Annals of the University of Craiova, Mathematics and Computer Science Series
Volume 46(2), 2019, Pages 344–365
ISSN: 1223-6934

Dynamics of superior fractals via Jungck SP orbit with s-convexity

Sudesh Kumari, Mandeep Kumari, and Renu Chugh

Abstract. The purpose of this paper is to generate new fractals for complex-valued polynomials via Jungck SP orbit with s-convexity. In this paper, we obtain a new escape algorithm for quadratic, cubic and higher degree complex valued polynomials to generate fractals. Also, we provide an algorithm as well as source programs to generate fractals. We have shown that beautiful graphics can be generated by using new escape algorithm. Our results are the generalization of corresponding results which is obtained by us [13] via SP orbit with s-convexity and Kang et al. [15] via Modified Jungck three step orbit.

2010 Mathematics Subject Classification. 37F45, 37F50.
Key words and phrases. SP orbit with s-convexity; escape criterion; complex polynomial; Mandelbrot set; Julia set.

1. Introduction

Generally, people believe that the geometry of nature is based on the simple figures like lines, circles, polygons, spheres, quadratic surfaces and so on. But there are so many examples in nature which show that the geometry does not depend on simple figures. Fractal geometry provides a general framework to study such type of figures. First of all, in 1982, Benoit Mandelbrot introduced the theory of fractals in his book [1] which consists different fractal shapes existing in the nature. Later on, many other mathematicians like George Cantor, Giuseppe Peano, David Hilbert, Helge von Koch, Waclaw Sierpinski etc. gave their contribution in the field of fractals. Fractal is a rough or fragmented geometric shape that can be subdivided into congruent parts, each of which is a reduced size copy of the whole.

Historically, different generalizations of fractals have been made. In 1919, French mathematician Gaston Julia [4] derived the Julia set when he was studying Cayley's problem which is related to the behavior of Newton's method in complex plane. After this, Mandelbrot extended the work of Julia and introduced Mandelbrot set in his first book [1]. He studied fractals in Complex plane. Further, some other functions such as rational [8], trigonometric and exponential [2] etc. were used in the generation of fractals. Mandelbrot and Julia sets were also extended from the complex numbers to quaternions [24], bicomplex numbers [23], tricomplex numbers [9] etc. Rani and Kumar [6, 7] introduced the superior iterate and generated superior Julia and Mandelbrot sets for quadratic and cubic polynomials. In 2009, D. Rochon [3] studied generalized Mandelbrot sets in bicomplex plane. Later on, the work of Rochon was extended by Wang et al. [19–22] and they carried further analysis of generalized Julia

Received May 11, 2018. Accepted August 10, 2019.

Graphics for Complex Polynomials in Jungck-SP Orbit

Sudesh Kumari[1,*], Mandeep Kumari[2], and Renu Chugh[3]

Abstract—**The objective of this paper is to generate fractals for complex valued polynomials using Jungck-SP orbit. We present an algorithm to generate fractals. With the help of this algorithm, we generate such beautiful graphics which may be useful for graphic designers. In this paper, we extend and improve the corresponding results of Kang et al. (2015) and Kumari et al. (2017) existing in the literature. One can further generalize our results and derive a new escape criterion to generate some more beautiful fractals.**

Index Terms—**Julia set; Mandelbrot set; Jungck-SP orbit; Escape criterion; Complex polynomials.**

I. Introduction

Fractal theory is a popular branch of mathematical art. In mathematical visualization, fractals are the complex objects that are used to simulate naturally occurring objects. Mathematicians have been using computer programming to generate fractals via iterative procedures. Gaston Julia was the first, who used the iterative process and obtained the Julia set ([7], p. 122). After that in 1975, Gaston's idea was extended by Benoit Mandelbrot and he introduced the Mandelbrot set. The geometry of fractals had been studied for quadratic [2], [7], [18], [25], cubic [1], [4], [5], [18], [24] and higher degree complex polynomials [35] using Picard orbit.

In the first decade of 21st century, researchers used Superior orbits to generate fractals (see, [6], [8], [12]–[19], [22], [26], [27], [29]–[33], [36], [37] and references therein). In the sequel, Ashish et al. [3] and M. Kumari et al. [9] obtained further generalized form of Mandelbrot and Julia sets for four step feedback processes.

In 2015, Kang et al. [22] established new escape criterion for Mandelbrot and Julia sets under Jungck-Mann and Jungck-Ishikawa orbits and presented some graphics of Mandelbrot and Julia sets. Further, they presented the generalized form of Mandelbrot sets and Julia sets for complex valued polynomials using Jungck three-step orbit [23]. In 2011, Chugh and Kumar [19] defined Jungck-SP iterative scheme and with the help of examples, they proved that the rate of convergence of Jungck-SP iterative scheme is faster than that of Jungck-Mann, Jungck-Ishikawa and Jungck-Noor iterative schemes. Recently, authors used SP orbit in Fractal theory and generated beautiful fractals (see [10], [11], [20], [21], [28], [34]).

In this paper, firstly, we recall some basic definitions. In Section III, we derive escape criterion to generate fractals of complex valued polynomials. Moreover, an algorithm to compute fractals have been presented in Section IV. The beautiful graphics of Mandlbrot sets and Julia sets have been generated in Section V. In Section VI, we conclude our findings.

Manuscript received May 28, 20019; revised August 06, 2019.

1*. Department of Mathematics, Government College for Girls Sector-14, Gurugram-122001, India.

2. Department of Mathematics, Government College Kharkhoda, Sonipat-131402, India.

3. Department of Mathematics, Maharshi Dayanand University, Rohtak-124001, India.

* Corresponding author e-mail: tanwarsudesh10@gmail.com

II. Preliminaries

Definition 2.1: (Orbit) [18] The orbit of a point $x_0 \in \mathbb{R}$ under a mapping T is defined as a sequence of points

$$x_0, x_1 = T(x_0), x_2 = T^2(x_0), ..., x_n = T^n(x_0), ...$$

Definition 2.2: ([18], p. 225) The Julia set of a function g is the boundary of the set of points $z \in \mathbb{C}$ that tends to infinity under repeated iteration by $g(z)$, i.e., for a function g, the Julia set is given by

$$J(g) = \partial\{z \in \mathbb{C} : g^n(z) \to \infty \ as \ n \to \infty\},$$

where $g^n(z)$ is the n^{th} iterate of function g.

Definition 2.3: ([18], p. 249) The Mandelbrot set M is the collection of all complex numbers for which the Julia set is connected, i.e.,

$$M = \{z \in \mathbb{C} : J(g) \ is \ connected\}.$$

Definition 2.4: Let X be a subset of set of complex numbers and $T \colon X \to X$ be a mapping. For any initial point $z_0 \in X$, consider a sequence $\{z_n\}$ of iterates such that

$$\begin{aligned} Sz_{n+1} &= (1-\alpha_n)Su_n + \alpha_n Tu_n, \\ Su_n &= (1-\beta_n)Sv_n + \beta_n Tv_n, \\ Sv_n &= (1-\gamma_n)Sz_n + \gamma_n Tz_n, \end{aligned} \tag{1}$$

where $\alpha_n, \beta_n, \gamma_n$ are sequences of positive numbers in $[0, 1]$ and $Sz = bz$. Then, (1) is called Jungck-SP orbit [19] having five tuples $(T, z_0, \alpha_n, \beta_n, \gamma_n)$.

Remark 2.5: The Jungck-SP orbit reduces to :

1. The **Jungck Thaiwan orbit** when $\gamma_n = 0$, i.e.

$$Sz_{n+1} = (1-\alpha_n)Su_n + \alpha_n T(u_n)$$

$$Su_n = (1-\beta_n)Sz_n + \beta_n T(z_n)$$

2. The **Jungck Mann orbit** [22] when $\gamma_n = \beta_n = 0$, i.e.

$$Sz_{n+1} = (1-\alpha_n)Sz_n + \alpha_n T(z_n)$$

3. The **Jungck Picard orbit** when $\gamma_n = \beta_n = 0$ and $\alpha_n = 1$, i.e.

$$Sz_{n+1} = T(z_n)$$

Appendix D (I)
Research Paper - 1

International Peer Reviewed & Refereed Journal

Journal of Indian
Health Psychology

VOL. 14, NO. 1, September, 2019

Editors

Prof. Rajbir Singh

Prof. NovRattan Sharma

Owned, Printed & Published by Dr. N.K. Singh, F-4, 'Hari Sadan', 20, Ansari Road, Daryaganj, New Delhi-110002

Printed at: R.K. Offset, Naveen Shahdara, Delhi-110032.

Contents

EFFECT OF EATING BEHAVIOUR AND BMI ON EXECUTIVE FUNCTIONS AMONG ADOLESCENTS

Rekha* and Deepti Hooda**

ABSTRACT

Executive functions encompass a system of diverse cognitive skills which enable the individual to perform and adjust in real-life conditions. There are various factors which influence executive functions e.g. genetic influence, age, maternal depression, eating behaviour. Limited research has examined eating behaviour in relation to executive functions, especially among adolescents. Keeping this in mind, the present investigation was designed to study the effect of eating behaviour on Executive functions of Adolescents using a 2×3 factorial design 2 (Eating behavior groups) × 3 (BMI groups). A sample of 100 adolescents (age 14-16 years) was selected from different schools using non-random technique. All respondents were assessed using Dietary Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents", BMI and "Executive Function Index" (EFI) scale. The sample was divided into 6 groups on the basis of BMI and eating behaviour scores. Data was analyzed using two-way ANOVA. Results indicated that significant differences on four subtests of EFI i.e. motivational drive, organization, strategic planning and impulse control between healthy eating behaviour and unhealthy eating behaviour groups. There were no statistically significant differences in executive functions between BMI groups. No significant interaction effect was found on any of the EFI subscales. Thus, adolescents having unhealthy eating behaviour posses poor executive functions.

Keywords: Executive Functions, Eating behaviour, BMI, school students

INTRODUCTION

A person's executive functioning ability makes it possible to live, work and learn with an appropriate level of independence and competence for his age.

* Research Scholar, Department of Psychology, M.D. University, Rohtak

** Associate Professor, Department of Psychology, M.D. University, Rohtak (Supervisor)

Executive Functioning helps to learn new information, remember and retrieve the information we have learned in the past, and use this information to solve problems of everyday life. It is an umbrella term, which encompasses different meta-cognitive domains that are commonly described as mental control processes. These abilities play a critical role in complex social behaviour. They help suppress improper actions and focus on purposeful information (Burgess, Veitch, De Lacy Costello, & Shallice, 2000; Grafman & Litvan, 1999; Smith & Jonides, 1999). These Executive Functions are critical for success in school as well as in daily life (Diamond, Barnett, Thomas, & Munro, 2007). There is growing evidence that Executive Functions continue to develop through late adolescence and into adulthood. It is a time of massive brain change, especially in the frontal lobes which control executive functions. Studies have reported that Executive Functions are affected by number of factors like Socioeconomic status (SES) (Sarsour, Sheridian, Jutte, Nuru-Jeter, Hinshaw, & Boyce, 2011), heredity (Jester, Nigg, Puttler, Long, Fitzgerald, & Zucker, 2009), family environment.(Talwar & Carlson, 2011), age (Stuss & Knight, 2002)., maternal depression (Cogill, Caplan, Alexandra, Robson, & Kumar, 1986) and eating behaviour. Eating behaviors refer to the patterns of food consumption that are influenced by individual's attitudes, perceptions and behavioral intentions (Oygard and Rise 1996, Gummeson et al. 1997, Verplanken and Faes 1999, Kassem et al. 2003). Eating behaviour plays a very important role in growth and development of adolescents, during which the development of healthy eating habits is of supreme importance. Children and adolescents often skip breakfast more than any other meal. Dietary habits and eating practices are even associated with increased risk of overweight and obesity among adolescents (Sedibe, Pisa, Feeley, Pedro, Kahn, & Norris, 2018).

Few studies have reported that eating behavior influences executive functions (Mahoney & Taylor, 2005; Sobaler & Ortega (2003); Wesnes & Pincock (2003); Smith & Kendrick (1994). Unhealthy dietary behaviors such as overeating and Consumption of high saturated fat foods is correlated with lower inhibition (Nederkoorn, Houben, Hofmann, Roefs & Jansen 2010; Guerrieri, Nederkoorn & Jansen 2008; Guerrieri, Nederkoorn, Schrooten, Martijn & Jansen 2009; Limbers & Young 2015). Healthy dietary behaviours which includes fruit and vegetable intake and eating breakfast are correlated with greater initiation/ planning skills (Wong & Mullan 2009). Greater intake of high-caloric-low nutritional foods and and lower consumption of fruits and vegetables are correlated with deficits in children's executive functions (Riggs, Spruijt-Metz, Sakuma, Chou & Pentz 2010; Wills, Isasi, Mendoza & Ainette 2007; Riggs, Chou, Spruijt-Metz & Pentz 2010; Tate, Unger, Chou, Spruijt-Metz, Pentz & Riggs 2015). Less healthy food choice is associated with increased impulsivity and reduced inhibitory control (e.g., Bryant et al., 2008; Jasinska et al., 2012). Wills et al. (2007) found that better initiation/planning skills are correlated with increased fruit and vegetable consumption and deficits in inhibition are related to higher intake of saturated-fat foods.

To sum up, researches suggest an association between eating behaviour and executive functions. Relatively fewer studies have evaluated dietary behaviours and executive functions in adolescents. Moreover, the relationship of eating behaviours and executive functions has mostly been examined from a clinical perspective of eating disorders or obesity with the focus on EF deficits in overweight populations compared to controls. So to fill this gap in knowledge the present study was designed to examine the effect of eating behaviour (e.g., increase of fruit and vegetable intake, decrease of saturated fat and sugar, breakfast consumption, physical activity, nutritional knowledge and bmi) on executive functions among adolescents. This will provide important knowledge about eating behaviour and how it should be targeted to improve the efficacy of executive functions.

Objectives

1. To study the main and interactive effects of eating behaviour and BMI on executive functions among adolescents.

Hypotheses

1. There would be significant main and interaction effect of eating behaviour and BMI on executive functions among adolescents.

METHOD

Design

2×3 Factorial design was used in the present study (2 eating behaviour group i.e. Healthy eating behaviour group and unhealthy eating behaviour group and 3 BMI group i.e Normal BMI, overweight and underweight)

Sample

For the present study a sample of 100 adolescents of both sex (boys and girls) was selected from the different schools of Sonipat and Rohtak within the age range of 14-16 years (mean age= 15.4).

Tools

In this study, the following tools were used in the present study to collect the required information from the subjects.

Measure of Eating Behviour

Dietary Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents: This multidimensional eating behaviour questionnaire was developed by Turconi, Celsa, Rezzani, Sartirana & Roggi (2003) consists of 99 items. It is divided into nine sections relating to Frequency of Food Consumption, Food Habits, Physical Activity and Lifestyle, Healthy and Unhealthy

Diet, Self-Efficacy, Barriers to Change, Nutrition Knowledge Section, Food Safety Knowledge, Food Safety and Behaviour in Hygiene Practices. The total score obtained in each section was analysed according to three ranges, assigning the worst evaluation to the lowest one, the medium evaluation to the medium one, the best evaluation to the highest one. For the present study Reverse scoring was done for section G “Barriers to change” to make evaluation uniform/one-directional. A score of 0 was assigned to the major barriers toward change. In this way lower scores indicate greater barriers to change. Cronbach’s alpha ranges from a minimum of 0.55 (section G) to a maximum of 0.75 (section C). Pearson correlation was used to assess test– retest reliability. Pearson correlation coefficients range from 0.78 to a maximum of 0.88.

BMI: BMI was measured by using the following formula

$$\text{BMI} = (\text{Weight in kg}) / (\text{Height in meters})^2$$

After BMI is calculated for adolescents, it is expressed as a percentile which can be obtained from either a graph or a percentile calculator. The BMI-for-age percentile growth charts are the most commonly used indicator to measure the size and growth patterns of children and adolescents. It is difficult to provide healthy weight ranges for children and teens because the interpretation of BMI depends on weight, height, age, and sex. These percentiles are calculated from the CDC growth charts, which were based on national survey data collected from 1963-65 to 1988-94.

Measure of Exective Functions

Executive function Index: *The* EFI (Spinella 2005) is a self-rating measure of executive functioning. It provides a quick, convenient measure of a person’s perception of their own executive functions. The EFI measures executive function rather than dysfunction. There are 5 subscales that are Empathy (EM), Strategic Planning (SP), Organization (ORG), Impulse Control (IC), and Motivational Drive (MD). Cronbach’s alpha was acceptable for the subscales: .76, .70, .75, .69, and .70, respectively, and .82 for the total score.

Procedure

The present research work aims to explore the effect of eating behaviour on executive functions of adolescents. For this purpose the permission from the principals of schools and consent from students were sought and “Dietary Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents” and executive function index was administered on them after establishing rapport with them. Instructions relevant to each test were given to them and they filled the questionnaire according to the instructions mentioned. When the tests were completed, scoring was done according to the norms of each test. Then students were distributed in 6 groups (2×3 factorial design) based on their score on eating behaviour questionnaire and BMI. As there were very few obese adolescents in sample so respondents were divided into 3 groups based on their BMI i.e Normal BMI, overweight and underweight, out of which 2 groups were from normal BMI category and other 2 groups were from overweight BMI category and rest 2 groups were from underweight category and it had students who practised healthy and unhealthy eating behaviour in respective categories. Thus 6 groups were formed with 90 respondents out of 100 sample size rest 10 were dropped as they did not fall in healthy & unhealthy eating groups. Thus six groups are as follows 1. Normal BMI with healthy eating behaviour i.e. N(BMI)+HE 2. Normal BMI with unhealthy eating behaviour i.e N(BMI)+UE 3. Overweight with healthy eating behaviour i.e. Ow+HE 4. Overweight with unhealthy eating behaviour i.e.Ow+UE 5. Underweight with healthy eating behaviour i.e. U+HE 6. Underweight with unhealthy eating behaviour i.e. U+UE. The subjects were assured of the confidentiality of the information. The analyses were carried out to examine various hypothesis formulated earlier. The comparison of groups was made by administering analysis of variances.

Data analysis

Two- way ANOVA was applied to analyse the data using Statistical package for social sciences (SPSS).

RESULTS

Descriptive statistics (Mean and SD) for each group and Two way ANOVA was analysed. A 2 ×3 factorial design was used in the present study to study the effect of eating behaviour and BMI on Executive functions of adolescents. Thus 6 groups were formed on the basis of Eating behaviour scores and BMI. 1. Normal BMI with healthy eating behaviour i.e. N(BMI)+HE 2. Normal BMI with unhealthy eating behaviour i.e N(BMI)+UE 3. Overweight with healthy eating behaviour i.e. Ow+HE 4. Overweight with unhealthy eating behaviour i.e.Ow+UE 5. Underweight with healthy eating behaviour i.e. Uw+HE 6. Underweight with unhealthy eating behaviour i.e. Uw+UE.

As described in the methodology section, Executive function index assess executive functions on 5 dimensions that are described one by one as follow:

Motivational drive

Two-way ANOVA showed no significant main effect of BMI, but highlights that a significant difference has been found among eating behaviour groups ($F=19.82$; $p<0.05$). Mean value of healthy eating behaviour group ($M=15.15$) is more than unhealthy eating behaviour group ($M=12.49$) on motivational drive. Healthy eating behaviour means they are having balanced diet, rich in fruits, vegetables, whole grains and low in saturated fat, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and less barriers in modifying their eating habits. Results shows that that students who were practicing healthy eating behaviour had lot of enthusiasm to do new things as compared to unhealthy eating group. No significant interaction effect of BMI and eating behaviour was observed on motivational drive. On the first dimension of EFI i.e. motivational drive the obtained results of F- value confirms that participants across three BMI groups did not differ on this dimension of EFI, which implies that adolescents whether healthy, overweight or underweight BMI groups were equally motivated.

Table 1 (a): Mean and SD values of motivational drive of 6 groups

1.Eating behaviour→ 2. BMI ↓	**Healthy eating group**		**Unhealthy eating group**		***Total (BMI)***	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Normal BMI	15.00	2.95	13.93	3.08	14.46	3.01
Overweight BMI	15.66	2.99	11.73	2.15	13.70	3.25
Underweight BMI	14.80	3.12	11.80	2.62	13.30	3.22
Total(Eating behaviour)	15.15	2.98	12.49	2.78	13.82	3.16

Table 1 (b): Summary table of two way ANOVA on motivational drive across 6 groups.

Sources	***SS***	***df***	***MS***	***F***
BMI	21.08	2	10.54	1.31
Eating behaviour	160.00	1	160.00	**19.82****
BMI× Eating behaviour	32.07	2	16.03	1.99
0Error	678.00	84	8.07	

**p<.01

Organisational ability

Table 2(a): Mean and SD values of organisational ability of 6 groups

1.Eating behaviour→ 2. BMI ↓	**Healthy eating group**		**Unhealthy eating group**		***Total (BMI)***	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Normal BMI	17.47	2.06	14.87	3.76	16.17	3.26
Overweight BMI	17.00	3.70	12.53	3.72	14.77	4.30
Underweight BMI	16.73	2.68	12.13	3.70	14.43	3.94
Total(Eating behaviour)	17.07	2.85	13.18	3.84	15.12	3.89

Table 2 (b): Summary table of two way ANOVA on organisational ability across 6 groups

Sources	*SS*	*df*	*MS*	*F*
BMI	50.76	2	25.38	2.28
Eating behaviour	340.28	1	340.28	**30.54****
BMI× Eating behaviour	18.76	2	9.38	0.84
Error	935.87	84	11.14	

**p<.01

Two Way ANOVA showed no significant main effect of BMI on organisational ability. On the other hand, a significant main effect of eating behaviour has been found (F=30.54; p<.01) between healthy eating participants and unhealthy eating participants on organisational ability. As it is clear from mean values that adolescents having healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and less barriers in modifying their eating habits scored better (M=17.07,SD=2.85) on organisational ability than students having unhealthy eating behaviour (M=13.18, SD=3.84). Further, no significant interaction effect has been observed on organisational ability.

Strategic planning

Table 3(a): Mean and SD values of strategic planning of 6 groups

1. Eating behaviour→ 2. BMI ↓	**Healthy eating group**		**Unhealthy eating group**		***Total (BMI)***	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Normal BMI	25.73	4.82	21.73	4.64	23.73	5.07
Overweight BMI	27.13	5.46	18.40	5.41	22.77	6.95
Underweight BMI	25.67	4.97	18.20	5.35	21.93	6.33
Total(Eating behaviour)	26.18	5.02	19.44	5.28	22.81	6.14

Table 3 (b): Summary table of two way ANOVA on Strategic planning across 6 groups

Sources	*SS*	*df*	*MS*	*F*
BMI	48.69	2	24.34	0.93
Eating behaviour	1020.10	1	1020.10	**38.97****
BMI× Eating behaviour	90.07	2	45.03	1.72
Error	2198.93	84	26.18	

**p<.01

Strategic planning is the third dimension of EFI, on which no significant main effect of BMI was observed. On the other hand, as shown in table 3(b) a significant main effect of eating behaviour has been found (F=38.97; p<.01) between healthy eating participants and unhealthy eating participants on strategic planning. Mean values for healthy eating behaviour group is (M=26.18), which is much higher than mean value of unhealthy eating group (M=19.44). This basically implies that Adolescents with healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and less barriers in modifying their eating habits had better strategic planning.

Whereas, no significant interaction effect has been observed on strategic planning.

Impulse control

Table 4 (a): Mean and SD values of impulse control of 6 groups

1. Eating behaviour→ **2. BMI** ↓	**Healthy eating group**		**Unhealthy eating group**		***Total (BMI)***	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Normal BMI	17.20	6.57	13.93	4.88	15.57	5.92
Overweight BMI	18.73	4.30	12.73	4.74	15.73	5.39
Underweight BMI	17.07	5.01	12.07	3.79	14.57	5.05
Total(Eating behaviour)	17.67	5.31	12.91	4.46	15.29	5.43

Table 4 (b): Summary table of two way ANOVA on impulse control across 6 groups

Sources	***SS***	***df***	***MS***	***F***
BMI	23.89	2	11.94	0.49
Eating behaviour	508.84	1	508.84	**20.72****
BMI× Eating behaviour	28.69	2	14.34	0.58
Error	2063.07	84	24.56	

**p<.01

Table 4 (b) depicts a summary of two way ANOVA across. The obtained F value shows that there is no significant main effect of BMI on impulse control. On the other hand significant main effect of eating behaviour (F=20.72, p<.01) was obtained i.e. healthy and unhealthy eating behaviour groups differ on impulse control ability. As it is clear from the Mean and SD values that healthy eating group (M=17.67) scored more than unhealthy eating group (M=12.91) i.e adolescents having healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and less barriers in modifying their eating habits scored better have greater control on temper and inappropriate urges. Further, no significant interaction effect has been observed on impulse control.

Empathy

Table 5 (a): Mean and SD values of Empathy of 6 groups

1. Eating behaviour→ 2. BMI ↓	Healthy eating group		Unhealthy eating group		*Total (BMI)*	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Normal BMI	21.40	2.97	20.80	4.00	21.10	3.48
Overweight BMI	22.00	5.06	20.07	2.84	21.03	4.15
Underweight BMI	20.00	4.22	20.40	2.50	20.20	3.42
Total(Eating behaviour)	21.13	4.16	20.42	3.12	20.78	3.68

Table 5 (b): Summary of two way ANOVA on empathy across 6 groups

Sources	***SS***	***df***	***MS***	***F***
BMI	15.09	2	7.54	0.55
Eating behaviour	11.38	1	11.38	0.83
BMI× Eating behaviour	20.56	2	10.28	0.75
Error	1156.53	84	13.77	

The results of two way ANOVA shows that no significant main effect of BMI and eating behaviour on empathy which means neither three BMI groups nor two eating behaviour groups do not differ with regard to empathy. Further, no significant interaction effect was observed on this dimension of EFI.

DISCUSSION

The objective of the present study was to evaluate the effect of eating behaviour and BMI on executive functioning (i.e. motivational drive, organisational ability, strategic planning, impulse control and empathy) in a sample of adolescents. Healthy eating behaviour includes healthy eating habits, active lifestyle, knowledge of healthy & unhealthy food, self-efficacy, no barriers affecting healthy food choices, nutritional and food safety knowledge. The first dimension of executive function Index is motivational drive, which means being energetic, enthusiastic and such people can not sit idle for long. The results shows that adolescents with high motivational drive tend to be those who had healthy dietary pattern, characterised by high intake of fruits, vegetables, cereals; knowledge of healthy & unhealthy food, self-efficacy, less barriers affecting healthy food choices, nutritional and food safety knowledge and physically active lifestyle. In other words, the enthusiasm to do new things was higher in adolescents who had healthy eating behaviour than those of unhealthy eating group. Second dimension of EFI is organisational ability, it refers to the ability to stay focussed on different tasks and using time, energy, strength, mental capacity, physical space etc. effectively and efficiently in order to achieve the desired outcome. In context of second dimension of EFI, results shows that adolescents with healthy eating habits having sufficient fresh fruits and vegetables, who have knowledge of healthy unhealthy food, have nutrition knowledge along with food safety knowledge, remain active and those who do not have any barriers affecting healthy food choices have better organizational ability. Third dimension of EFI is Strategic planning, it is the mental process that allows one to choose the necessary actions to reach a goal, decide the right order and establish a plan of action. The results of the present finding highlight that strategic planning ability was better in adolescent group with healthy eating behaviour i.e. eating according to nutritional knowledge, healthy & unhealthy food and food safety knowledge. Fourth dimension of EFI is inhibitory control, results revealed that adolescents in healthy eating group were better in inhibition control, which means adolescents having fruits, vegetables, grains, diary and protein in their daily meals and snacks i.e. healthy food choices along with active lifestyle, have better control on their impulses. They do not indulge in any risky behaviour & don't even lose temper when they get upset. Outcomes of the present findings are in line with the previous findings and confirmed that unhealthy eating pattern is related to more impulsive behaviour (Guerrieri, Nederkoorn & Jansen, 2008; Guerrieri, Nederkoorn, Jansen, Schrooten & Martijn, 2009; Wong & Mullan 2009; Nederkoorn, Houben, Hofmann, Roefs & Jansen 2010; Limbers & Yung 2015). It is noteworthy that there are studies which depict that sugar-sweetened beverages, sweet snack and salty/ fatty snack consumption is associated with poor inhibitory control (Riggs, Spruitz, Metz and Sakuma 2010; Ames, kisbusakarya & Reynolds 2014), pointing out poor inhibition control in individuals who consume unhealthy junck food. Fifth and last dimension of executive function Index is empathy, which refers to concern for the well being of other people. Empathetic people take other people's feelings into account while doing something. Obtained results indicate that both healthy eating group and unhealthy eating group did not differ on empathy, which means eating behaviour does not effect empathy.

Further, findings also indicate that there was no significant effect of BMI on executive function index. Previous studies have also reported no relationship between inhibitory ability and BMI (Volkow, Wang, Telang, Fowler, Goldstein & Alia, 2008 ;Duchesne. Mattos, Appolinário, Freitas, Coutinho & Santos, 2010). These findings support the results of the present study. However, few studies suggest that obese individuals demonstrate consistent impairment on complex executive functioning tasks measuring set shifting and decision making (Brogan, A., Hevey, D., & Pignatti, 2010; Davis, Patte, Curtis & Reid, 2010; Pignatti, Bertella, Albani, Mauro, Molinari, & Semenza 2006; Danner, Ouwehand, Haastert, Hornsveld & Ridder, 2012; Davis, Levitan, Muglia, Bewell, & Kennedy, 2004). The resuls of current investigation contradict these findings. This may be because, the sample of the present study did not any obese subject, all the participants in the higher BMI group were overweignt.

This study has provided evidence that executive functions were better in adolescents who had healthy eating behaviour i.e. healthy eating habits, active lifestyle, good nutritional knowledge, food safety knowledge and having less barriers affecting healthy food choices. Thus, to have have better exective functions healthy eating behaviour should be promoted. The present study also emphasis the need for developing intervention programs for school students that aim to inculcate healthy eating behaviors that may in turn also improve executive functions.

REFERENCES

Allom, V., & Mullan, B. (2014). Individual differences in executive function predict distinct eating behaviours. *Appetite*, *80*, 123–130.

Brogan, A., Hevey, D., & Pignatti, R. (2010). Anorexia, bulimia, and obesity: shared decision making deficits on the Iowa Gambling Task (IGT). *Journal of the International Neuropsychological Society*, 16(4), 711–715.

Burgess, P. W., Veitch, E., De Lacy Costello, A., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multi-tasking. *Neuropsychologia*, *38*, 848–863.

Cogill, S. R., Caplan, H. L., Alexandra, H., Robson, K. M., & Kumar, R. (1986). Impact of maternal postnatal depression on cognitive development of young children. *British Medical Journal*, 1165-1167.

Danner, U., Ouwehand, C., van Haastert, N., Hornsveld, H. & de Ridder, D. (2012). Decision making impairments in women with binge eating disorder in comparison with obese and normal weight women. *European Eating Disorders Review,* 20, 56–62.

Davis, C., Patte, K., Curtis, C., & Reid, C. (2010). Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite*, 54(1), 208–213.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 318*(5855), 1387-1388.

Duchesne, M., Mattos, P., Appolinário, J., de Freitas, S., Coutinho, G., Santos, C., et al. (2010). Assessment of executive functions in obese individuals with binge eating disorder. *Revista Brasileira de Psiquiatria*, 32, 381–388.

Grafman, J., & Litvan, I. (1999). Importance of deficits in executive functions. *Lancet, 354*(9194), 1921-1923.

Guerrieri, R., Nederkoorn, C., & Jansen, A. (2008). The interaction between impulsivity and a varied food environment: its influence on food intake and overweight. *International Journal of Obesity., 32*(4), 708–714.

Guerrieri, R., Nederkoorn, C., Schrooten, M., Martijn, C., & Jansen, A. (2009). Inducing impulsivity leads high and low restrained eaters into overeating, whereas current dieters stick to their diet. *Appetite, 53*(1), 93–100.

Gummeson, L., Jonsson, I., & Conner, M. (1997). Predicting intentions and behavior of Swedish 10-16-year-olds at breakfast. *Food Quality and Preference*, *8*, 297-306.

Jester, J. M., Nigg, T. J., Puttler, I. L., Long, C. J., Fitzgerald, H. E., & Zucker, R. A. (2009). Intergenerational transmission of neuropsychological executive functioning. *Brain and Cognition, 70*(1), 145-153.

Kassem, N. O., Lee, J. W., Modeste, N. N., & Johnston, P. K. (2003). Understanding soft drink consumption among female adolescents using the Theory of Planned Behavior. *Health Education Research*, *18*, 278-291.

Kim, J.Y., & Kang, S. W.(2017) Relationships between Dietary Intake and Cognitive Function in Healthy Korean Children and Adolescents. *Journal of lifestyle medicine,* 7(1), 10–17.

Limbers, C. A., & Young, D. (2015). Executive functions and consumption of fruits/ vegetables and high saturated fat foods in young adults. *Journal of Health Psychology., 20*(5), 602–611.

Mahoney, C. R., Taylor, H. A., & Kanarek, R. B. (2005). Effect of breakfast composition on cognitive processes in elementary school children. *Physiology of Behaviour., 85*, 635–645.

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychology., 29*(4), 389–393.

Nederkoorn, C., Braet, C., Van Eijs, Y., Tanghe, A., & Jansen, A. (2006). Why obese children cannot resist food: the role of impulsivity. *Eating Behaviour*., *7*, 315–322.

Nederkoorn, C., Smulders, F., Havermans, R., Roefs, A., & Jansen, A. (2006). Impulsivity in obese women. *Appetite, 47*(2), 253–256.

Oygard, L. & Rise, J. (1996). Predicting the intention to eat healthier food among young adults. *Health Education Research*, *11*, 453-461.

Pignatti, R., Bertella, L., Albani, G., Mauro, A., Molinari, E., & Semenza, C. (2006). Decision-making in obesity: a study using the gambling task. *Eating and Weight Disorders*, 11(3), 126–132.

Riggs, N. R., Chou, C. P., Spruijt-Metz, D., & Pentz, M. A. (2010). Executive cognitive function as a correlate and predictor of child food intake and physical activity. *Child Neuropsychology., 16*(3), 279–92.

Riggs, N. R., Spruijt-Metz, D., Sakuma, K. L., Chou, C. P., & Pentz, M. A. (2010). Executive cognitive function and food intake in children. *Journal of Nutritional Education and Behaviour., 42*(6), 398–403.

Riggs, N. R., Spruijt-Metz, D., & Sakuma, K. L. (2010) Executive cognitive function and food intake in children. *Journal of Nutritional Education and Behaviour, 42*, 398–403.

Sarsour, K., Sheridan, M., Douglas, J., Amani, N., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: the roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society*, *17*, 120-132.

Sedibe, M. H., Pisa, P. T., Feeley, A. B., Pedro, T. M., Kahn, K., & Norris, S. A. (2018). Dietary Habits and Eating Practices and Their Association with Overweight and

Obesity in Rural and Urban Black South African Adolescents. *Nutrients*, *10*(2), 145. doi:10.3390/nu10020145

Smith, E. E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science, 283*(5408), 1657-1661.

Spinella, M. (2005). Self-rated Executive function: development of the executive function Index. *International Journal of Neuroscience*., *115(5)*, 649–667.

Struss, D. T. & Knight, R. T. (2002). *Principles of frontal lobe function*. New York: Oxford University Press.

Talwar, V., Carlson, S. M., & Lee, K. (2011). Effects of punitive environment on children's executive functioning: a natural experiment. *Social Development, 20*(4), 805-824.

Turconi, G., Celsa, M., Rezzani, C., Biino, G., Sartirana, M. A., Roggi, C. (2003) Reliability of a dietary questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents. *European Journal of Clinical Nutrition, 57* (6),753.

Verplanken, B., & Faes, S. (1999). Good intentions, bad habits, and effects of forming implementation intentions on healthy eating. *European Journal of Social Psychology*, *29*, 591–604.

Volkow, N., Wang, G., Telang, F., Fowler, J., Goldstein, R., Alia-Klein, N., et al. (2008). Inverse association between BMI and prefrontal metabolic activity in healthy adults. *Obesity,* 17(1), 60–65.

Wesnes, K. A., Pincock, C., & Richardson, D. (2003). Breakfast reduced declines in attention and memory over the morning in schoolchildren. *Appetite, 41*, 329–331.

Wills, T. A., Isasi, C. R., Mendoza, D., & Ainette, M. G. (2007). Self-control constructs related to measures of dietary intake and physical activity in adolescents. *J. Adolescents. Health, 41*(6), 551–558.

Wong, C. L., & Mullan, B. A. (2009). Predicting breakfast consumption: an application of the theory of planned behaviour and the investigation of past behaviour and executive function. *British Journal of Health Psychology, 14*(3), 489–504.

Appendix D (II)
Research Paper - 2

International Peer Reviewed & Refereed Journal

Journal of Indian Health Psychology

VOL. 14, NO. 2, March, 2020

Owned, Printed & Published by Dr. N.K. Singh, F-4, 'Hari Sadan', 20, Ansari Road, Daryaganj, New Delhi-110002

Printed at: R.K. Offset, Naveen Shahdara, Delhi-110032.

CONTENTS

Effect of Eating Behaviour and Body Weight on Inhibition and Cognitive Flexibility Among Adolescents

Rekha and Deepti Hooda***

Abstract

Executive functions are necessary for the cognitive control of behavior in day to day life, which includes processes like attention control, cognitive inhibition, working memory, cognitive flexibility and problem solving. In the present study two executive functions i.e. cognitive inhibition and cognitive flexibility were taken into account. Executive functions (EF) are known to develop through childhood and adolescence. Limited research has examined eating behaviour in relation executive functions, especially among adolescents. Keeping this in mind, the present investigation was designed to study the effect of eating behavior and BMI on inhibition and Cognitive Flexibility of adolescents using a 3×2 factorial design (3 (BMI)×2(Eating behaviour). A sample of 102 adolescents (age 14-16 years) was selected from different schools using non-random technique. All respondents were assessed using Dietary Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents", BMI, Color-Word interference test of the Delis-Kaplan Executive Functions System (D-KEFS). Scoring was done as per the manual. The sample was divided into 6 groups on the basis of BMI and eating behaviour scores. Data was analyzed using two-way ANOVA. Results are discussed at length in full paper.

Keywords: executive functions, eating behaviour, BMI, school students

Executive functions (EFs) refer to a set of cognitive processes, required in working toward a goal, making judgments/decisions in novel or unforeseen situations and regulating thought and action. They are necessary for the cognitive

* Research Scholar, Department of Psychology, M.D. University, Rohtak

** Associate Professor (Supervisor), Department of Psychology, M.D. University, Rohtak

control of behavior: selecting and successfully monitoring behaviors that facilitate the attainment of chosen goals. EFs include basic cognitive processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility. Two core executive functions are inhibition and cognitive flexibility. Inhibition (inhibitory control) is the ability to control one's attention, behavior, thoughts, and emotions to override a strong another predisposition and do or perform what is needed. It is the capacity to obstruct automatic or habitual or dominant responses when they are not appropriate in a given the context (Miyake et al., 2000). It includes the ability to suppress the influence of interfering information (Barkley, 1999; Bexkens et al., 2015). Cognitive flexibility is the ability to flexibly adjust to new demands or rules and changing environment. It is the ability to flexibly switch between tasks. Task-switching, is also known as shifting which includes operating backwards and forwards among different mental sets or tasks or to think about multiple concepts simultaneously.

The development of Executive functions may begin during childhood and preadolescence, but it is the adolescence period that different brain systems become better integrated and the development of executive functions is at peak. This stage witnesses the development and implementation of executive functions more efficiently and effectively this time period (Garver, Urban, Lazar & Sweeney, 2004; Leon-Carrion, García-Orza, Pérez-Santamaría, 2004). The development of executive functions during childhood and adolescence are important to later successful adjustment and achievement.

EFs are affected by so many factors like Socio-economic status (SES), heredity, family environment, age, maternal depression and eating behaviour. Individual differences in eating behaviour have been hypothesized to contribute to Body Weight whether it is underweight or overweight. Studies in adults have demonstrated unhealthy dietary behaviors such as overeating and Consumption of high saturated fat foods is correlated with lower inhibition (Nederkoorn, Houben, Hofmann, Roefs & Jansen 2010; Limbers & Young 2015). Healthy dietary behaviours in adults which includes fruit and vegetable intake and eating breakfast are correlated with greater initiation/ planning skills (Allom & Mullan, 2014; Wong & Mullan 2009).

Relatively fewer studies have evaluated executive functions and dietary behaviours in school-aged children. These studies have reported that greater intake of high-caloric-low nutritional foods and lower consumption of fruits and vegetables are correlated with deficits in children's executive functions (Riggs, Spruijt-Metz, Sakuma, Chou & Pentz 2010; Wills, Isasi, Mendoza & Ainette 2007; Riggs, Chou, Spruijt-Metz & Pentz 2010; Tate, Unger, Chou, Spruijt-Metz, Pentz & Riggs 2015). Less healthy food choice is associated with increased impulsivity and reduced inhibitory control (e.g., Bryant et al., 2008; Jasinska et al., 2012)

To sum up, review of researches related to inhibition and eating behaviour fail to offer a clear picture of the relationship between variables under study. Moreover, the topic has mostly been examined from a clinical perspective of eating disorders or obesity with the focus on EF deficits in overweight populations. Further, only few studies would be traced that focused on EFs in relation to eating behaviour. Inconsistencies and limitations in the existing literature calls for more research in this area to solidify the relationships between

Therefore, the present study was conducted with the objective to examine inhibition and cognitive flexibility in relation to eating behaviour and body weight (BMI). This will provide important knowledge about eating behaviour and how it should be targeted to improve the efficacy of inhibition & flexibility.

Objectives:

1. To study the main effect of BMI on inhibition and cognitive flexibility among adolescents.
2. To study the main effect of eating behaviour on inhibition and cognitive flexibility among adolescents.
3. To study the interaction effect of BMI and Eating behaviour on inhibition and cognitive flexibility among adolescents.

Hypothesis:

1. There would be significant main effect of BMI on inhibition and cognitive flexibility among adolescents.
2. There would be significant main effect of eating behaviour on inhibition and cognitive flexibility among adolescents.
3. There would be significant interaction effect of BMI and Eating behaviour on inhibition and cognitive flexibility among adolescents.

Method

Design

3×2 Factorial design was used in the present study (3 BMI groups i.e Normal BMI, overweight and underweight and 2 eating behaviour groups (Healthy eating behaviour group and unhealthy eating behaviour group).

Sample

For the present study a sample of 102 adolescents of both sex (boys and girls) was selected from the different schools of Sonipat and Rohtak within the age range of 14-16 years (mean age= 15.4).

Tools

In this study the following tools were used in the present study to collect the required information from the subjects.

Body Weight:

BMI: BMI was measured by using the following formula

BMI = (Weight in kg) / (Height in meters)²

In case of adolescents after calculating BMI, it is expressed as a percentile. The BMI-for-age percentile growth charts are the most commonly used indicator to measure the size and growth patterns of children and adolescents. It is difficult to provide healthy weight ranges for children and teens because the interpretation of BMI depends on weight, height, age, and sex. BMI-for-age weight status categories and the corresponding percentiles ranges are as follows: Less than the 5^{th} percentile- Underweight, 5^{th} percentile to less than 85^{th} percentile -Normal or healthy weight, 85^{th} to less than 95^{th} percentile- Overweight and Equal to or greater than 95^{th} percentile- Obese. These percentiles are calculated from the CDC growth charts, which were based on national survey data collected from 1963-65 to 1988-94.

Inhibition and Cognitive flexibility (Executive Functions):

Delis- Kaplan Executive Function System (D-KEFS) - Colour -Word Interference Test: The D-KEFS is a battery of nine tests developed by Delis, Kaplan & Kramer (2001) designed to measure multiple types of executive functions. Out of these nine tests Colour -Word Interference Test was administered, which consists of four conditions: Color naming, word reading, inhibition and inhibition/ switching. Time (in sec) taken to complete the task was used as the outcome measure. Raw scores were converted to age and gender- specific scaled scores with a mean of 10 and standard deviation of 3, with lower scores signifying poorer performance.

Eating Behaviour:

Dietary Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents: This multidimensional eating behaviour questionnaire was developed by Turconi, Celsa, Rezzani, Sartirana & Roggi (2003) consists of 99 items. It is divided into nine sections relating to Frequency of Food Consumption, Food Habits, Physical Activity and Lifestyle, Healthy and Unhealthy Diet, Self-Efficacy, Barriers to Change, Nutrition Knowledge Section, Food Safety Knowledge, Food Safety and Behaviour in Hygiene Practices. Cronbach's alpha ranges from a minimum of 0.55 (section G) to a maximum of 0.75 (section C). Pearson correlation was used to assess test–retest reliability. Pearson correlation coefficients range from 0.78 to a maximum of 0.88.

Procedure

The present research work aims to explore the effect of eating behaviour on executive functions of adolescents. For this purpose the permission from the principals of schools and consent from students were sought and "Dietary

Questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents" and Color-Word Interference Test was administered on them after establishing rapport with them. Instructions relevant to each test were given to them and they filled the questionnaire according to the instructions mentioned. When the tests were completed, scoring was done according to the norms of each test. Then students were distributed in 6 groups (3×2 factorial design) based on their score on eating behaviour questionnaire and BMI. Firstly, respondents are divided into 3 groups based on their BMI i.e Normal BMI, overweight and underweight, out of which 2 groups are from normal BMI category and other 2 groups are from overweight BMI category and rest 2 groups are from underweight category and it has students who eat healthy and unhealthy in respective categories. Thus 6 groups are formed with 102 respondents out of 120 sample size rest 18 were dropped as they did not fall in healthy & unhealthy eating groups. Thus six groups are as follows 1. N(BMI)+HE i.e normal BMI with healthy eating behaviour 2. N(BMI)+UE i.e normal BMI with unhealthy behaviour 3. Ow+HE i.e overweight with healthy eating behaviour 4. Ow+UE i.e overweight with unhealthy eating behaviour 5. U+HE i.e underweight with healthy eating behaviour. 6. U+UE i.e underweight with unhealthy eating behaviour. The subjects were assured of the confidentiality of the information. The analyses were carried out to examine various hypothesis formulated earlier. The comparison of groups was made by administering analysis of variances.

Results

The data was analysed using two-way ANOVA on Statistical Package for Social Sciences (SPSS. The colour- word interference test assesses linguistic ability (Colour naming and word reading), inhibition and cognitive flexibility (switching).

The Condition 1 of the Color-Word Interference test i.e. *Colour Naming*, requires basic naming skills. The results of two-way analysis of the variance on scores on condition 1, are shown in the table 1(a) and 1(b).

Table 1(a)

Mean and SD values of colour naming (6 groups)

1.Eating behaviour'→ 2. BMI ↓	*Healthy eating group*		*Unhealthy eating group*		*Total (BMI)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Normal BMI	8.82	2.57	6.11	3.56	7.47	3.35
Overweight BMI	6.58	3.02	5.88	3.62	6.23	3.30
Underweight BMI	7.05	2.72	2.29	1.75	4.67	3.30
Total (Eating behaviour)	7.49	2.89	4.76	3.51	6.12	3.48

Table 1 (b)

Summary table of two way ANOVA on colour naming

Sources	*SS*	*df*	*MS*	*F*
BMI	133.31	2	66.65	7.66*
Eating behaviour	189.42	1	189.42	21.78*
BMI× Eating behaviour	70.02	2	35.01	4.02*
Error	834.58	96	8.69	

**p<.05

The results of two-way ANOVA on colour naming shows significant difference (F=7.66; pd".05) among 3 BMI groups. Similarly, significant main effect of eating behaviour has been found (F=21.78; p<.05) between healthy eating participants and unhealthy eating participants on colour naming. Mean values for healthy eating behaviour group is (M=7.49), which is much higher than mean value of unhealthy eating group (M=4.76). This implies that adolescents with healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and fewer barriers in modifying their eating habits had better speed in naming (linguistic skill). Along with significant main effect of BMI and Eating Behaviour differences, a significant interaction effect (F=4.02; pd".05) has been found between the two factors i.e. BMI (3 levels) and eating behaviour (2 levels).Further, post hoc analysis was applied, the results are shown in table 1(c) and 1(d).

Table 1 (c)

Significance of mean differences based on Post hoc (LSD) test on colour naming of three BMI groups

BMI Groups	*Normal* 7.4706	*Overweight* 6.2353	*Underweight* 4.6765
Normal 7.4706	-	1.23	2.79*
Overweight 6.2353		-	1.55*
Underweight 4.6765			-

*p<.05

Table 1(c) highlights that underweight students (healthy and unhealthy eating behaviour), significantly differ from Normal BMI students as well as overweight students. No significant difference has been found between students of normal BMI and overweight. The post hoc (LSD) for the interaction effect as shown in Table 1(d) reveals that underweight students having unhealthy eating (Mean=2.29) differ on colour naming from all participants across BMI and Eating behaviour groups. Similarly, normal BMI with Healthy eating group (Mean=8.82) differ on colour naming from all BMI and Eating behaviour groups except underweight students with healthy eating behaviour. Other respondents of various BMI group and eating behaviour groups do not significantly differ from each other.

Table 1 (d)

Significance of mean differences based on Post hoc (LSD) test on colour naming across 6 groups

BMI× Eating behaviour	*N+HE* 8.82	*N+UE* 6.11	*OW+HE* 6.58	*OW+UE* 5.88	*UW+HE* 7.05	*UW+UE* 2.29
N+HE 8.82	-	2.70*	2.23*	2.94*	1.76	6.52*
N+UE 6.11		-	-.47	.23	-.94	3.82*
OW+HE 6.58			-	.70	-.47	4.29*
OW+UE 5.88				-	-1.17	3.58*
UW+HE 7.05					-	4.76*
UW+UE 2.29						-

*p<.05

Colour Reading, condition 2 of the Color-Word Interference test, requires basic reading skills. Table 2(a) and 2(b) depict the results two-way analysis of the variance on scores on condition 2. The two-way analysis of variance shows significant main effect of body weight (BMI) difference (F=10.24; pd".05) among 3 BMI groups. Similarly, significant main effect of eating behaviour has been found (F=26.06; pd".05) between healthy eating participants and unhealthy eating participants on word reading. Mean value for healthy eating behaviour group is (M=7.90), which is much higher than the mean value of unhealthy eating group (M=5.23). This implies that Adolescents with healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and fewer barriers in modifying their eating habits had better speed of reading (linguistic skill). Along with significant main effect of BMI and Eating Behaviour, a significant interaction effect of BMI (3 levels) and eating behaviour (2 levels) (F=3.69; pd".05) has been observed. A post hoc analysis (LSD) was also applied to compare multiple mean groups.

Table 2 (a)

Mean and SD values of word reading of 6 groups

1.Eating behaviour'→ 2. BMI ↓	*Healthy eating group*		*Unhealthy eating group*		*Total (BMI)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Normal BMI	9.11	2.39	6.58	3.06	7.85	2.99
Overweight BMI	7.35	2.34	6.35	3.16	6.85	2.78
Underweight BMI	7.23	2.75	2.76	1.88	5.00	3.24
Total(Eating behaviour)	7.90	2.60	5.23	3.23	6.56	3.21

Table 2 (b)

Summary table of two way ANOVA on word reading across 6 groups

Sources	*SS*	*df*	*MS*	*F*
BMI	142.49	2	71.24	10.24*
Eating behaviour	181.33	1	181.33	26.06*
BMI× Eating behaviour	51.43	2	25.71	3.69*
Error	667.76	96	6.95	

*p<.05

Table 2 (c)

Significance of mean differences based on Post hoc (LSD) test on word Reading of three BMI groups

BMI Groups	*Normal* 7.85	*Overweight* 6.85	*Underweight* 5.00
Normal 7.85	-	1.00	2.85*
Overweight 6.85		-	1.85*
Underweight 5.00			-

*p<.05

Table 2 (d)

Significance of mean differences based on Post hoc (LSD) test on Word Reading across 6 groups

BMI× Eating behaviour	*N+HE* 9.11	*N+UE* 6.58	*OW+HE* 7.35	*OW+UE* 6.35	*UW+HE* 7.23	*UW+UE* 2.76
N+HE 9.11	-	2.52*	1.76	2.76*	1.88*	6.35*
N+UE 6.58		-	-.76	.23	-.64	3.82*
OW+HE 7.35			-	1.00	.11	4.58*
OW+UE 6.35				-	-.88	3.58*
UW+HE 7.23					-	4.47*
UW+UE 2.76						-

*p<.05

The results of post hoc analysis as shown in table 2(c) indicate that underweight students (healthy and unhealthy eating behaviour), significantly differ from Normal BMI and overweight students. No significant difference has been found between students of normal BMI and overweight on word reading ability. The post hoc (LSD) for the interaction effect as shown in table 2(d) reveals that underweight students having unhealthy eating (Mean=2.76) differ on word reading from all students across BMI and Eating behaviour groups. Similarly, normal BMI with Healthy eating group (Mean=9.11) differs on word reading from all school students (adolescents) across BMI and Eating behaviour groups except overweight students with healthy eating behaviour. Other BMI group and eating behaviour groups do not significantly differ from each other.

Inhibition, condition 3 of the Color-Word Interference test, assess the ability to control one's automatic responses to do or give a more appropriate or needed response. The respondents were required to inhibit the more salient, automatic task of reading words in order to name the color of the ink in which the words were printed. Table 3(a) and 3(b) depict the results of two-way analysis of the variance on scores on condition 3.

Table 3 (a)

Mean and SD values on inhibition

1.Eating behaviour'→ 2. BMI ↓	*Healthy eating group*		*Unhealthy eating group*		*Total (BMI)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Normal BMI	8.18	3.15	5.76	2.11	6.97	2.91
Overweight BMI	5.59	2.67	5.23	1.75	5.41	2.23
Underweight BMI	6.41	2.18	3.47	3.68	4.94	3.33
Total(Eating behaviour)	6.72	2.68	4.82	3.02	5.77	2.96

Table 3 (b)

Summary table of two way ANOVA on inhibition

Sources	*SS*	*df*	*MS*	*F*
BMI	76.72	2	38.36	5.38*
Eating behaviour	70.83	1	70.83	9.93*
BMI× Eating behaviour	53.20	2	26.60	3.73*
Error	685.06	96	7.14	

*p<.05

The results of two- way ANOVA on inhibition show significant difference (F=5.38; pd".05) among 3 BMI groups i.e. healthy BMI, overweight and underweight. This implies that three BMI groups differ with regard to their inhibition ability. Similarly, significant main effect of eating behaviour was observed between healthy eating and unhealthy eating school students (F=9.93; p<.05). Mean value for healthy eating behaviour group is (M=6.72), which is much higher than the mean value of unhealthy eating group (M=4.82). This basically implies that adolescents with healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and fewer barriers in modifying their eating habits had better inhibition. A significant interaction effect of BMI (3 level) and eating behaviour (2 level) (F=3.73; p<.05) has been observed on inhibition, further post hoc test was applied.

Table 3 (c)

Significance of mean differences based on Post hoc (LSD) test on inhibition of three BMI groups

BMI Groups	*Normal* (6.97)	*Overweight* (5.41)	*Underweight* (4.94)
Normal (6.97)	-	1.56*	2.03*
Overweight (5.41)		-	.47
Underweight (4.94)			-

*p<.05

Table 3(c) indicates the results of post hoc analysis that report normal BMI group (healthy and unhealthy eating behaviour) to be significantly higher from overweight and underweight students. On the other hand, no difference has been obtained between overweight and underweight on inhibition. The results of post hoc analysis for the interaction effect as shown in table 3(d) reveals that Normal BMI students having healthy eating (Mean=8.18) significantly differ from all other groups across BMI and Eating behaviour except the group underweight having healthy eating behaviour. Normal BMI students with healthy eating behaviour (Mean=8.18) have scored the highest score and differ on inhibition from all participants across BMI and Eating behaviour groups except underweight students with healthy eating habits. Further, findings of the post-hoc (LSD) confirm that underweight students with unhealthy eating habits (Mean=3.47) have scored lowest on inhibition and hence significantly differ on inhibition from all students across BMI and Eating behaviour groups except overweight students with unhealthy eating behaviour. Other BMI groups and eating behaviour groups do not significantly differ from each other.

Table 3 (d)

Significance of mean differences based on post hoc (LSD) test on Inhibition across 6 groups

BMI× Eating behaviour	*N+HE* 8.18	*N+UE* 5.76	*OW+HE* 5.59	*OW+UE* 5.23	*UW+HE* 6.41	*UW+UE* 3.47
N+HE 8.18	-	2.42*	2.59*	2.95*	1.77	4.71*
N+UE 5.76		-	.17	.53	.65	2.29*
OW+HE 5.59			-	-36	.82	2.12*
OW+UE 5.23				-	1.18	1.76
UW+HE 6.41					-	2.94*
UW+UE 3.47						

*p<05

The Condition 4 of the Color-Word Interference, *Inhibition/ Switching (Cognitive Flexibility)*, requires adequate naming speed, reading speed, verbal inhibition, and cognitive flexibility. The results of two-way analysis of the variance on scores on condition 4, are shown in the table 4(a) and 4(b). Two Way ANOVA showed significant main effect Eating Behaviour on inhibition/switching (F=5.83; pd".05). On the other hand, no significant main effect of BMI & interaction effect has been found on inhibition/switching. Table 4(a) reveals that the mean scores (Mean=8.50) of students having healthy eating behaviour differ significantly from those students who were having unhealthy eating habits (Mean= 7.19). This basically implies that Adolescents with healthy food habits, good nutritional knowledge, active lifestyle, better food safety knowledge, hygienic food and less barriers in modifying their eating habits had better cognitive flexibility

Table 4(a)

Mean and SD values of inhibition/switching of 6 groups

1.Eating behaviour'→ *2. BMI* ↓	*Healthy eating group*		*Unhealthy eating group*		*Total (BMI)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Normal BMI	9.17	1.62	8.00	2.73	8.58	2.29
Overweight BMI	8.05	2.10	6.88	2.64	7.47	2.42
Underweight BMI	8.29	3.65	6.70	3.21	7.50	3.48
Total(Eating behaviour)	8.50	2.60	7.19	2.87	7.85	2.80

Table 4 (b)

Summary table of two way ANOVA on inhibition/switching

Sources	*SS*	*df*	*MS*	*F*
BMI	27.58	2	13.79	1.82
Eating behaviour	44.01	1	44.01	5.83*
BMI× Eating behaviour	.96	2	.48	.06
Error	1760.0	96	18.33	

*p<.05

Discussion

The objective of the present study was to evaluate the effect of eating behaviour and BMI on executive functioning (i.e. inhibition and Flexibility) in a sample of school students. The results show that adolescents, who had healthy dietary pattern, high intake of fruits, vegetables, cereals; knowledge of healthy & unhealthy food, self-efficacy, fewer barriers affecting healthy food choices, and lead physically active lifestyle had better linguistic ability. Linguistic ability (colour naming and reading), was found to be best in adolescents who had healthy eating behaviour and normal body weight (BMI). Whereas underweight school students who had unhealthy eating behaviour performed poorest on linguistic ability tasks (colour naming and colour reading) as compared to all other adolescents/ school students.

Inhibitory control, ability to inhibit impulses or habitual/ dominant responses in order to make a more appropriate response in the particular situation, without which individual would be slave of impulses and old habits. The results of the present findings highlight that normal BMI adolescents were good at inhibition as compared to overweight and underweight students. However, the research findings of Frazier-wood et al. (2014) did not to find any association between response inhibition and BMI. Adolescent school students with healthy eating behaviour were better at inhibition task i.e. they had good inhibition control as compared to unhealthy eating behaviour. Students with normal body weight (BMI) and healthy eating behaviour had better performance on inhibition task. These results are in line with other studies and confirmed that adolescents with normal body weight have better inhibitory control than overweight and underweight adolescents (Nederkoorn, Braet, Eijs, Tanghe & Jansen 2006). Gailliot & Baumeister (2007) suggested that as inhibition depletes large amount of blood glucose, which is one of the important part of the energy source of self- control/ inhibition, low level of blood glucose after initial attempt on self-control / inhibition tasks results in poor performance on later subsequent attempts. Further,it was observed that intake of glucose rich food items reduce the impaired performance after initial attempt. Volkow et al. (2009) reported a negative association between the BMI and the baseline prefrontal metabolic activity that is likely to result in cognitive impairment among healthy overweight/obese. Duchesne et al. (2010) found that obese individuals with binge eating disorder had impairments in problem-solving ability, cognitive flexibility and working memory. Thus, pointing towards the influence of healthy diet and ideal body weight on inhibition/ inhibitory control.

The results of the present study also report significant effect of eating behaviour on cognitive flexibility, which implies that students with healthy eating behaviour performed better on cognitive flexibility task, condition 4 (inhibition/ switching). Effect of healthy and balanced eating on cognitive flexibility was also reported by Khan, Raine, Drollette, Scudder & Hillman (2015), they found that children consuming diets higher in saturated fats and cholesterol exhibit compromised ability to flexibly modulate their cognitive operations, specially under greater cognitive challenge. Whereas no significant difference was observed on cognitive flexibility among different BMI groups and no interaction effect of BMI and eating behaviour was observed. One possible reason of no difference in performance on condition 4 (inhibition/switching) among different BMI and eating behaviour groups may be practice effect. By the time a individuals reach condition 4, inhibition/switching, he or she may be to some extend have practiced the inhibition process on the inhibition (condition 3) and put this skill to use on the inhibition/switching (condition 4), which may decrease time taken and errors committed on the inhibition/switching trial. There are studies which have pointed out an atypical pattern of performance on the colour-word interference task, where individuals perform faster, with equal or fewer errors, on the supposedly more difficult inhibition/switching than the inhibition task (Berg, Swan, Banks & Miller, 2016; Lippa, S. M., & Davis, 2010).

A number a studies on role of fatty acids in cognition observed that in children, low polyunsaturated fatty acids in blood (n-3 PUFA) have been associated with an increased risk of developing cognitive deficits, attention deficit hyperactivity disorder (ADHD) and autism (Frensham, Bryan, & Parletta, 2012; Ramakrishnan, Imhoff-Kunsch & DiGirolamo, 2009). Whether these differences are due to poor nutritional and diet intake or due to altered polyunsaturated fatty acids metabolism is not clear (Young, G. S., Maharaj, N. J. & Conquer, 2004). Montgomery, Burton, Sewell, Spreckelsen, & Richardson (2013) reported that lower DHA (Docosahexaenoic Acid) concentrations were associated with poorer reading ability and working memory performance. Joffre, Nadjar, Lebbadi, Calon, & Laye, (2014) found that DHA, an omega 3 fatty acid, is a potential suitable micronutrient for the maintenance of cognitive performance at all periods of life. Kuratko, Barrett, Nelson, & Salem, (2013) reported the important role of DHA not only in cognitive functions but also in school performance. Thus, healthy eating which includes foods rich in PUFA and DHA like chia seeds, flex seeds, walnuts, cod liver oil, Sunflower seeds and fish e.g. salmon influence cognitive functions.

Based on the results of the study, it can be concluded that normal body weight (BMI) adolescents with healthy eating behaviour (active lifestyle, taking healthy and balanced diet, good nutritional knowledge, food safety knowledge and having fewer barriers affecting healthy food choices) have better executive functions (inhibition and cognitive switching/ flexibility). Thus, the results emphasize the need for developing intervention programs for school students that aim to promote healthy eating behaviour and maintain normal or healthy body weight which may in turn improve inhibition and cognitive flexibility.

References

Allom, V., & Mullan, B. (2014). Individual differences in executive function predict distinct eating behaviours. *Appetite*, *80*, 123–130.

Berg, Jody-Lynn., Swan, N. M., Banks, S. J. & Miller, J. B. (2016) Atypical performance patterns on Delis–Kaplan Executive Functioning System Color–Word Interference Test: Cognitive switching and learning ability in older adults, *Journal of Clinical and Experimental Neuropsychology*, 38:7, 745-751, DOI: 10.1080/13803395.2016.1161734

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System (D-KEFS): Examiner's manual*. San Antonio, TX: The Psychological Corporation.

Duchesne, M., Mattos, P., Appolinário, J. C., de Freitas, S. R., Coutinho, G., Santos, C., & Coutinho, W. (2010). Assessment of executive functions in obese individuals with binge eating disorder. *Revista brasileira de psiquiatria*, *32*(4), 381–388. https://doi.org/10.1590/s1516-44462010000400011

Frazier-Wood, A. C., Carnell, S., Pena, O., Hughes, S. O., O'Connor, T. M., Asherson, P., & Kuntsi, J. (2014). Cognitive performance and BMI in childhood: Shared genetic influences between reaction time but not response inhibition. *Obesity (Silver Spring, Md.)*, *22*(11), 2312–2318. https://doi.org/10.1002/oby.20862

Frensham, L. J., Bryan, J., & Parletta, N. (2012). Influences of micronutrient and omega-3 fatty acid supplementation on cognition, learning, and behavior: methodological considerations and implications for children and adolescents in developed societies. *Nutrition reviews*, *70*(10), 594–610. https://doi.org/10.1111/j.1753-4887.2012.00516.x

Gailliot, M. T., Baumeister, R. F., DeWall, C. N., Maner, J. K., Plant, E. A., Tice, D. M., Brewer, L. E., & Schmeichel, B. J. (2007). Self-control relies on glucose as a limited energy source: willpower is more than a metaphor. *Journal of personality and social psychology*, *92*(2), 325–336. https://doi.org/10.1037/0022-3514.92.2.325

Joffre, C., Nadjar, A., Lebbadi, M., Calon, F., & Laye, S. (2014). n-3 LCPUFA improves cognition: the young, the old and the sick. *Prostaglandins, leukotrienes, and essential fatty acids*, *91*(1-2), 1–20. https://doi.org/10.1016/j.plefa.2014.05.001

Khan, N. A., Raine, L. B., Drollette, E. S., Scudder, M. R., & Hillman, C. H. (2015). The relation of saturated fats and dietary cholesterol to childhood cognitive flexibility. *Appetite*, *93*, 51–56. https://doi.org/10.1016/j.appet.2015.04.012

Kuratko, C. N., Barrett, E. C., Nelson, E. B., & Salem, N., Jr (2013). The relationship of docosahexaenoic acid (DHA) with learning and behavior in healthy children: a review. *Nutrients*, *5*(7), 2777–2810. https://doi.org/10.3390/nu5072777

Lippa, S. M., & Davis, R. N. (2010). Inhibition/switching is not necessarily harder than inhibition: an analysis of the D-KEFS color-word interference test. *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists*, *25*(2), 146–152. https://doi.org/10.1093/arclin/acq001

Leon-Carrion, J.; García-Orza, J.; Pérez-Santamaría, FJ (2004). Development of the inhibitory component of the executive functions in children and adolescents. *International Journal of Neuroscience*, 114 *(10): 1291–1311. doi:10.1080/00207450490476066. PMID 15370187.*

Limbers, C. A., & Young, D. (2015). Executive functions and consumption of fruits/vegetables and high saturated fat foods in young adults. *Journal of Health Psychology.*, *20*(5), 602–611.

Luna, B; Garver, K.E.; Urban, TA; Lazar, N.A.; Sweeney, J.A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development,* ***75*** *(5): 1357–1372. CiteSeerX 10.1.1.498.6633. doi:10.1111/j.1467-8624.2004.00745.x. PMID 15369519.*

Montgomery, P., Burton, J. R., Sewell, R. P., Spreckelsen, T. F., & Richardson, A. J. (2013). Low blood long chain omega-3 fatty acids in UK children are associated with poor cognitive performance and behavior: a cross-sectional analysis from the DOLAB study. *PloS one*, *8*(6), e66697. https://doi.org/10.1371/journal.pone.0066697

Nederkoorn, C., Braet, C., Van Eijs, Y., Tanghe, A., & Jansen, A. (2006). Why obese children cannot resist food: the role of impulsivity. *Eating Behaviour.*, *7*, 315–322.

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychology.*, *29*(4), 389–393.

Ramakrishnan, U., Imhoff-Kunsch, B., & DiGirolamo, A. M. (2009). Role of docosahexaenoic acid in maternal and child mental health. *The American journal of clinical nutrition*, *89*(3), 958S–962S. https://doi.org/10.3945/ajcn.2008.26692F

Riggs, N. R., Chou, C. P., Spruijt-Metz, D., & Pentz, M. A. (2010). Executive cognitive function as a correlate and predictor of child food intake and physical activity. *Child Neuropsychology.*, *16*(3), 279–92.

Riggs, N. R., Spruijt-Metz, D., Sakuma, K. L., Chou, C. P., & Pentz, M. A. (2010). Executive cognitive function and food intake in children. *Journal of nutrition education and behavior*, *42*(6), 398–403. https://doi.org/10.1016/j.jneb.2009.11.003

Turconi, G., Celsa, M., Rezzani, C., Biino, G., Sartirana, M. A., Roggi, C. (2003) Reliability of a dietary questionnaire on food habits, eating behaviour and nutritional knowledge of adolescents. *European Journal of Clinical Nutrition*, *57* (6),753.

Volkow, N. D., Wang, G. J., Telang, F., Fowler, J. S., Goldstein, R. Z., Alia-Klein, N., Logan, J., Wong, C., Thanos, P. K., Ma, Y., & Pradhan, K. (2009). Inverse association between BMI and prefrontal metabolic activity in healthy adults. *Obesity (Silver Spring, Md.)*, *17*(1), 60–65. https://doi.org/10.1038/oby.2008.469

Wills, T. A., Isasi, C. R., Mendoza, D., & Ainette, M. G. (2007). Self-control constructs related to measures of dietary intake and physical activity in adolescents. *J. Adolescents. Health*, *41*(6), 551–558.

Wong, C. L., & Mullan, B. A. (2009). Predicting breakfast consumption: an application of the theory of planned behaviour and the investigation of past behaviour and executive function. *British Journal of Health Psychology*, *14*(3), 489–504.

Young, G. S., Maharaj, N. J., & Conquer, J. A. (2004). Blood phospholipid fatty acid analysis of adults with and without attention deficit/hyperactivity disorder. *Lipids*, *39*(2), 117–123. https://doi.org/10.1007/s11745-004-1209-3