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Original Article

Biochemistry Section

Effect of Vitamin C Supplementation on Anthropometric Measurements, Lipid Profile and Atherogenic Indices in Obese and Non Obese Individuals

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ABSTRACT

Introduction: The prevalence of obesity is increasing day by day in India. Since obesity is associated with occurrence of oxidative stress, antioxidants can be used to treat the obesity and overcome associated complications.

Aim: The present study was aimed to analyse the effect of vitamin C intake on anthropometric measurements, lipid profile and atherogenic indices in obese and non obese individuals and to find out the correlation between study variables.

Materials and Methods: Total 39 male individuals; 20 obese and 19 non obese were involved in this study and they received 1500 mg vitamin C daily for three months. After 12-14 hours of overnight fast, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Body Mass Index (BMI), Body Adiposity Index (BAI), Waist Circumference (WC), Hip Circumference (HC), Waist to Hip Ratio (WHR), Waist to Height Ratio (WHtR), serum lipid profile and atherogenic indices were measured, in obese and non obese individuals, at the initiation of the work and after consumption of vitamin C, by the end of three months. Total study subjects were divided into two groups for convenience and called on two consecutive days. Data were analysed by using two tailed Student's t-test.

Results: Present study reported significant decrease in SBP, BMI, BAI, WC, HC, WHR, WHtR, in both obese and non obese individuals and significant decrease in TC, TG, VLDL-C but no alteration in Low Density Lipoprotein-Cholesterol (LDL-C) and HDL-C in obese individuals. Similarly, no significant changes were observed in lipid profile of non obese and atherogenic indices of both obese and non obese subjects, after the consumption of vitamin C.

Conclusion: Present study concludes that, daily intake of 1500 mg of vitamin C has positive lowering effect on anthropometric measurements and lipid profile however it is not significantly effective in lowering atherogenic indices in a short span of three months. Long term administration of vitamin C may be helpful for dieticians and clinicians in advising high intake of vitamin C through the diet like amla, guava, citrus fruits etc., in controlling obesity and related disorders.

Keywords: Atherogenic index, Body mass index, Obesity, Plasma, Total cholesterol, Triglycerides

INTRODUCTION

Cardiovascular Diseases (CVDs), particularly Coronary Heart Disease (CHD), have achieved rampant proportion globally. Worldwide CVD resulted in 17.5 million deaths in 2012 [1]. In developing countries like India, the mortality from CHD is rapidly increasing in contrast to developed countries [2]. This increase is motivated by urbanization, industrialization and related lifestyle changes [3]. It has been reported by the Registrar General of India that, CHD resulted in 17% of total deaths and 26% of adult deaths in 2001-2003, which again progressed to 23% of total and 32% of adult deaths in 2010-2013 [4]. Hypercholesterolemia is the major cause of CHD and premature death and disability in India, therefore estimation of cardiovascular risk has become the cornerstone of CVD prevention [2,5,6].

It has been found that, abnormalities in lipoprotein metabolism are one of the important factors that lead to atherogenesis and represent about 50% of the attributable population risk of developing CVD management [7]. Recently, epidemiologists and clinicians have agreed that, coronary risk assessment based solely on LDL-C is not enough [8], especially in subjects who are at intermediate risk of developing cardiovascular complications [9].

Vitamin C reduces the risk of CHD by ameliorating plasma Total Cholesterol (TC) [10,11]. It incorporates at the 7-alpha hydroxylation stage and helps in the transformation of cholesterol into bile acids [12]. It is also an essential cofactor for the biosynthesis of carnitine [13,14] which is a key metabolite for the β-oxidation of fatty acids [15,16]. Besides that, various other important functions are carried out by the vitamin C which involve; stimulation of various enzymes, collagen maturation, activation of certain hormones, acts as antioxidant, detoxifies histamine and various drugs, phagocytosis, nitrosamine formation etc., [17]. So, overall vitamin C has a multifactorial role and positive impact on the human body.

In the previous studies, supplementation of 500 mg of vitamin C/day reduced serum TC by 7.6 mg/dL and 17.2 mg/dL in both borderline-high and high cholesterolemic groups respectively [11] and in the subjects who had taken 700 mg/day of vitamin C showed 25% reduction in incidence of CHD [18]. The relation of plasma vitamin C with BMI [19], WHR [20] and CVD [21] is inverse and overweight women showed weight reduction [22] after the intake of vitamin C.

Recently different atherogenic indices like CRI-I [23-25], CRI-II [26], AC [27] and AIP [28,29] are used and found superior to predict cardiovascular health than independently determined Triglycerides (TG), LDL-C or HDL-C. However, surprisingly there is hardly any study which has seen the effect of vitamin C on atherogenic indices in human subjects. Present study was therefore designed to investigate the effect of vitamin C intake on anthropometric measurements, lipid profile and atherogenic indices in obese and non obese individuals.

MATERIALS AND METHODS

This was the interventional type of study, which involved obese and non obese individuals from the Krishna Institute of Medical Sciences deemed to be University and proximal location. Study was carried out in the Department of Biochemistry, Krishna Institute of Medical sciences and Research Centre, Karad, Maharashtra, during July 2016-October 2017. Sample size was calculated with the help of software based on the other studies [30,31]. A total of 39 male subjects; 20 obese and 19 non obese were selected for the present study.

Ethical Approval and Consent to Participate

The present study design was reviewed and approved by the Institutional Ethics Committee of Krishna Institute of Medical Sciences (Ethic committee Registration number ECR/307/Inst/MH/2013), with the IEC approval letter number KIMSDU/KIMS/IEC/3/2013.

Declaration and written informed consent was obtained from all the subjects who desired to participate in this work. All the demographic, social and clinical data were obtained by interview using a questionnaire.

Utmost care in accordance with the Declaration of Helsinki 1975; revised in 2000 [32] was practiced during this work.

Inclusion criteria: Non-alcoholic, non-smoker, apparently healthy male subjects, of the age 20-45 years, were selected for the present study.

Exclusion criteria: Subjects with diabetes mellitus, tuberculosis, malignancy, hepatitis, renal diseases, Cushing's syndrome, hypothyroidism and those on hypolipidaemic drugs were excluded from the study. Subjects on medication for minor or major illnesses were also excluded from this study.

Blood Pressure and Anthropometric Measurements

The resting blood pressures; SBP and DBP were recorded with sphygmomanometer, following standard procedure. Body height was measured with a standard stadiometer and weight on weighing scale. WC and HC were recorded in duplicate to the nearest 0.10 cm with a stress resistant tape to ensure constant tension during measurement. The WC was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest using a stretch resistant tape. HC was measured around the widest portion of the buttocks, with the tape parallel to the floor. BMI was calculated as weight in kilogram divided by height in square meter (kg/m^2) and subjects were considered obese if their BMI is ≥25 and non obese if their BMI is ≥18.5 upto 22.9 [33], WHR, as waist circumference (cm) divided by hip circumference (cm).

BAI was calculated as, {HC (cm)/Height $(m)^{1.5}$-18} [34] and Waist to Height Ratio (WHtR) as waist circumference (cm) divided by their height (cm).

Blood Collection and Biochemical Analyses

Total 5 mL of blood was drawn by puncturing the antecubital vein in a clot vial bulb, separated at 3500 rpm within 1 hour and analysed for different biochemical parameters. Then all the participants were provided with 500 mg of vitamin C tablets and asked to take 3 tablets daily after breakfast, lunch and dinner for three months. Regular follow-up was taken either by meeting them or making phone calls.

All the subjects had taken vitamin C tablets regularly for three months. Initially, few people felt nausea after taking vitamin C, otherwise nobody experienced any major complaint. There was no drop out in the present study. After three months, all the anthropometric measurements were recorded again and blood samples were collected and analysed for biochemical investigations.

Lipid profile was assessed using commercially available kits from Erba Mannheim company by using EM 360 fully automated analyser. For the TC determination reagent used was based on the formulation of Allain CC et al., [35] which was further improved by Roeschlau P et al., [35,36]. HDL assay was based on the modified Poly-Vinyl Sulfonic acid (PVS) and Polyethylene-Glycol-Methyl Ether (PEGME) coupled classic precipitation method with the improvement in using optimised quantities of PVS/PEGME and selected detergents [37]. Triglyceride estimation was based on the principle of McGowan [38]. Plasma Very Low-Density Cholesterol (VLDL-C) and LDL-C were calculated by using the Friedewald equation [39] as follow: VLDL-C=TG/5 and LDL-C={(TC)-(HDL-C+VLDL-C)}.

Calculation of Atherogenic Indices

The atherogenic indices were calculated as, Castelli's Risk Index-I (CRI-I)=TC/HDL-C, Castelli's Risk Index-II (CRI-II)=LDL-C/HDL-C [40], Atherogenic Coefficient (AC)=(TC-HDL-C)/HDL-C [41] and Atherogenic Index of Plasma (AIP)=log (TG/HDL-C) [42].

STATISTICAL ANALYSIS

Data were reported as mean±SD, and all statistical analyses were performed using SPSS, version 20. The two-tailed Student's t-test was used to evaluate differences between study parameters, assessed before and after the supplementation of vitamin C. Pearson correlation coefficients between study variable of obese and non obese were determined. Differences and correlation coefficients were considered significant if $p<0.05$.

RESULTS

Following results were obtained in obese and non obese subjects, in obese individuals there was significant reduction in SBP, BMI, BAI, WC, HC, WHR, WHtR, TC, TG and VLDL-C [Table/Fig-1].

Obese males* (n=20)				
Parameters	3 months before vitamin C intake (Mean±SD)	After 3 months of vitamin C intake (Mean±SD)	t-test value	p-value
1. SBP (mmHg)	128±11	125±6	t=3.298	**p=0.0038**
2. DBP (mmHg)	82±5	81±2	t=1.252	p=0.2258
A. Anthropometric measurements				
1. BMI (kg/m^2)	29.51±2.63	27.82±2.47	t=11.756	**p<0.0001**
2. BAI (Body fat %)	29.94±3.23	28.76±3.14	t=7.951	**p<0.0001**
3. WC (cm)	103.35±7	98.95±7	t=8.718	**p<0.0001**
4. HC (cm)	107.30±6	104.7±5	t=8.592	**p<0.0001**
5. WHR	0.96±0.04	0.95±0.04	t=3.454	**p=0.0027**
6. WHtR	0.60±0.04	0.58±0.04	t=7.804	**p<0.0001**
B. Lipid profile				
1. TC (mg/dL)	188.25±38.36	176.10±42.1	t=2.487	**p=0.0224**
2. TG (mg/dL)	170.49±104.54	133.62±46.51	t=2.245	**p=0.0369**
3. LDL-C (mg/dL)	108.05±30	102.06±31.30	t=0.9696	p=0.3444
4. VLDL-C (mg/dL)	34.10±21	26.72±9	t=2.245	**p=0.0369**
5. HDL-C (mg/dL)	46.10±9.81	47.32±13.76	t=0.5777	p=0.5703
C. Atherogenic indices				
1. CRI-I	4.15±0.69	3.86±0.85	t=1.485	p=0.1540
2. CRI-II	2.36±0.66	2.25±0.73	t=0.5716	p=0.5743
3. AC	3.15±0.69	2.86±0.85	t=1.485	p=0.1540
4. AIP	0.52±0.23	0.44±0.19	t=1.817	p=0.0850

[Table/Fig-1]: Effect of vitamin C supplementation on anthropometric measurements, lipid profile and atherogenic indices in obese individuals.
*Age (Mean±SD)=33.85±5.84 years
SBP: Systolic blood pressure; DBP: Diastolic blood pressure; BMI: Body mass index; BAI: Body adiposity index; WC: Waist circumference; HC: Hip circumference; WHR: Waist to hip ratio; WHtR: Waist to height ratio; TC: Total cholesterol; TG: Triglycerides; LDL-C: Low density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; HDL-C: High density lipoprotein cholesterol; CRI-I: Castelli's risk index-I; CRI-II: Castelli's risk index-II, AC: Atherogenic coefficient; AIP: Atherogenic index of plasma

In non obese individuals there was significant reduction in SBP, BMI, BAI, WC, HC, WHR, and WHtR [Table/Fig-2].

Non obese males* (n=19)				
Parameters	3 months before vit C intake (Mean±SD)	After 3 months of vit C intake (Mean±SD)	t-test value	p-value
1. SBP (mmHg)	122±6	120±3	t=2.535	**p=0.0207**
2. DBP (mmHg)	79±8	80±2	t=0.7825	p=0.4441
A. Anthropometric measurements				
1. BMI (kg/m^2)	22.33±1.68	21.64±1.49	t=7.019	**p<0.0001**
2. BAI (Body fat %)	25±2.46	24.46±2.49	t=4.202	**p=0.0005**
3. WC (cm)	80.79±4.73	78.63±4.75	t=15.62	**p<0.0001**
4. HC (cm)	94.90±3.91	93.68±3.37	t=4.011	**p=0.0008**
5. WHR	0.85±0.038	0.84±0.042	t=4.025	**p=0.0008**
6. WHtR	0.48±0.023	0.46±0.024	t=9.987	**p<0.0001**
B. Lipid profile				
1. TC (mg/dL)	184.16±54.94	170.16±27.66	t=1.405	p=0.176
2. TG (mg/dL)	104.31±65.68	90.105±34.73	t=0.965	p=0.347
3. LDL-C (mg/dL)	115.70±43.77	103.08±22.47	t=1.459	p=0.1619
4. VLDL-C (mg/dL)	20.86±13.13	18.02±6.95	t=0.9657	p=0.3470
5. HDL-C (mg/dL)	47.60±7.67	49.06±9.74	t=0.6397	p=0.53
C. Atherogenic indices				
1. CRI-I	3.84±0.84	3.60±0.78	t=1.196	p=0.247
2. CRI-II	2.41±0.74	2.19±0.69	t=1.144	p=0.2674
2. AC	2.84±0.85	2.57±0.81	t=1.340	p=0.1968
3. AIP	0.29±0.19	0.24±0.16	t=1.046	p=0.3095

[Table/Fig-2]: Effect of vitamin C supplementation on anthropometric measurements, lipid profile and atherogenic indices in non obese individuals.
*Age (Mean±SD)=35.21±8.59 years

Atherogenic indices: There were no significant changes noted in the values of CRI-I, CRI-II, AC and AIP both in obese [Table/Fig-1] and non obese [Table/Fig-2] individuals (p>0.05).

As shown in the [Table/Fig-3], we subtracted the values obtained after the vitamin C supplementation from the values obtained before vitamin C supplementation and compared them between obese and non obese by using Unpaired t-test and non parametric test (Mann Whitney U-Statistics). Both these methods revealed resemblance in reduction in TC, TG, LDL-C, VLDL-C CRI-I, CRI-II, AC and AIP and increase in HDL-C, in obese and non obese subjects after the three months of intake of vitamin C.

[Table/Fig-4,5] shows the correlations between lipid profile and atherogenic indices in obese individuals and non obese individuals after three months.

Parameters	Obese males (N=20) Mean±SD	Non obese males (N=19) Mean±SD	Unpaired 't' test value and 'p' value	Mann Whitney U-Statistic
Age (years)	**33.85±5.84**	**35.21±8.59**		
TC mg/dL	12.15±21.85	14±43.42	t=0.1694	U=180.00
			p=0.8664	p=0.7895
TG mg/dL	36.87±73.46	14.20±64.1	t=1.025	U=134.00
			p=0.3122	p=0.1190
LDL-C mg/dL	6±28	13±38	t=0.6277	U=189.00
			p=0.5341	p=0.9888
VLDL-C mg/dL	7.4±15	2.8±13	t=1.025	U=134.00
			p=0.3122	p=0.1190
HDL-C mg/dL	1.22±9.45	1.5±10	0.07667	U=175.00
			p=0.9393	p=0.6837
CRI-I	0.30±0.9	0.24±0.9	t=0.1939	U=186
			p=0.8473	p=0.9217
CRI-II	0.12±0.94	0.21±0.81	t=0.3272	U=171.50
			p=0.7453	p=0.6130
AC	0.30±0.90	0.27±0.88	t=0.09435	U=182.50
			p=0.9253	p=0.8441
AIP	0.1±0.2	0.04±0.2	t=0.5320	U=160.50
			p=0.5979	p=0.4151

[Table/Fig-3]: Comparison of changes (mean±SD) in pre and post intake of vitamin C in obese and non obese males.

Correlation between different study parameters in obese individuals before and after vitamin C supplementation is summarised in [Table/Fig-6,7] respectively.

Correlation between different study parameters in non obese individuals before and after vitamin C intake is summarised in [Table/Fig-8,9] respectively.

DISCUSSION

The present study revealed a significant decrease in all the anthropometric parameters like BMI, BAI, WC, HC, WHR and WHtR in obese and non obese subjects, after the intake of vitamin C [Table/Fig-1,2]. In the nutshell overall body mass is reduced after the intake of vitamin C. This finding is consistent with the previous studies which have reported intake of 500 mg vitamin C/day for eight weeks decreased body mass both in men and women [43] and during submaximal exercise in young adults [44] to the significant extent.

Vitamin C is inversely correlated with BMI, WC [43] and WHR [20] and is necessary for the degradation of fatty acids [13-16]. In the present study, intake of vitamin C could have reduced body fat mass and therefore improved anthropometry in all the subjects.

Obese males* (n=20)								
	Before vitamin C intake				After vitamin C intake			
Parameters	CRI-I	CRI-II	AC	AIP	CRI-I	CRI-II	AC	AIP
TC (mg/dL)	r=0.2778	r=0.3185	r=0.2778	r=0.1481	r=0.2098	r=0.3222	r=0.2098	r=-0.1594
	p=0.2357	p=0.1711	p=0.0771	p=0.5332	p=0.3747	p=0.1660	p=0.3747	p=0.5021
TG (mg/dL)	r=0.4490	r=-0.4016	r=0.4490	r=0.8966	r=0.2926	r= 0.07837	r=0.2926	r=0.7152
	p=0.0470	p=0.0792	**p=0.0470**	**p<0.0001**	p=0.2106	p=0.7426	p=0.2106	**p=0.0004**
LDL-C (mg/dL)	r=0.2044	r=0.7369	r=0.2044	r=-0.3234	r=0.4433	r=0.6025	r=0.4433	r=-0.1684
	p=0.3575	**p=0.0002**	p=0.3875	p=0.1046	**p=0.0502**	**p=0.0049**	**p=0.0502**	p=0.4779
VLDL-C (mg/dL)	r=0.4490	r=-0.4016	r=0.4490	r=0.8966	r=0.2926	r=0.07837	r=0.2926	r=0.7152
	p=0.0470	p=0.0792	**p=0.0470**	**p<0.0001**	p=0.2106	p=0.7426	p=0.2106	**p=0.0004**
HDL-C (mg/dL)	r=-0.4957	r=-0.1521	r=-0.4957	r=-0.3427	r=-0.5651	r=-0.4387	r=-0.5651	r=-0.5880
	p=0.0262	p=0.5219	**p=0.0262**	p=0.1391	**p=0.0094**	**p=0.0530**	**p=0.0094**	**p=0.0064**

[Table/Fig-4]: Correlation between lipid profile and atherogenic indices before and after the 3 months of intake of vitamin C in obese subjects.
*Age (Mean±SD)=33.85±5.84 years

Non obese males* (n=19)								
	Before vitamin C intake				After vitamin C intake			
Parameters	CRI-I	CRI-II	AC	AIP	CRI-I	CRI-II	AC	AIP
TC (mg/dL)	r=0.8439	r=0.8156	r=0.8439	r=0.5084	r=0.5441	r=0.4581	r=0.4988	r=0.5670
	p<0.0001	**p<0.0001**	**p<0.0001**	**p=0.0262**	**p=0.0160**	**p=0.0485**	**p=0.0297**	**p=0.0114**
TG (mg/dL)	r=0.5539	r=0.3043	r=0.5539	r=0.9171	r=0.4277	r=0.2692	r=0.3824	r=0.8243
	p=0.0139	p=0.2053	**p=0.0139**	**p<0.0001**	p=0.0678	p=0.2651	p=0.1061	**p<0.0001**
LDL-C (mg/dL)	r=0.8564	r=0.8947	r=0.8564	r=0.3606	r=0.7922	r=0.7840	r=0.7832	r=0.5769
	p<0.0001	**p<0.0001**	**p<0.0001**	p=0.1294	**p<0.0001**	**p<0.0001**	**p<0.0001**	**p=0.0097**
VLDL-C (mg/dL)	r=0.5539	r=0.3043	r=0.5539	r=0.9171	r=0.4277	r=0.2692	r=0.3824	r=0.8243
	p=0.0139	p=0.2053	**p=0.0139**	**p<0.0001**	p=0.0678	p=0.2651	p=0.1061	**p<0.0001**
HDL-C (mg/dL)	r=0.2099	r=0.2157	r=0.2099	r=0.01381	r=-0.5876	r=-0.6996	r=-0.6630	r=-0.3086
	p=0.3883	p=0.3752	p=0.3883	p=0.9552	p=0.0082	**p=0.0009**	**p=0.0020**	p=0.1987

[Table/Fig-5]: Correlation between lipid profile and atherogenic indices before and after the 3 months of intake of vitamin C in non obese subjects.

Obese males* (n=20)								
Variables	TC	TG	LDL-C	HDL-C	CRI-I	CRI-II	AC	AIP
Age (years)	r=0.3536	r=-0.044	r=0.3172	r=0.5063	r=-0.3056	r=-0.067	r=-0.3056	r=-0.2913
	p=0.1261	p=0.8537	p=0.1728	**p=0.0227**	p=0.1901	p=0.7774	p=0.1901	p=0.2128
SBP (mmHg)	r=0.1410	r=0.1436	r=0.0768	r=0.0105	r=0.2243	r=0.0214	r=0.2243	r=0.0435
	p=0.5531	p=0.5460	p=0.7476	p=0.9647	p=0.3419	p=0.9285	p=0.3419	p=0.8553
DBP (mmHg)	r=0.4432	r=0.1959	r=0.3372	r=0.2841	r=0.1673	r=0.0912	r=0.1673	r=0.0010
	p=0.0503	p=0.4077	p=01460	p=0.2247	p=0.4809	p=0.7020	p=0.4809	p=0.9967
BMI (kg/m^2)	r=-0.1842	r=0.2667	r=-0.3909	r=-0.0934	r=-0.0266	r=-0.400	r=-0.0266	r=0.3171
	p=0.4367	p=0.2556	p=0.0883	p=0.6950	p=0.9114	p=0.0803	p=0.9114	p=0.1731
BAI (Body fat %)	r=-0.0503	r=0.1313	r=-0.1292	r=-0.0806	r=0.0504	r=-0.095	r=0.0504	r=0.1633
	p=0.8330	p=0.5812	p=0.5863	p=0.7352	p=0.8326	p=0.6877	p=0.8326	p=0.4916
WC (cm)	r=0.1047	r=0.2272	r=-0.0618	r=0.1143	r=0.0358	r=-0.216	r=0.0358	r=0.1941
	p=0.6604	p=0.3355	p=0.7958	p=0.6313	p=0.8808	p=0.3599	p=0.8808	p=0.4123
HC (cm)	r=0.0863	r=0.2274	r=-0.0932	r=0.1382	r=0.0038	r=-0.231	r=-0.0380	r=0.1412
	p=0.7173	p=0.3351	p=0.6959	p=0.5613	p=0.9873	p=0.3264	p=0.9873	p=0.5527
WHR	r=0.0851	r=0.0611	r=0.0565	r=0.02934	r=0.0589	r=-0.021	r=0.0589	r=0.1059
	p=0.7213	p=0.7978	p=0.8127	p=0.9023	p=0.8051	p=0.9311	p=0.8051	p=0.6567
WHtR	r=0.0284	r=0.2154	r=-0.1080	r=-0.0175	r=0.0778	r=-0.169	r=0.0778	r=0.2420
	p=0.9052	p=0.3618	p=0.6504	p=0.9418	p=0.7444	p=0.4763	p=0.7444	p=0.3039

[Table/Fig-6]: Correlation between different variables in obese individuals before intake of vitamin C.

Obese males* (n=20)								
Variables	TC	TG	LDL-C	HDL-C	CRI-I	CRI-II	AC	AIP
Age (years)	r=0.3788	r=-0.0380	r=0.3731	r=0.3113	r=-0.0309	r=0.06415	r=-0.0309	r=-0.2248
	p=0.1074	p=0.8734	p=0.1052	p=0.1816	p=0.8971	p=0.7882	p=0.8971	p=0.3406
SBP (mmHg)	r=0.3823	r=0.04815	r=0.4451	r=0.1239	r=0.2631	r=0.2958	r=0.2631	r=-0.1007
	p=0.0962	p=0.8402	**p=0.0492**	p=0.6028	p=0.2623	p=0.2055	p=0.2623	p=0.6728
DBP (mmHg)	r=0.6862	r=0.3315	r=0.6383	r=0.4225	r=0.2026	r=0.2566	r=0.2026	r=-0.0383
	p=0.0008	p=0.1534	**p=0.0025**	p=0.0635	p=0.3917	p=0.2748	p=0.3917	p=0.8725
BMI (kg/m^2)	r=-0.0814	r=0.1885	r=-0.0802	r=-0.1939	r=0.1449	r=0.04238	r=0.1449	r=0.3080
	p=0.7329	p=0.4260	p=0.7366	p=0.4127	p=0.5422	p=0.8592	p=0.5422	p=0.1865
BAI (Body fat %)	r=-0.0814	r=0.1885	r=-0.0802	r=-0.1939	r=0.1449	r=0.04238	r=0.1449	r=0.3080
	p=0.7329	p=0.4260	p=0.7366	p=0.4127	p=0.5422	p=0.8592	p=0.5422	p=0.1865
WC (cm)	r=0.2144	r=-0.0097	r=0.2920	r=-0.0021	r=0.2398	r=0.2690	r=0.2398	r=0.02113
	p=0.3640	p=0.9675	p=0.2115	p=0.9929	p=0.3086	p=0.2514	p=0.3086	p=0.9296
HC (cm)	r=0.1501	r=0.0967	r=0.1303	r=0.09722	r=0.01357	r=-0.0084	r=0.01357	r=0.01884
	p=0.5277	p=0.6850	p=0.5841	p=0.6835	p=0.9547	p=0.9718	p=0.9547	p=0.9372
WHR	r=0.1565	r=-0.1303	r=0.3008	r=-0.1177	r=0.3556	r=0.4273	r=0.3556	r=0.01088
	p=0.5098	p=0.5840	p=0.1975	p=0.6214	p=0.1239	p=0.0602	p=0.1239	p=0.9637
WHtR	r=0.09755	r=0.09181	r=0.2040	r=-0.2279	r=0.3848	r=0.3644	r=0.3848	r=0.2628
	p=0.6824	p=0.7003	p=0.3884	p=0.3340	p=0.0939	p=0.1142	p=0.0939	p=0.2629

[Table/Fig-7]: Correlation between different variables in obese individuals after intake of vitamin C.

Non obese males* (n=19)								
Parameter	**TC**	**TG**	**LDL**	**HDL**	**CRI-I**	**CRI-II**	**AC**	**AIP**
Age (years)	r=0.1631	r=-0.112	r=0.2401	r=-0.0098	r=0.2308	r=0.2970	r=0.2308	r=-0.0011
	p=0.5046	p=0.6888	p=0.3222	p=0.9680	p=0.3418	p=0.2169	p=0.3418	p=0.9963
SBP (mmHg)	r=0.1405	r=0.2712	r=0.0709	r=0.1372	r=0.0709	r=0.0709	r=0.0709	r=0.2246
	p=0.5663	p=0.2615	p=0.7730	p=0.5753	p=0.7730	p=0.9770	p= 0.7730	p=0.3553
DBP (mmHg)	r=-0.1168	r=-0.2062	r=-0.0803	r=-0.3652	r=-0.1569	r=-0.1139	r=-0.1569	r=-0.2015
	p=0.6338	p=0.3970	p=0.7438	p=0.1242	p=0.5213	p=0.6423	p=0.5213	p=0.4082
BMI (kg/m^2)	r=0.3736	r=-0.108	r=0.0452	r=0.2799	r=0.3226	r=0.4211	r=0.3226	r=-0.1056
	p=0.1151	p=0.6591	p=0.0518	p=0.2458	p=0.1780	p=0.0726	p=0.1780	p=0.6671
BAI (Body fat %)	r=0.3734	r=0.0220	r=0.4251	r=0.2115	r=0.3898	r=0.4530	r=0.3898	r=0.0232
	p=0.1153	p=0.9289	p=0.0696	p=0.3848	p=0.0990	p=0.0515	p=0.0990	p=0.9248
WC (cm)	r=0.0420	r=0.0466	r=0.0593	r=-0.1174	r=0.1325	r=0.1330	r=0.1325	r=-0.0082
	p=0.8644	p=0.8497	p=0.8094	p=0.6321	p=0.5887	p=0.5872	p=0.5887	p=0.9734
HC (cm)	r=0.0239	r=-0.225	r=0.0940	r=0.0204	r=0.0589	r=0.1526	r=0.0589	r=-0.2799
	p=0.9228	p=0.3533	p=0.7018	p=0.9341	p=0.8105	p=0.5330	p=0.8105	p=0.2458
WHR	r=-0.0135	r=0.2365	r=-0.0500	r=-0.2163	r=0.0875	r=0.0059	r=0.0875	r=0.2248
	p=0.9564	p=0.3297	p=0.8389	p=0.3739	p=0.7214	p=0.9806	p=0.7214	p=0.3548
WHtR	r=0.2822	r=0.1745	r=0.3027	r=-0.0047	r=0.3858	r=0.3850	r=0.3858	r=0.1271
	p=0.2418	p=0.4749	p=0.2078	p=0.9846	p=0.1028	p=0.1036	p=0.1028	p=0.6040

[Table/Fig-8]: Correlation between different variables in non obese individuals before intake of vitamin C.
*Age (Mean±SD)=35.21±8.59 years

Non obese males* (n=19)								
Parameter	**TC**	**TG**	**LDL-C**	**HDL-C**	**CRI-I**	**CRI-II**	**AC**	**AIP**
Age (years)	r=0.1444	r=0.1262	r=0.1089	r=0.06880	r=0.1352	r=0.06939	r=0.08739	r=0.1285
	p=0.5553	p=0.6066	p=0.6571	p=0.7796	p=0.5810	p=0.7778	p=0.7020	p=0.6002
SBP (mmHg)	r=0.1802	r=0.1392	r=0.2903	r=-0.2572	r=0.3113	r=0.3314	r=0.3274	r=0.3017
	p=0.4604	p=0.5698	p=0.2280	p=0.2877	p=0.1945	p=0.1658	p=0.1712	p=0.2093
DBP (mmHg)	r=-0.2915	r=-0.3288	r=-0.0840	r=-0.3995	r=0.1129	r=0.1444	r=0.1072	r=-0.03936
	p=0.2260	p=0.1693	p=0.7324	p=0.0902	p=0.6554	p=0.5553	p=0.6624	p=0.8729
BMI (kg/m^2)	r=0.07207	r=0.1008	r=0.09122	r=-0.0776	r=0.1763	r=0.1477	r=0.1659	r=0.2130
	p=0.7694	p=0.6814	p=0.7103	p=0.7520	p=0.4704	p=0.5461	p=0.4972	p=0.3812
BAI (Body fat %)	r=0.5471	r=0.3573	r=0.4105	r=0.3518	r=0.07235	r=0.02555	r=0.05006	r=0.1648
	p=0.0153	p=0.1331	p=0.0808	p=0.1397	p=0.7685	p=0.9173	p=0.8387	p=0.5001
WC (cm)	r=-0.1027	r=-0.2815	r=-0.0578	r=0.04262	r=-0.2426	r=-0.1610	r=-0.2051	r=-0.3351
	p=0.6758	p=0.2431	p=0.8140	p=0.8625	p=0.3170	p=0.5103	p=0.3997	p=0.1608
HC (cm)	r=0.02681	r=-0.0860	r=-0.0925	r=0.3511	r=-0.3123	r=-0.3312	r=-0.3382	r=-0.2511
	p=0.9132	p=0.7263	p=0.7062	p=0.1405	p=0.1930	p=0.1661	p=0.1567	p=0.2997
WHR	r=-0.1258	r=-0.2647	r=0.01281	r=-0.1981	r=-0.05852	r=0.05127	r=0.004865	r=-0.2110
	p=0.6078	p=0.2734	p=0.9585	p=0.4163	p=0.8119	p=0.8349	p=0.9842	p=0.3859
WHtR	r=0.3027	r=-0.0072	r=0.3057	r=0.1596	r=-0.07321	r=-0.0048	r=-0.0346	r=-0.5678
	p=0.2078	p=0.9764	p=0.2031	p=0.5139	p=0.7658	p=0.9844	p=0.8879	p=0.1399

[Table/Fig-9]: Correlation between different variables in non obese individuals after intake of vitamin C.
*Age (Mean±SD)=35.21±8.59 years

A person's Waist to Height Ratio (WHtR) is their waist circumference divided by their height and higher values of WHtR specify greater threat of obesity and related cardiovascular complications [45]. For people under the age 40 years the critical value of WHtR is 0.5, for people aged 40-50 years the critical value is between 0.5-0.6, and for people over 50 years the critical values start at 0.6 [46].

In the present study, the WHtR for obese men (0.60±0.04) [Table/Fig-1] was found to be greater than non obese men (0.48±0.023) [Table/Fig-2] which indicates greater cardiovascular risk to obese men than non obese. There was significant reduction in these values in obese (0.58±0.04) [Table/Fig-1] and non obese (0.46±0.024) [Table/Fig-2] and it is possible that long term administration of vitamin C can reduce these values below the critical limit in obese subjects. There is hardly any study which had reported the effect of vitamin C on WHtR. Present study signifies the association of vitamin C intake with reduction in WHtR.

It has been found that, high levels of TC, TG and LDL-C and low levels of HDL-C are associated with increased risk of Coronary Artery Disease (CAD) [47]. In this study, vitamin C supplementation provided significant reductions in TC, TG and VLDL-C in obese subjects, but failed to provide increase in their HDL-C, to the significant level [Table/Fig-1]. Further there were no statistically remarkable alterations in lipid profile in non obese individuals [Table/Fig-2]. This is surprising because, many of the studies have linked the intake of vitamin C with rise in plasma HDL-C [48,49]. Also, the intake of vitamin C and vitamin E together with exercise have significantly improved HDL-C [50].

However, in the studies supplementation of 500 mg/day of vitamin C for 30 days and for five years provided no positive results upon HDL-C [51,52]. The present study results coincide with them and indicate that even a supplementation of 1500 mg/day of vitamin C for three months is not enough to raise the HDL-C. It could be because of effect of exercise may be more prominent on increase in HDL-C than antioxidants alone.

Tofler GH et al., and Gaur GS and Dixit AK (2000) observed significant decrease in the cholesterol after vitamin C supplementation, 2 gm/day and 500 mg/day respectively [11,51]. The present study result coincides with them [Table/Fig-1]. The reduction in TG in the present study [Table/Fig-1], coincides with the study conducted by Afkhami-Ardekani M and Shojaoddiny-Ardekani A who observed a significant reduction in TG in the subjects who consumed 1000 mg/day of vitamin C for six weeks [53] whereas, Kim MK et al., found no reduction in TG in the subjects who consumed 500 mg vitamin C/day for 30 days [52]. Vitamin C metabolise the cholesterol [12] and fatty acids [13-16], which would have resulted in decrease in TC, TG and VLDL-C in obese individuals.

A rise in LDL-C is associated with atherogenesis, whereas decreased HDL-C with metabolic syndrome [54]. There has been observed an association between low plasma vitamin C level and increased LDL-C [55]. In this study LDL-C was decreased but not to the significant extent after the vitamin C intake in both obese and non obese individuals [Table/Fig-1,2].

With advancement in science and research, it seems rather beneficial to determine atherogenic indices like CRI-I [23-25], CRI-II [26], AC [27] and AIP [28,29] than independently determined TG, LDL-C or HDL-C to monitor the cardiovascular health. The values of CRI-I >3.5 in males, >3 in females, CRI-II >3.3 and AC >3.0 determine the cardiovascular risk [56] whereas, AIP between -0.3 to 0.1 associated with low, within 0.11 to 0.24 with medium and above 0.24, with high risk of cardiovascular events [57]. In another study, subjects who had CRI-I ≥4 had CAD and proximal plaque [58].

In the present study various atherogenic indices were reduced but not to the significant extent after the intake of vitamin C both in obese and non obese individuals (p>0.05). Although these changes were not significant, but long-term administration of vitamin Cmay reduce atherogenic indices to the significant extent.

LIMITATION

Small sample size was the main limitation of this study therefore large variation in the differences was observed. However, the results obtained from the present study can not be underestimated since both Unpaired t-test and Mann-Whitney U statistic showed the similar effect in the results.

CONCLUSION

Present study concludes that, daily intake of 1500 mg of vitamin C has positive lowering effect on anthropometric measurements and lipid profile however it is not significantly effective in lowering atherogenic indices in a short span of three months. Long-term administration of vitamin C may be helpful for dieticians and clinicians in advising high intake of vitamin C through the diet like amla, guava, citrus fruits etc., in controlling obesity and related disorders.

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