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Original article

Association of diet quality with serum high-sensitivity C-reactive protein level and the adherence to the Saudi dietary guidelines among female college students

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ABSTRACT

Objective: Assess adherence to the Saudi Dietary Guidelines and identify the diet quality using the Healthy Eating Index (HEI-2015), and measure levels of high-sensitivity C-reactive protein (hs-CRP), an indicator of the risk of chronic diseases, among female Saudi college students.
Methods: A cross-sectional study of 401 randomly selected female students aged 19–35 years at [removed for blind peer review]. Data from an interview-based Saudi Food Frequency Questionnaire, health history, anthropometric measurements, and hs-CRP were collected. Multivariable linear regression analyses were used to examine the associations between HEI-2015 score and hs-CRP.
Results: There was an overall low adherence (43%) to the Saudi Dietary Guidelines, higher intake of cereal, bread, meat and sodium, and lower intake of dairy products compared to recommended levels. The mean HEI-2015 score was (62.7 ± 10.2), indicating poor diet quality, and the mean hs-CRP level was high (2.62 ± 3.31 mg/l). The HEI-2015 score was inversely correlated with the hs-CRP level (r = −0.43) and body mass index (BMI, r = −0.23). A higher HEI-2015 score per 1 SD (10 points) was associated with −0.2 (95% CI: −0.4, −0.1 mg/l) lower hs-CRP, independent of lifestyle factors and BMI.
Conclusion: Poor quality diet was associated with higher hs-CRP levels, an indicator of adverse health conditions. Further research and intervention studies to develop potential strategies to enhance positive dietary behavior changes are needed.

1. Introduction

Healthy lifestyle and dietary habits are among the most important preventative measures for non-communicable diseases (NCDs) such as obesity, cardiovascular disease (CVD), and diabetes (Moradi-Lakeh et al., 2017; World Health Organization, 2018). The World Health Organization (WHO) has defined a healthy dietary habit as having adequate amounts of fruits, vegetables, and whole grains while reducing intake of refined grains, saturated fat, and salty foods (World Health Organization, 2018). Different dietary guidelines have been developed to provide guidance for ideal proportions for dietary intake; the most commonly used guideline is the US Department of Agriculture (USDA) guideline (USDA NDS, 27). In 2012, the Saudi Ministry of Health issued the Saudi Dietary Guidelines regarding appropriate amounts of macro- and micronutrients that promote healthy dietary habits in the community, prevent NCDs related to dietary habits, and support growth and development (Ministry of Health, 2012). Despite the availability of dietary guidelines, the Global Burden of Diseases, Injuries, and Risk Factors study in 2010 revealed that the consumption of fruits, vegetables, whole grains, nuts, and polyunsaturated fatty acids among Saudi adults was far less than the recommended level, while the consumption of saturated fat, processed meat, sugar

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; CDC, Center for Disease Control and Prevention; FFQ, Food Frequency Questionnaire; Hs-CRP, high-sensitivity C-reactive protein; HEI, healthy Eating Index; KSU, King Saud University; NCDs, non-communicable diseases; USDA, US Department of Agriculture; WHO, World Health Organization.

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and salty foods was higher than the recommended level (Afshin et al., 2015).

Dietary habits in the Kingdom of Saudi Arabia have undergone a drastic dietary transformation over the past few decades, as they transitioned from traditional healthy dietary habits rich in whole grains and fiber to more "Westernized" habits that contain higher amounts of fats, salt, refined grains, and sugar (DeNicola et al., 2015; Moradi-Lakeh et al., 2017). This transition has contributed to the increasing burden of NCDs among the Saudi community (Afshin et al., 2015).

College students are at a risk of developing adverse health conditions owing to non-adherence to recommended dietary guidelines, as the transition from adolescence to adulthood may be accompanied by poor dietary changes among college students, which could persist into later life (Deforche et al., 2015; El Ansari et al., 2014; Papier et al., 2015). A prospective study among Belgian college students revealed lifestyle and dietary habit changes, such as a reduction in consumption of fruits and vegetables, whole grains, and dairy products and an increased consumption of saturated fats and sweets, accompanied by yearly weight gain and increased body mass index (BMI) (Deforche et al., 2015).

In Saudi Arabia, there is an absence of a national representative survey on dietary intake. Most previous studies have evaluated students' adherence to specific food group recommendations (e.g., fruits and vegetables), and investigators argue that whole dietary intake should be considered because individuals do not consume single food groups. In this context, identifying the diet quality of individuals at a younger age and their adherence to recommended guidelines is essential in preventing and managing NCDs (Al-Otaibi, 2014; El Ansari et al., 2015, 2014). Owing to the lack of available literature, we aimed to assess adherence to the Saudi Dietary Guidelines and the diet quality using the Healthy Eating Index (HEI-2015) among female Saudi college students, and to measure levels of high-sensitivity C-reactive protein (hs-CRP) as an indicator of chronic disease risk. To the best of our knowledge, this is the first study to assess dietary adherence of Saudi college students to the Saudi Dietary Guidelines.

2. Materials and methods

2.1. Study design and setting

This cross-sectional study was conducted between February and May 2019. The study sample comprised 401 randomly selected female college students aged 19–35 years from King Saud University (KSU), Riyadh, Saudi Arabia. Participants who were diagnosed with any chronic disease (e.g., diabetes mellitus), inflammatory disease (e.g., rheumatoid arthritis), or infection were excluded (Ansar and Ghosh, 2013). In addition, participants who were taking antidepressant medications (Hamer et al., 2011), were taking more than 300 mg/day of nonsteroidal anti-inflammatory medications (e.g., aspirin) (Vaucher et al., 2014), were on hormonal contraceptives (Divani et al., 2015), or were pregnant (Mei et al., 2016) were also excluded. Anthropometric, demographic, and dietary data were collected at the clinic of the Community Health Sciences Department of the College of Applied Medical Sciences, and blood samples were collected by a trained nurse in the phlebotomy room of the Laboratory Department of the same college. The estimated time to complete each visit was approximately 1 h per participant. Signed consent forms were obtained from all participants, and they had the right to withdraw from the study at any time. The protocol of this study was approved by the Deanship of Scientific Research at KSU (ref. no. 19/0105/IRB).

2.2. Study tools

2.2.1. Dietary assessment

Food consumption was assessed using the validated Saudi Food Frequency Questionnaire (FFQ) (Alkhalaf et al., 2015). The FFQ comprises 10 sections with 133 food items. Participants were asked about their habitual dietary intake during the previous 12 months. An interview-based questionnaire was conducted to obtain data on food consumption and portion size estimation for each food using pictures, household measures, and food modules. All food items were converted to grams or milliliters per day based on the USDA food composition database (USDA NDS, 27). Food groups were defined according to the Saudi Dietary Guidelines (Ministry of Health, 2012). Dietary information was entered into the NutriBase version 20 (CyberSoft Inc., Phoenix, AZ), and the first version of the Arabic program (National King Fahad Library 5716/1427, Riyadh, Saudi Arabia, 2007), which has been used in a previous study (Al-Musharaf et al., 2018), was used for local foods.

2.2.2. The Saudi Dietary Guidelines

The development of the Saudi Dietary Guidelines has been previously described in details (Ministry of Health, 2012). Briefly, it was developed to provide specific dietary guidelines in terms of food groups and portion sizes that suit the Saudi culture based on scientific evidence (Ministry of Health, 2012). The recommended food groups and serving sizes are represented in the form of a palm tree: cereals and bread (6–11 servings/day), vegetables (3–5 servings/day), fruits (2–4 servings/day), milk and dairy products (2–4 servings/day), meat (2–4 servings/day), in addition to added fat and sugar.

2.2.3. Healthy Eating Index 2015

The diet quality of the participants was assessed using HEI-2015 based on the FFQ data. HEI-2015 is a dietary index intended to assess overall diet quality by measuring an individual's dietary compliance with the 2015 Dietary Guidelines for Americans (Krebs-Smith et al., 2018). The HEI-2015 score ranges from 0 to 100, and an ideal score of 100 indicates that the dietary intake aligns with the Dietary Guidelines for Americans. In general, a higher score reflects better overall diet quality than a lower score (Krebs-Smith et al., 2018). HEI-2015 scores were calculated based on an energy-adjusted approach per 1000 kcal of energy using cup or ounce equivalents for food components according to the Food Patterns Ingredients Database definitions (Bowman et al., 2018) and applying a ratio [(monounsaturated fatty acids (MUFA)s + polyunsaturated fatty acids (PUFA)s)/saturated fatty acids (SFA)s] for fatty acids, grams for sodium, and percentage of energy for added sugars and saturated fats.

2.2.4. Biochemical blood test (hs-CRP)

A trained nurse collected a total of 2 ml in blood samples from each participant between 8:00 a.m. and 3:00p.m. after 15 min of sitting. Centrifugation was used to separate the serum for 10 min within 1 h of collection, and all blood samples were frozen at −80 °C and stored to be used for analysis at the end of sample collection. An enzyme-linked immunosorbent assay (ELISA) was used to measure hs-CRP levels using a human hs-CRP ELISA kit (Aviva Systems Biology, OKBA00016, San Diego, CA) that was calibrated according to the international standards of the Center for Disease Control and Prevention (CDC). To ensure the accuracy of results, all samples and standards were run in duplicate. To minimize cost, hs-CRP levels of 289 randomly selected participants were measured. An hs-CRP level greater than 3 mg/L was classified as high, 1–3 mg/L as moderate, and less than 1 mg/L as low according to the CDC classification for identifying individuals with a higher risk

of CVD (Pearson et al., 2003). The blood biochemical analysis was done in collaboration with the central laboratory of KSU.

2.2.5. Anthropometric measures

Measurements and calculations were performed according to the WHO guidelines. Body weight and height were measured twice to the nearest 0.1 kg and 1 mm, respectively, by trained staff. Measurements were taken using the same mechanical weight beam physician scale and stadiometer (Detecto, Webb City, MO). BMI was calculated in kg/m^2 using the average of two readings. BMI categories were also classified according to the WHO guidelines (World Health Organization, 2019). Waist and hip circumference were measured twice using a measuring tape, and the average of two readings was used to calculate the waist-to-hip ratio. A waist-to-hip ratio greater than 0.85 was used to determine female abdominal obesity (World Health Organization, 2008). Bioelectrical impedance (InBody 770; InBody Inc., Cerritos, CA) was measured to provide data on body composition according to the manufacturer's protocol.

2.2.6. Other variables

An interview-based questionnaire was used to collect data on general sociodemographic characteristics [marital status, education level, academic level, college, family income per month classified based on the Saudi General Authority of Statistics in SR (<5000, 5000–10,000, 10,000–19,000, ≥19,000)] ("General Authority of Statistics, Kingdom of Saudi Arabia (2018), Household Income and Expenditure Survey"), medical history, lifestyle (sleeping hours per day as per the National Sleep Foundation (Hirshkowitz et al., 2015), frequency of physical activity per week, duration of physical activity), and dietary habits (previous weight reduction diets; breakfast, lunch, and dinner consumption habits; whether they ate a snack between meals; and the effects of the surrounding environment on their dietary intake)).

2.3. Statistical analyses

Quantitative variables were tested for normality before analysis. Outcomes of descriptive analysis are presented as frequencies and percentages for categorical data and as means, medians, and standard deviations for continuous data. The independent-samples *t*-test was used to evaluate associations between continuous variables and outcomes. Pearson's chi-squared test was used to evaluate associations between categorical variables and outcomes. Pearson's partial correlation was used to assess correlations between the HEI-2015 score and hs-CRP.

Multivariable linear regression analyses were used to examine the associations of HEI-2015 score with hs-CRP per 1 standard deviation (SD), which equals 10 points of the HEI-2015. This is approximately equivalent to: 2.8 servings of cereal and bread, 0.3 servings of fruits, 0.5 servings of meat, 0.2 servings of milk, 0.5 servings of vegetables, and 1.1 cups of water. The models were adjusted for lifestyle factors that might confound the association. Model 1 was a simple model adjusted for age; Model 2 was adjusted for age with additional adjustment for education level, college (medical or non-medical), family income, presence of chronic medical conditions, special weight loss diet, and duration of physical activity; and Model 3 was the same as Model 2 with additional adjustment for hours spent sleeping per day and BMI. All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC) and SPSS Statistics for Windows (version 24; IBM Corp., Armonk, NY). P-values <0.05 were considered statistically significant.

3. Results

3.1. Participant characteristics

In total, this study included 401 female college students. Descriptive characteristics of the study participants are presented in Table S1. The mean age of the study participants was 21.66 ± 3.12 years, mean body weight was 60.29 ± 13.85 kg, mean BMI was 24.05 ± 6.04 kg/m^2, and mean waist-to-hip ratio was 0.75 ± 0.17. Body composition analysis results showed that 79.8% of participants had a total body fat percentage of 35.11% ± 7.72% and a muscle percentage was 53.47% ± 13.59%. The mean hs-CRP level was 2.62 ± 3.31 mg/L, which is considered moderate to high according to the CDC cut-off criteria (Pearson et al., 2003). Descriptive characteristics (sociodemographic, dietary habits, and physical activity) of our study participants are presented in Table S2. Regarding dietary habits, most participants (63%) were not following any special weight loss diet, and the average weight loss per month was 1.6 ± 0.5 kg. Most participants (>52%) reported that they always consumed breakfast and lunch, and approximately 55% of participants consumed dinner occasionally. Approximately half of the participants (≥50%) consumed snacks between their main meals. The mean daily intakes of macro- and micronutrients of our study participants are presented in Table S3.

3.2. Adherence to the Saudi dietary guidelines

Adherence to the recommended dietary guidelines is presented in Table 1. There was low overall dietary adherence 43% to the Saudi Dietary Guidelines. The average intake of cereals and breads was 477.76 ± 359.35 g, which was significantly higher 173% than the recommended level. The mean intake of dairy products was 340.43 ± 330.65 ml, which was 69% lower than the minimum recommended level. The mean intake of fruits and vegetables met the minimum recommended level. The average intake of meat was 312.59 ± 217.31 g or approximately 104% of the maximum recommended level. The sodium intake was 178% of the recommended amount (Table 1).

3.3. Diet quality

Overall, the mean HEI-2015 score was 62.74 ± 10.21. The HEI-2015 score and its components are presented in Table S4. Whole grains and dairy product intake of the participants were lower than the recommended levels, and the intake of sodium, added sugar, and refined grains was approximately the maximum recommended level. There was good compliance to guidelines regarding fruit, vegetable, and total protein intakes.

3.4. Association of HEI-2015 score with hs-CRP

Pearson's partial correlation of the relationship between the HEI-2015 score and other variables is presented in Table S5. HEI-2015 score was inversely correlated with the hs-CRP level ($r = -0.43$) and BMI ($r = -0.23$) and positively correlated with special weight loss diet ($r = 0.12$).

A higher HEI-2015 score per 1SD (10 points) was associated with a −0.2 (95% CI: −0.4, −0.1 mg/L) lower hs-CRP level after adjustment for lifestyle factors (Model 2; Table 2). This association was independent of BMI.

4. Discussion

In this study, an overall low adherence (43%) to the Saudi Dietary Guidelines was observed, with a mean HEI-2015 score of 62.

Table 1
Dietary adherence of participants to the recommended dietary guidelines.[b]

Variable	N	Mean (g/day)	± SD	Mean (g/2000 kcal)	± SD	Mean intake per 2000 kcal converted to serving size	Measuring unit	USDA Guidelines/ 2000 kcal[a]	Saudi Dietary Guidelines recommended serving
Cereals and bread	401	447	305	478	359	19	Serving	6 oz	6–11
Fruits	401	263	311	376	416	3	Serving or cup	2 cups	2–4
Meat and substitutes	401	249	172	313	217	4	Serving	5.5 oz	2–4
Milk and dairy products	401	319	287	340	331	1	Serving or cup	3 cups	2–4
Vegetables	401	467	436	460	400	3	Serving or cup	2.5 cups	3–5
Water	401	1796	1466	1887	1659	1887	ml	2700 ml	1500 ml
Sodium	401	4	2	4	2	4	gm	<2.3 g	< 2.3 g

[a] United State Department of Agriculture.
[b] Data are mean ± standard deviation (SD).

Table 2
Estimated mean differences in hs-CRP level associated with 1SD higher HEI-2015 score among female participants.[a,b]

	Hs-CRP		
	Difference in hs-CRP mg/L	(95% CI)	p-value
HEI-2015 score			
Model 1	−0.4	(-0.4, −0.2) *	0.03
Model 2	−0.2	(-0.4, −0.1) *	0.04
Model 3	−0.1	(-0.14, −0.02) *	0.05

[a] Healthy Eating Index (HEI); High sensitivity C reactive protein (hs-CRP). Values are presented as mean (95%CI); *p value $\leq$0.05.
[b] Model 1 is a simple model adjusted for age; model 2 is model 1 with additional adjustment for education level, college, family income, presence of medical conditions, special weight loss diet, and duration of physical activity; model 3 is model 2 with additional adjustment for hours spent in sleeping per day, and BMI; 1 SD = equals 10 points in HEI.

74 ± 10.21, indicating poor diet quality (Krebs-Smith et al., 2018). Furthermore, the mean hs-CRP level was 2.62 ± 3.31 mg/L, indicating moderate to high levels according to the CDC cut-off values (1–3 mg/L to >3 mg/L) for identifying individuals at a high risk of developing CVD (Pearson et al., 2003). Furthermore, a higher HEI-2015 score per 1 SD (10 points) was associated with a 0.2 (95% CI: −0.4, −0.1 mg/L) decrease in hs-CRP levels, independent of lifestyle factors and BMI. To the best of our knowledge, this is the first study to assess the adherence of college students to the Saudi Dietary Guidelines.

Our findings coincide with those of a study of a national representative sample of 10,735 Saudi adults, reporting that only a minority of the Saudi population met the recommended levels of the dietary guidelines (Moradi-Lakeh et al., 2017). In a study among Spanish participants, most adults did not follow the recommended dietary guidelines (Rodríguez-Rodríguez et al., 2017). In contrast, a moderate level of dietary adherence (>50%) was observed in a cross-sectional study conducted among Finnish college students, which may be attributed to different cultural habits (El Ansari et al., 2015). The low HEI-2015 score in the current study indicates poor diet quality (Krebs-Smith et al., 2018), comparable to data reported by the National Health and Nutrition Examination Survey 2007–2010 among US adults and college students aged 20–29 years (Rehm et al., 2015).

Our report regarding the mean intake of cereals and breads was comparable to previous studies indicating high carbohydrate intake among college students (El Ansari et al., 2014; Papier et al., 2015). Approximately half of the participants in our study consumed snacks containing high amounts of energy, fats, and carbohydrates between their meals (AlJaber et al., 2019). Our results regarding the mean intake of the dairy products were similar to those of a Nigerian study, which reported that only 25% of female college students met the minimum recommended level for intake of milk and dairy products (Otemuyiwa and Adewusi, 2012). Conversely, high levels of dietary adherence for the dairy group was observed among Spanish and Finnish college students (El Ansari et al., 2015; Rodríguez-Rodríguez et al., 2017). In addition, the levels of dietary vitamin D and calcium were low (1.5 ± 1.33 μg/day and 223.2 ± 98.84 mg/day, respectively) among participants of our study compared with the recommended dietary allowances (Ross et al., 2011). The mean intake of fruits and vegetables among participants of our study met the minimum recommended level, whereas a previous study conducted among Saudi college students reported that 78% of students consumed fewer than 5 daily servings of fruits and vegetables (Al-Otaibi, 2014). The unhealthy dietary habits were attributed to the absence of healthy food choices at the university campus (Al-Otaibi, 2014). The variability in the definition and portion size estimations of fruits and vegetables may explain the different findings between studies.

Additionally, the average meat intake was compatible with data reported by the Saudi Health Interview Survey, which showed a high consumption of meat, specifically among younger people (Moradi-Lakeh et al., 2017). Moreover, college students in Egypt reported a high intake of meat (El Ansari and Samara, 2018). Sodium intake was also high compared to recommended values, similar to previous findings (Kazi et al., 2020).

Furthermore, our study revealed that poor diet quality may be associated with a greater risk of inflammation, as indicated by higher hs-CRP levels ($p < 0.01$) (Azadbakht and Esmaillzadeh, 2009; Ley et al., 2014). A recent systematic review of observational and clinical trials showed that unhealthy dietary habits, especially high intakes of red meat, increased the risk of several chronic diseases, such as obesity and CVD, owing to the proinflammatory effects of red meat (Medina-Remón et al., 2018). Additionally, a previous study reported a positive association between high-fat and high-carbohydrate foods and inflammatory biomarkers, particularly hs-CRP (Levitan et al., 2008). This finding was reflected in the results of our study of moderate to high mean hs-CRP levels according to the CDC cut-off values for identifying individuals at a high risk of developing CVD (Pearson et al., 2003).

In the current study, participants reported unhealthy dietary habits characterized by high total energy intake, with a mean of 2051.5 ± 670.23 kcal/day, combined with high intake of refined grains, sodium, and saturated fatty acid and low intake of fruits, vegetables, whole grains, and fiber. These unhealthy dietary habits were correlated with the high BMI levels (mean BMI of 24.05 ± 6.04 kg/m^2), indicating a high risk of becoming overweight according to the WHO BMI classification (World Health Organization, 2019). Furthermore, results of the body composition analysis revealed that the majority of participants (79.8%) had a high body fat

percent according to the American Council on Exercise ("The American Council on Exercise," 2020).

This study had several strengths; to the best of our knowledge, it is the first in depth analysis of the dietary habits of Saudi college students and the adherence to the Saudi Dietary Guidelines. We also identified the diet quality to assess adherence to international dietary guidelines using HEI-2015. Our sample size was sufficient, with a power of 95%. Furthermore, the study used validated assessment tools (e.g., FFQ). To increase the accuracy of measurement tools, data were collected using an interview-based instead of a self-administered survey, and serving sizes were standardized according to the USDA Composition Database (USDA NDS, 27). All measurements were recorded twice by a trained researcher following the WHO guidelines. The inflammatory biomarker hs-CRP was also available as an objective measure to help detect risks for chronic diseases; unlike previous literature (El Ansari et al., 2015; El Ansari and Samara, 2018).

However, this study had some limitations that need to be addressed when interpreting the results. The cross-sectional design of this study was a major limitation, making it difficult to establish a causal relationship. The dietary data collection method may have led to some degree of recall bias. Furthermore, results could be limited by the gender-specific restriction since previous studies reported a difference in food selection among male and female college students (El Ansari et al., 2014; Papier et al., 2015). Additionally, the current study was performed at a single institution. Therefore, the sample may not be representative of the total population of college students in Riyadh, Saudi Arabia.

5. Conclusion

In conclusion, our study reported that Saudi college students have low adherence to recommended dietary guidelines. This finding could have important public healthcare implications regarding unhealthy dietary habits among college students and the adverse health consequences thereof. The study findings suggest the need for a comprehensive program to provide targeted nutritional education that encourage adherence to healthy balanced diets in compliance with the recommended dietary guidelines and improve awareness among students about unhealthy dietary habits that could substantially increase the risk of chronic diseases. Having healthy food choices across the university campus is recommended.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contribution

LF and GA's roles were: conceptualization, data curation, formal analysis, and investigation, writing. GA and SO reviewed and edited the final version. All authors were involved in writing the manuscript and had final approval of the submitted and published version.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jksus.2021.101765.

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