Secular trend in dietary patterns of Iranian adults from 2006 to 2017: Tehran Lipid and Glucose Study

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Research

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Abstract

Background: by focusing on nutrition transition in the Middle East and North Africa, this study aim to investigate the general structure and secular trend of dietary patterns extracted from the Tehran Lipid and Glucose Study (TLGS) and adherence to these dietary patterns among Iranian population from 2006 till 2017.

Methods: We investigated on four examination surveys of TLGS including survey 1 (2006-2008), survey 2 (2009-2011), survey 3 (2012-2014), and survey 4 (2015-2017). The dietary intakes was gathered by a validated and reliable food frequency questionnaire. Generalized Estimating Equations was used to assess secular trends in anthropometric, biochemical, and dietary variables across the study period. To identify general structure and secular trend of dietary patterns during each survey, principle component analysis (PCA) and K-mean cluster analysis were used, respectively.

Results: After adjusting for potential confounders including age, sex, body mass index, and total energy intake, the carbohydrate and protein intake gradually increased and the total fat intake decreased during study period (P-value<0.001); however total energy intake remained stable. During the study period, participants consumed notable less refined grain, solid fat, dairy products, and simple sugar. Snack and dessert consumption increased and meat intake had no significant changes during a decade (all P-values<0.001). Three dietary patterns were extracted buy using PCA including: *Healthy dietary pattern* characterized by higher intake of vegetable, fruit, dairy products, liquid oil, nuts and seeds, and honey and jam, Western dietary pattern featured by refined grain, solid fat, meat, snack and dessert, potato, and soft drink, and the Mixed dietary pattern highlighted by tea and coffee, and simple sugar. Based on cluster analysis, 27.8% of participants in survey 4 followed a Western dietary pattern, and 34.1% followed the Mixed dietary pattern. The Healthy dietary pattern was stable among study population during the last decade.

Conclusions: The structure and the type of foods that population have chosen to eat had changed since 2006. And a new secular trend in dietary patterns including a stability of *Healthy* dietary pattern, a decline of the *Western* dietary pattern and an increase in the *Mixed* dietary pattern was presented in our investigation.

Introduction

Nutrition transition in the Middle East and North Africa (MENA) region, has been occurred due to the rapid demographic change, social development, and urbanization [1, 2]. The nutrition transition has been proposed as a set of dietary changes from healthy diets into a pattern of westernized foods [3]. According to the Global Burden of Disease (GBD) report, although the mean daily intake of some healthy foods including fruit, vegetables, fiber, and legume increased in the MENA region from 1990 to 2017, the burden of chronic diseases such as hypertension, type 2 diabetes, and cardiovascular disease have been raised, simultaneously [4–6]. This finding is indicating that concentrating on a single food per se cannot explain the link between the rapid raising of non-communicable diseases in the current decade and higher intake of some healthy foods.

People eat meals consisting of foods in different combinations. As there are plentiful synergistic and adversary interactions between nutrients, studying the dietary patterns is a better approach to identify a holistic view of eating behaviors of populations rather than focusing on the single dietary factor [7, 8].

Principal component analysis (PCA) is one of the most commonly used approach to derive dietary patterns which is based on data reduction method and provide a more useful picture of diet for study population.

Changes in dietary patterns among population are a subject of growing interest in various regions [9–12]. Despite the rapid economic changes in China, dietary patterns of the Chinese population remained relatively stable from 1991 to 2009 [9]. Lim et al. demonstrated that approximately 40% of participants still followed a traditional Korean diet which remained relatively stable since 1998 to 2010; however, the secular trend of Western diet decreased from 30% in 1998 to 10% in 2010 [10].

As dietary intake is one of the main contributors to chronic diseases, a robust, quantitative understanding of dietary patterns is imperative for designing strategies to reduce national and global diet-related disorders [13]. According to the important effect of globalization and urbanization on dietary pattern alterations as well as increased incidence of chronic diseases in the MENA, this study has two main objectives; first, to investigate the general structure and secular trend of dietary patterns extracted from the Tehran Lipid and Glucose Study (TLGS) and second, adherence to these dietary patterns among Iranian population from 2006 till 2017.

Methods

Study population

This study was conducted within the framework of the TLGS, a long term prospective general population study initiated in 1998 to determine the prevalence of non-communicable disease risk factors and its outcomes among the Tehranian urban population, which has been previously described [14]. Briefly, the first examination was initiated in 1999 among 15,005 people, aged ≥ 3 years from district 13 of Tehran using the multistage cluster random sampling method. Participants are undergoing a follow-up visit every 3 years, and data on any changes in demographic, anthropometric, reproductive and metabolic features and laboratory assessments were collected. The baseline examination was a cross-sectional study conducted from 1999–2001, and surveys II (2002–2005), III (2006–2008), IV (2009–2011), V (2012–2014), and VI (2015–2017) were prospective follow-up surveys. From the third examination survey of the TLGS (2006–2008), dietary assessment has been beginning in 3462 participants which were randomly selected from 12523 examined participants.

For the present study we investigated on four examination survey of TLGS including survey 1 (2006–2008), survey 2 (2009–2011), survey 3 (2012–2014), and survey 4 (2015–2017). In each examination survey, we included all adults aged ≥ 18 years with completed dietary data for at least two survey. We excluded who was on specific dietary change such as diet therapy for hypertension, dyslipidemia, and hyperglycemia (3372 participants were excluded). Furthermore, we also excluded 202 individuals because of under or over report of energy intakes (± 3 standardized deviation). Finally, 2215 from the survey 1, 1242 from the survey 2, 1833 from the survey 3, and 1218 from the survey 4 were selected.

The study was approved by the research ethics committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, and informed written consent was obtained from the parents of each subject.

Dietary assessment and food grouping

In each survey to assess the regular dietary intakes of participants over the previous year, trained dieticians during face-to-face interviews, gathered dietary data by a validated and reliable food frequency questionnaire (FFQ). For each food item on the FFQ, a portion size was specified using US Department of Agriculture (USDA) serving sizes whenever possible; if this was not possible, household measures were chosen and were then converted to grams. Energy and nutrient contents of food items were obtained from USDA food composition tables (FCT) because Iranian FCTs are incomplete. Iranian FCT was used for traditional food items that are not listed in the USDA FCT.

To identify dietary patterns, dietary data were categorized into 17 groups based on food and nutrient composition similarity [15] as follow: (1) Whole grains; (2) Refined grains; (3) Potatoes; (4) Dairy products; (5) vegetables; (6) Fruits; (7) legumes; (8) Meats; (9) Nuts and seeds; (10) Solid fats; (11) Liquid oils; (12) Tea and coffee; (13) Salty snacks; (14) Simple sugars; (15) Honey and jams; (16) Soft drinks; and (17) Snacks and desserts.

Measurements

Height was measured by well-trained examiners while participants wear no shoes and was recorded to the nearest 0.5 cm. Weight was measured using digital scales (Seca, Hamburg, Germany) and was recorded to the nearest 100 grams while the subjects were minimally clothed and without shoes. Body mass index (BMI) was calculated as the weight divided by the square of the height (kg/m2). Waist circumference (WC) was measured to the nearest 0.5 cm using a measuring tape in the standing position at the level of the umbilicus. Blood pressure (BP) was measured twice using a standard mercury sphygmomanometer after at least a 5-minute rest period. The mean of the 2 measurements was defined as the participant's blood pressure.

After a 12- to 14-hour overnight fasting, venous blood samples were obtained from the antecubital vein. All the blood analyses were done at the Tehran Lipid Glucose Study research laboratory. Fasting blood glucose (FBS) was measured using enzymatic colorimetric method by glucose oxidase kit (Pars Azmoon, Tehran, Iran) with inter-assay and intra-assay variation coefficients of < 2.2%. Total cholesterol (TC) was assayed, using the enzymatic colorimetric method with cholesterol esterase and cholesterol oxidase. HDL-c was measured after precipitation of the apolipoprotein B (apo B)-containing lipoproteins with phosphotungistic acid. Triglyceride (TG) was assayed using glycerol phosphate oxidase. Intra-assay and inter-assay coefficients of variations for TC, HDL-c, and TG were less than 1.9, 3, and 2.1%, respectively. Analyses were performed using related kits (Pars Azmon Inc., Tehran, Iran) and a Selecta 2 auto-analyzer (Vital Scientific, Spankeren, Netherlands). Low-density lipoprotein cholesterol (LDL-C) was calculated from the serum TC, TG, and HDL-C concentrations expressed in mg/dL using the Friedewald formula.

Statistical analysis

All statistical analyses were performed using SPSS (version 16.0), and a P-value less than 0.05 was considered significant. The normality of the distribution of variables was assessed by the Kolmogorov-Smirnov tests and checked by Histogram. As plasma TG was skewed, the log transformation was used. Characteristics of participants were expressed as mean ± standard error (SE) for continuous and percentages

for categorical variables. Generalized Estimating Equations (GEE) were used to assess secular trends in anthropometric, biochemical, and dietary variables across the years from 2006 to 2017. Since present study examined participants for a decade, all the anthropometric and biochemical measurements were adjusted for age. Moreover, nutrient intakes and dietary food groups were adjusted for age, sex, BMI, and energy intake of participants. To identify dietary patterns during each examination survey, PCA was used based on eigenvalues more than 1, scree plot and factor interpretability. Variables with factor loadings 0.3 or greater were used in interpreting the factors. Factors were rotated with the varimax procedure to assist interpretation of the factors. Each dietary pattern was labeled by a descriptive name after the most important loading variables as “Western dietary pattern”, “Healthy dietary pattern” and “Mixed dietary pattern”. Finally, K-mean cluster analysis was used to assess the secular trend of dietary pattern among study population.

Results

Trends in anthropometric and biochemical parameters

The secular trends in anthropometric and biochemical parameters during the four surveys are shown in table 1. In the age-adjusted model, there was an increase in the BMI and waist circumference from 26.5 kg/m^2 in survey 1 to 27.7 kg/m^2 in survey 4 and 88.2 cm in survey 1 to 93.6 cm in survey 4, respectively. Likewise, diastolic blood pressure (DBP), FBS, and HDL-c had increased from survey 1 to 4.

Table 1. General characteristics of the study population throughout the survey cycles

	Survey1 (2006-2008)	Survey2 (2009-2011)	Survey3 (2012-2014)	Survey4 (2015-2017)	P for trend
Participants (n)	2215	1242	1833	1218	
Age (year)	38.0±0.2	39.6±0.3	42.7±0.3	46.2±0.3	<0.001
Female (%)	52.7	54.0	52.4	51.1	0.001
Waist (cm)	88.2±0.2	91.8±0.3	92.5±0.3	93.6±0.3	<0.001
Body mass index (kg/m^2)	26.5±0.1	27.0±0.1	27.4±0.1	27.7±0.1	<0.001
Systolic blood pressure (mmHg)	109.5±0.3	111.6±0.4	113.0±0.4	112.0±0.4	0.407
Diastolic blood pressure (mmHg)	72.6±0.2	75.8±0.3	76.4±0.2	75.8±0.3	<0.001
Fasting blood glucose (mg/dl)	88.8±0.3	93.7±0.4	95.1±0.5	95.0±0.5	<0.001
Triglycerides (mg/dl)	132.5±1.6	125.5±3.3	136.9±1.8	133.7±2.0	<0.001
Total cholesterol (mg/dl)	181.2±0.8	181.3±1.0	189.4±1.0	188.1±1.1	0.077
High-density lipoprotein cholesterol (mg/dl)	42.7±0.2	48.0±0.3	49.4±0.3	47.9±0.3	<0.001
Low-density lipoprotein cholesterol (mg/dl)	112.1±0.6	108.9±0.8	112.4±0.7	113.9±0.9	<0.001

Values are expressed as age-adjusted mean ± SE for continuous and percent for categorical variables. General estimate equation was used, and age was adjusted.

Changes in nutrient and energy intake

Table 2 shows the stability in total energy intake among study population over the last decade. Moreover, percent of energy from carbohydrate and protein intake gradually increased (P-value<0.001). While, dietary total fat intake, saturated fatty acid, MUFA, and PUFA decreased slightly since the first survey (all P-value<0.001). Interestingly, dietary sodium intake has been decreased from 2006 mg/1000Kcal in survey 1 to 1556 mg/1000Kcal in survey 4 (P-value<0.001). Participants in survey 1 consumed 16.2 gr/1000kcal of dietary fiber which has been increased to 19.5 gr/1000kcal in survey 4. Finally, total sugar intake was stable throughout the study period.

Table 2. Changes in nutrient and energy intake among study population over the four surveys

	Survey1 (2006-2008)	Survey2 (2009-2011)	Survey3 (2012-2014)	Survey4 (2015-2017)	P for trend
Energy (Kcal)	2383±19.8	2518±27.3	2396±24.6	2282±30.3	0.370
Carbohydrate (% of energy)	57.2±0.1	58.7±0.2	58.9±0.1	59.7±0.1	<0.001
Protein(% of energy)	13.6±0.0	14.8±0.0	14.6±0.0	15.1±0.1	<0.001
Fat (% of energy)	31.6±0.1	29.8±0.1	29.6±0.1	29.1±0.1	<0.001
Saturated fatty acid (% of energy)	10.6±0.1	9.8±0.0	9.5±0.0	9.3±0.0	<0.001
Monounsaturated fatty acid (% of energy)	11.0±0.0	9.9±0.0	9.8±0.0	9.8±0.0	<0.001
Polyunsaturated fatty acid (% of energy)	6.6±0.0	5.9±0.0	5.9±0.0	5.8±0.0	<0.001
Sodium (mg/1000Kcal)	2006±31.9	1529±12.3	1537±11.4	1556±12.2	<0.001
Dietary fiber (gr/1000Kcal)	16.2±0.1	19.4±0.2	18.3±0.1	19.5±0.2	<0.001
Total sugar (gr/1000Kcal)	52.6±0.3	53.0±0.3	54.0±0.3	55.0±0.3	0.166

Values are expressed as adjusted mean ± SE. All variables were adjusted by age, sex, body mass index and energy intake. General estimate equation was used.

Changes in dietary food groups

Figure 1 indicates food groups which were consumed among population through the four surveys. During the study period, participants consumed notable less refined grain, solid fat, and simple sugar (all P-values<0.001). In addition, intake of dairy products decreased significantly during the last decade (P-value<0.001). During the study period, meat consumption had no significant changes among study

participants. Interestingly, snack and dessert increased rapidly, especially in the third survey (all P-value<0.001). Moreover, fruit and vegetable intake remained stable throughout the study period (data not shown).

Changes in dietary patterns

Table 3 shows the factor loading of food items throughout four surveys. The first dietary pattern explored by PCA was *Healthy dietary pattern* which was characterized by higher intake of vegetable, fruit, dairy products, liquid oil, nuts and seeds, and honey and jam. The second dietary pattern was *Western dietary pattern* which was featured by refined grain, solid fat, meat, snack and dessert, potato, and soft drink. Finally, the *Mixed dietary pattern* was also extracted which was highlighted by tea and coffee, and simple sugar. In the second survey, the 3 dietary patterns were changed as follow: first of all, meat, soft drink, and potato were added to the *Healthy* dietary pattern; secondly, people ate more legumes along with their *Western dietary pattern*; and finally, solid fat was concurrently expressed from *Western* to the *Mixed* dietary pattern. In comparison to the previous survey, participants in survey 3 modified their dietary patterns. Honey and jam intake did not loaded in the *Healthy* dietary pattern, and potato intake shifted from *Healthy* to *Western* dietary pattern. Then in the fourth survey, soft drink, meat, and potato intake were loaded in the *Western* dietary pattern. Interestingly, dietary refined grain has been shifted slightly from *Western* to *Mixed* dietary pattern.

Table 3. Food groups loadings for 3 dietary pattern found by principle component analyses among study population

Food groups	Survey1			Survey2			Survey3			Survey4		
	H	W	M	H	W	M	H	W	M	H	W	M
vegetables	0.591	-	-	0.631	-	-	0.513	-	-	0.693	-	-
Fruits	0.683	-	-	0.685	-	-	0.621	-	-	0.682	-	-
Dairy products	0.544	-	-	0.511	-	-	0.513	-	-	0.418	-	-
Liquid oils	0.534	-	-	0.478	-	-	0.653	-	-	0.334	-	-
Nuts and seeds	0.522	-	-	-	-	-	0.319	-	-	0.422	0.314	-
Honey and jams	0.366	-	-	0.434	-	0.324	-	-	-	0.319	-	0.379
Soft drinks	-	0.446	-	0.487	-	-	0.489	-	0.405	-	0.585	-
Snacks and desserts	-	0.447	-	-	0.721	-	-	0.708	-	-	0.701	-
Meats	-	0.459	-	0.407	-	-	0.460	-	-	-	0.383	-
Refined grains	-	0.602	-	-	0.471	-	-	-	0.423	-	-	0.474
potatoes	-	0.446	-	0.447	-	-	-	0.372	-	-	0.503	-
Solid fats	-	0.536	-	-	-	0.337	-	-	0.470	-	-	0.301
Salty snacks	-	0.309	-	0.312	-	-	-	-	-	0.519	-	-
Simple sugars	-	-	0.711	-	-	0.830	-	-	0.764	-	-	0.735
Tea and coffee	-	-	0.765	-	-	0.747	-	-	0.586	-	-	0.574
Whole grains	-	-	-	-	0.337	-	-	-	-	-	-	-
legumes	-	-	-	-	0.726	-	-	0.785	-	-	0.639	-

Values less than 0.3 were excluded for simplicity. H: Healthy dietary pattern, W: Western dietary pattern. M: Mixed dietary pattern.

Based on cluster analysis, the secular trends in dietary patterns is presented in Figure 2. The overall trend was a decline in the *Western* dietary pattern from 31.2% in survey 1 to 27.8% in survey 4, and the emergence of the *Mixed* dietary pattern from 29.7% in survey 1 to 34.1% in survey 4. Finally, the *Healthy* dietary pattern was stable among study population during the last decade.

Discussion

In the present study which analyzed dietary data collected from four surveys over the course of a decade (from 2006 to 2017), we derived three dietary patterns using factor analysis which was mostly centered on these food groups: a Healthy dietary pattern characterized by vegetable, fruit, dairy products, liquid oil, and

nuts and seeds, a Western dietary pattern featured by soft drink, snack and dessert, meat, refined grain, and solid fat intake, and a Mixed dietary pattern highlighted by tea and coffee, and simple sugars. Our findings indicated that the structure of these dietary patterns did not seem to be stable over a decade. It means that the type of food groups that population have chosen to eat in combination had changed since 2006. This revealed a secular trend in dietary patterns including an emerging adherence of study population to Mixed dietary pattern, maintenance of Healthy dietary pattern, and a decline of Western dietary pattern.

Most of the previous epidemiological studies which focused on dietary patterns, have analyzed the relation of dietary pattern with risk of chronic diseases [16–21], and less of them investigated the secular trend of dietary patterns over the time[9, 10, 22, 23]. Mostly three common dietary patterns have been identified throughout these investigations. Healthy or Prudent dietary pattern which is mostly based on fruit, vegetable, dairy product, and liquid oil, Unhealthy or Westernized dietary pattern which is mostly characterized by solid fat, snack, soda, and meat; however, the third one which mostly named by modified, new or mixed dietary pattern, differ in each study with different factor loading and food items. Healthy and Western dietary patterns loaded in the current study is mostly similar to the results of other studies[9, 21]. Adherence of our study population to the three dietary patterns is similar to the result of Korean population, in which the number of participants following the Western dietary pattern declined, and the new dietary pattern increased in population over time [10].

According to the results of this study, energy intake of study population remained stable since the first survey. However, the percent of energy from carbohydrate and protein intakes increased and percent of energy from fat and all its subtypes (saturated, mono- and polyunsaturated fatty acids) decreased. People have become increasingly aware of the health benefits of vegetable oils and it seems that the source of fat intake has been changed during the last decade and there are a significant shift from intake of solid fat to the liquid oil [24]. Likewise, the sources of protein intake has been changed from animal to plant based including legumes.

In term of the trend in food consumption, our findings indicated that fruit and vegetable intake has remained consistent. It seems that policy approaches must be considered to increase fruit and vegetable intake, as consumption of these food groups is hardly possible for the populations with low income. Whole grain, has increased significantly since the first survey, which was in contrast with the trend of other MENA region countries [4]. In the current study, intake of meat as a protein source was stable over the last decade, which was in contrast to the results of other Asian country including China and India where meat intake had increased since the westernization [25]. It is important to note that with the growing rate of urbanization, study population have eaten more snacks and desserts. One of the important points of current study is that the dietary dairy intake decreased significantly throughout the surveys. This result has been proven by the World Health Organization STEP wise approach to Surveillance (STEPS), which indicated that only near the 18 percent of Iranian population meet the appropriate amount of dairy intake [26].

According to the results of current study, Mixed dietary pattern has increased since the survey 1. This dietary pattern consist of simple sugar, tea and coffee, and whole grain which is mostly similar to the traditional dietary pattern of Iranian population. Simple sugar and tea and coffee were loaded in all four surveys and it shows a deeply rooted of these food items in the traditional dietary pattern of Iranian culture. Interestingly, in the second and mostly third surveys unhealthy food items such as refined grain, and solid fat was added to

the Mixed dietary pattern and this may be influenced by modified Iranian meals like western style dinner. The traditional Iranian diet is wheat-based. Tea is the major beverage and dairy products such as yoghurt and cheese was consumed widely [2]; however, the consumption of dairy products decreased since last decade. It is noteworthy that about 38% of our study populations tried to maintain a Healthy dietary pattern; however, the intake of food groups have been changed and they accepted Western-style foods according to changing environmental factors. It appears that Iranian modified their dietary pattern, in another words it is not pure westernized but lots of unhealthy foods was added to the traditional dietary patterns of study population.

The strength of the present study is the large sample size, and the longitudinal design of the study, so we could track changes in dietary pattern individually. Moreover, the food frequency questionnaire which help to capture food groups that are only episodically consumed and the tool did have a validity test. Besides, we believe that our comparisons between years were not affected by the cohort effect, not only because all the subjects were included in at least two surveys but also because we adjusted all the results by age in the first survey.

One of the limitations of the present study is that some food groups including dairy products, fast foods, and meat intakes were not separated into subgroups. For this reason, it is not clear that putting these food groups in one of the three dietary patterns is because of which food item. For example meat consist of egg, red meat, poultry, and fish. Another important limitation is that the number of foods available in the food supply exceeds by far the number of those available in food composition tables so the present study was unable to capture all the changes in dietary intake, particularly of processed packaged foods. Recall bias was also an inevitable problem when asking participants to remember and report dietary intakes.

Conclusions

Taken together, it is clear that the structure and the type of foods that population have chosen to eat had changed since 2006. And a new secular trend in dietary patterns including a stability of Healthy dietary pattern, a decline of the Western dietary pattern and an increase in the Mixed dietary pattern was presented in our investigation.

List Of Abbreviations

BMI: Body mass index

BP: Blood pressure

DBP: diastolic blood pressure

FBS: Fasting blood glucose

FCT: food composition tables

FFQ: food frequency questionnaire

GBD: Global Burden of Disease

GEE: Generalized Estimating Equations

MENA: middle East and North Africa

PCA: principle component analysis

SE: standard error

STEPS: STEP wise approach to Surveillance

TC: Total cholesterol

TLGS: Tehran Lipid and Glucose Study

USDA: US Department of Agriculture

WC: Waist circumference

Declarations

Ethics approval and consent to participate: The design of this study was approved by the institutional ethics committee of the Research Institute for Endocrine Sciences, affiliated to the Shahid Beheshti University of Medical Sciences, and written informed consent was obtained from study participants.

Consent for publication: Not applicable

Availability of data and material: All data generated or analyzed during this study are included in this published article.

Competing interests: The authors declare that they have no competing interests

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Authors' contributions: All authors have read and approved the final manuscript. Overall P. M., G. A. supervised the project and approved the final version of the manuscript to be submitted. G. A. and M. A. designed the research; M. A. and E. Y. analyzed and interpreted the data; F. A. critically reviewed the manuscript; and M. M. drafted the initial manuscript statistical methodology.

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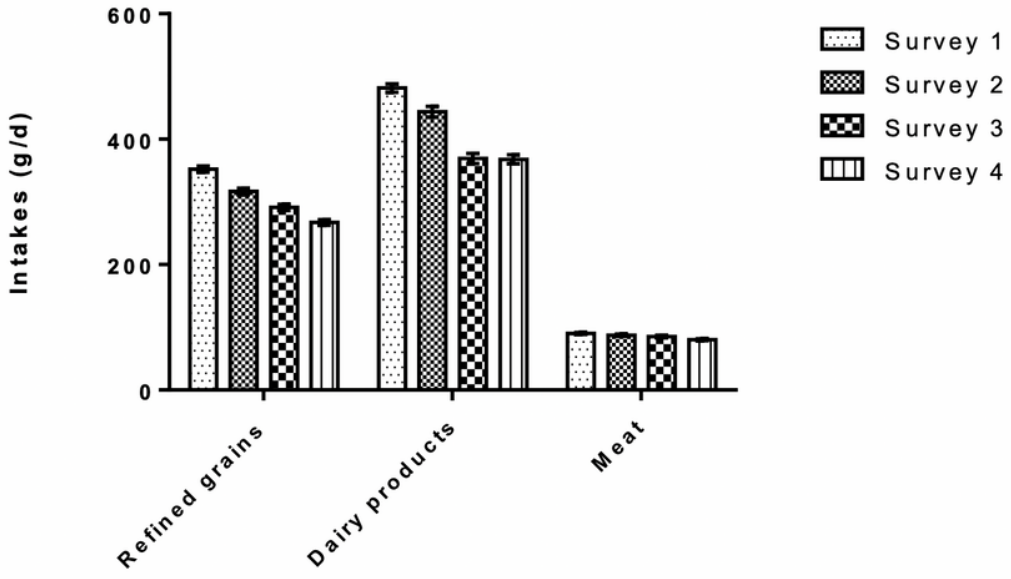
Figures



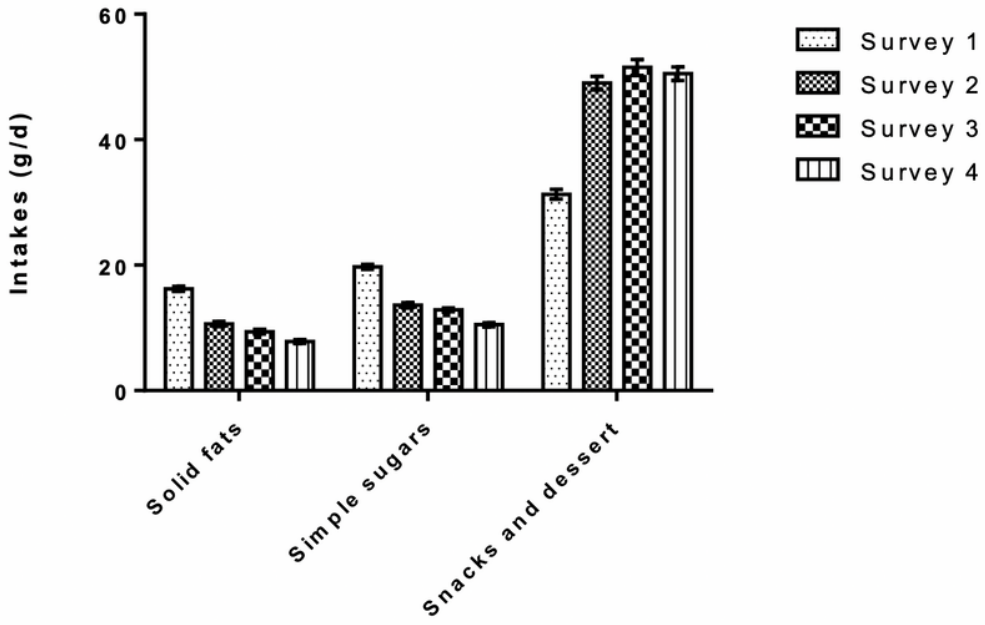


Figure 1

Changes in food groups among study population throughout the four surveys. Values are expressed as adjusted mean ± SE. All variables were adjusted by age, sex, body mass index and energy intake. General estimate equation was used.

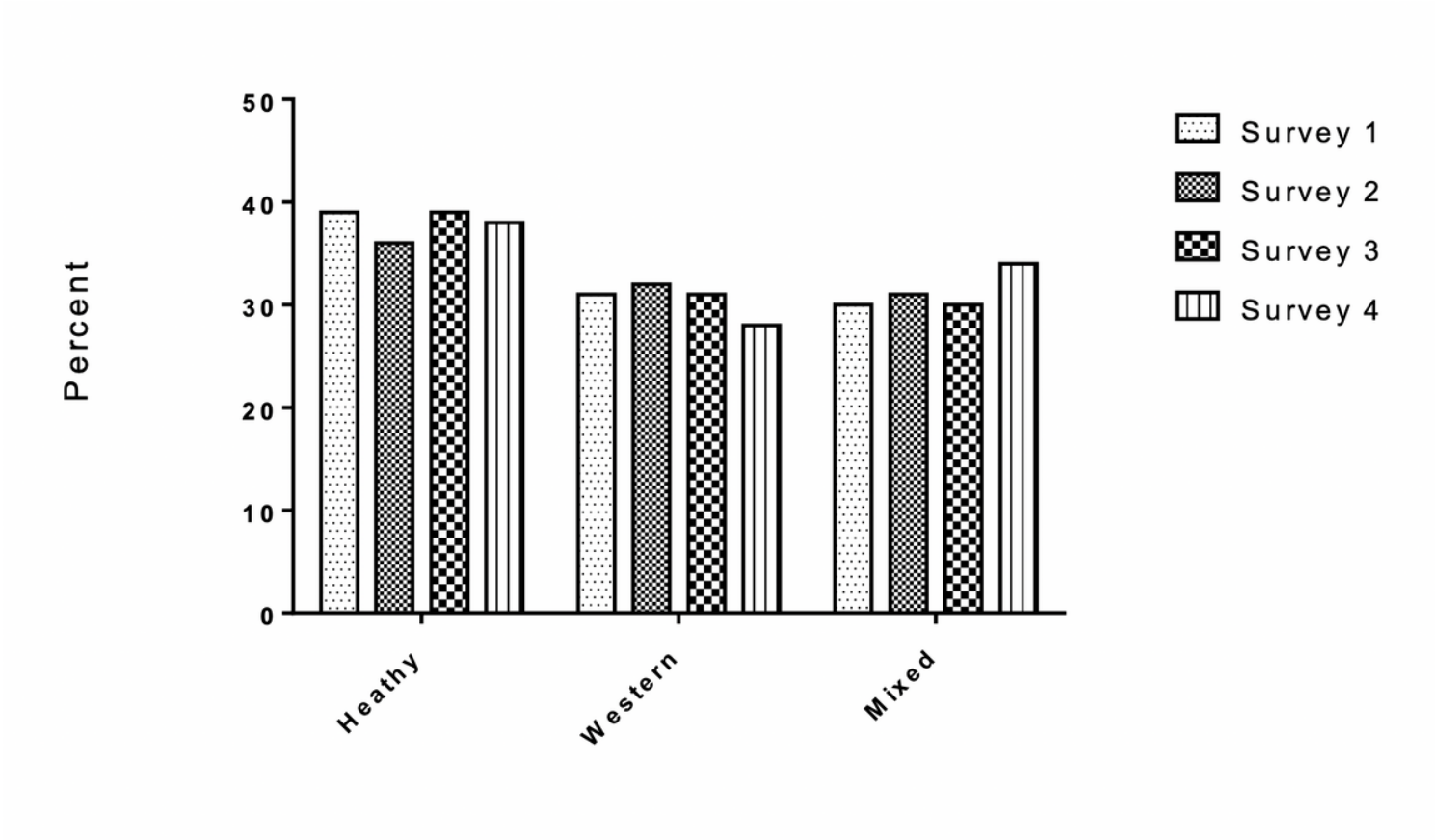


Figure 2

Changes dietary patterns among study population in Iran between 2006- 2017 K-mean cluster analysis was used.