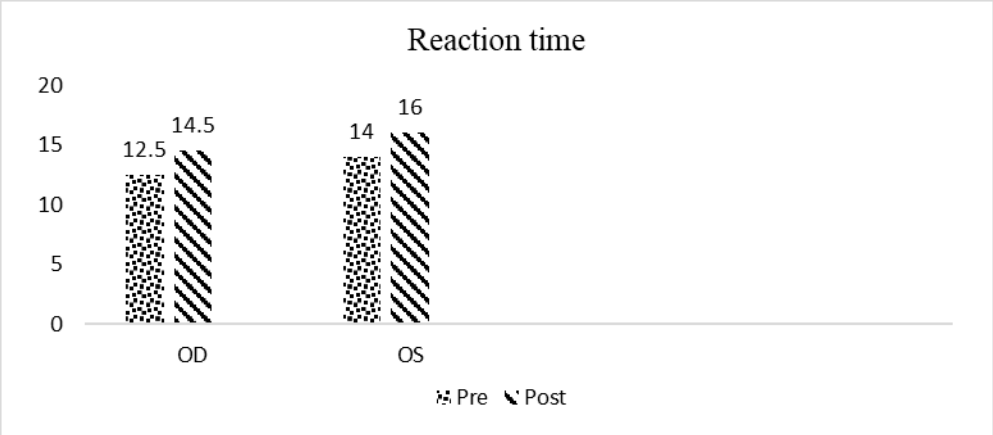

Fig 3. Comparing Pre and Post reaction time

Table 3. Median (IQR) of Intraocular pressure (IOP)

IOP	Group	Median (IQR)	P-Value
OD	Pre-consumption	13 (12-14.2)	0.183
	Post-consumption	12 (10-13.2)	
OS	Pre-consumption	13 (11-16)	0.033
	Post-consumption	11.5 (9-14)	

dark chocolate. Flavanols are the most important source of components in dark chocolate that have been reported to enhance visual functions.

A Study conducted by Rabin et al[12], has discussed that consumption of dark chocolate resulted in improved visual performance compared to milk chocolate, with observed differences of 0.04 in visual acuity, 0.05 in large letter contrast sensitivity, and 0.15 in small letter contrast sensitivity. These improvements were attributed to the presence of flavanols in dark chocolate, which are known to support visual function. In alignment with these findings, the current study also demonstrated a 0.1 improvement in visual acuity and a 0.15 enhancement in contrast sensitivity following dark chocolate consumption.

Contrast sensitivity has been an important visual function to distinguish between object's shading patterns on a black and white background. In our study we found that the pre-unaided contrast sensitivity in OD was 0.75 (0.45-0.90) and in OS was 0.75(0.60-0.90), after the consumption of dark chocolate in a 2 hour time interval, the unaided contrast sensitivity in OD was 0.90 (0.75-1.05) and in OS was 0.90 (0.75-1.05) which shows a significance p=0.00 which is illustrated in Figure 1.

For aided contrast sensitivity pre-consumption value was 1.05 (1.05-1.05) which shows an improvement on post consumption of dark chocolate as 1.20 (1.05-1.20) with a significance of p=0.00 in OU which is illustrated in Figure 2.

In our study, unaided visual acuity showed significant improvement two hours after dark chocolate consumption. In the right eye (OD), pre-consumption acuity was 0.7, which improved to 0.6 post-consumption. Similarly, in the left eye (OS), values improved from 0.6 to 0.5, with a statistically significant difference (p = 0.00), as shown in Table 1. Aided visual acuity also improved significantly. In OD, baseline measurements of 0.0 improved to –0.1, and in OS, from 0.0 to –0.1, with both changes reaching statistical significance (p = 0.00), as shown in Table 2.

In contrast, Jakob's et al.[14] reported no significant short-term changes in visual function or retinal blood flow following the intake of 20 g of flavanol-rich dark chocolate. Their study found a 95% confidence interval (CI) difference of 1.93 for visual acuity using the ETDRS chart, and minor, non-significant changes in contrast sensitivity: 0.06 with the Pelli-Robson test and 0.03 with the Mars test. The disparity in findings may be attributed to methodological differences - Jakob's study assessed visual function binocularly, whereas our study used monocular testing. Binocular fusion is known to compensate for discrepancies between the eyes, potentially masking subtle visual changes. Additionally, the quantity of dark chocolate used in their study (20 g) was considerably lower than the 50 g administered in ours, which may have contributed to the differing outcomes

In addition, we found enhanced visual performance like improved reaction time, and a reduction in intra-ocular pressure with dark chocolate intake. Our study has been supported by Raj CV et al[15] reported short-term improvements in unaided and aided visual acuity among myopic participants following a 2-hour intervention. Unaided visual acuity improved significantly in

both eyes, with mean values decreasing from 0.33 to 0.19 in OD and from 0.31 to 0.16 in OS. Aided visual acuity also improved, with OD changing from -0.03 to -0.13 and OS from -0.06 to -0.14. Additionally, modulation transfer function (MTF) values showed a significant increase post-intervention in both eyes with improvement from 43.38 to 47.63 in OD and 43.43 to 48.05 in OS ($p < 0.05$). However, intraocular pressure (IOP) showed no statistically significant change in either eye ($p > 0.05$).

Our study findings show that there is a significantly decreased IOP was seen in OS after consumption of dark chocolate as 11.5(9-14) compared to the pre-consumption value of 13 (11-16) which shows a statistically significant ($p = 0.03$). Though the IOP in OD was not statistically significant ($p=0.18$), there was a clinically significant difference between the post consumption value 12 (10-13.2) and the pre-consumption value 13 (12-14.2).

Huber et al[7] State that a reduction in IOP occurs due to hypercapnia, which shows a decreased significance of 0.94mmHg which is achieved by inhalation of CO_2 and room air, due to the vasodilation effect of Carbon dioxide.

Similar to this, Engler et al[5] state that dark chocolate, which is rich in flavonoids promotes endothelial dependent vasodilation, which occurs by Nitric oxide and perhaps prostanoids derived from the endothelium and released during flow mediated dilation of the brachial artery, which is an endothelial dependent function. He concluded that dark chocolate with high level of flavonoids enhances endothelial function in healthy adults and has been linked with higher plasma epicatechin concentrations. Thus, flavonoid induced Vaso-dilatation probably leads to reduced IOP.

Likely Riccardo Sacconi[16] et al also found to have improved arterial dilatation after flicker stimulus in Dynamic vessel analyzer as $(4.145 \pm 3.055\%)$ after dark chocolate consumption compared to the $(2.750 \pm 2.054\%)$ as pre consumption value states that dark chocolate as a positive retinal vessel dilatation effect.

Reaction time has been done in our study to assess the effects of dark chocolate on the reaction tasks. Our study reveals that there is a significantly increased in reaction to stimulus after 2 hours of consumption of dark chocolate as 14.5 (13-16) compared to pre-consumption 12.5 (11-14) in OD, whereas in OS post consumption value was increased by 16 (14-17) compared to pre-consumption 14 (12.7-16.2). This increased reaction might be attributed to the increased cerebral blood flow which causes increased attentiveness to the tasks stated by Field et al[6]., found reaction time in predictable and unpredictable phases, For high cocoa flavanol condition, and estimated the 40msec faster significant difference in high cocoa flavanol content than the low content (517 vs 557msec, $p <0.01$) during the predictable phase, whereas unpredictable phase doesn't show any significant difference. In supporting our results, Akihiro Sasaki et al[17] studied the cognitive function in high and low percentage of cacao polyphenols and found that improved reaction time after consumption of low concentration of cocoa polyphenols from (97.3 %) to (96.4 %).

In order to provide continual oxygen and glucose supply to neurons, cerebral blood flow must be well maintained for optimal brain functioning. An increase in cerebral blood flow enhances cerebral function.[18] Enhanced visual function (contrast sensitivity) and cognitive performance is seen in young adults due to the consumption of Cocoa flavanols. Increased cerebral blood flow induced by cocoa flavanols could be a cause for these effects, whereas changes in retinal blood flow are caused by Cocoa flavanol consumption which causes increases in contrast sensitivity.[6] further cocoa flavanols Improves cognitive performance such as attention, reaction time, and memory.[19] Increase in attention to the work occurs due to increased cerebral blood flow.[6]

4 Conclusion

The result of the study shows that consumption of dark chocolate shows an immediate and temporary improvement in visual acuity, contrast sensitivity, and reaction time after 2 hours and is also found to have reduction in IOP. Thus, it's beneficial in sports activities, high visual demanding tasks for short period. However, it is unclear about the retention effect of dark chocolate on visual functions and ocular health benefits.

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