Research Paper
Indirect Assessment of Diet Quality Trends in Iranian Households, 1991–2020

Omid Emami[1], Ahmadreza Dorosty Motlagh[2], Amirhossein Takian[1, 3*], Ehsan Mousa Farkhani[4]

1. Department of Food and Nutrition Policy, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran.
2. Health Equity Research Center (HERC), Tehran University of Medical Sciences (TUMS),Tehran, Iran.
3. Department of Global Health, Center of Excellence for Global Health, School of Public Health, Tehran University of Medical Sciences (TUMS), Tehran, Iran.
4. Department of Epidemiology and Biostatistics, School of Health, Mashhad University of Medical Science, Mashhad, Iran.

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ABSTRACT

Background: The healthy eating index (HEI) is a valuable tool in health and nutrition research, providing a measure of diet quality aligned with key recommendations from the Dietary Guidelines for Americans. This study aimed to examine the trends and sociodemographic correlates of dietary quality, as measured by the HEI-2015, among Iranian households over 30 years from 1991 to 2020.

Methods: Data from the Household Income-expenditure Survey of 665,254 Iranian households (out of 926,339 surveyed from 1991 to 2020) were analyzed in this cross-sectional study. A hierarchical age-period-cohort (HAPC) model, implemented in SAS software, version 9.4, was used to disentangle age, period, and cohort effects.

Results: HEI scores initially increased from 1999 to 2017, indicating improved dietary quality, then declined since 2018. Significant sociodemographic disparities were observed, with higher household income (P<0.0001), education level (P<0.0001), and urban residence (P<0.0001) associated with higher HEI scores. The HAPC model enabled disentangling age, period, and cohort effects, providing insights into the distinct influences shaping dietary patterns across population subgroups over time. This study revealed a statistically significant positive trend in scores, with a mean increase of 8 points over 18 years (1999-2000 to 2015-2016). Scores rose from 43.86 (1999-2000) to 51.86 (2015-2016).

Conclusion: This study highlights the need for targeted interventions to promote healthy eating habits, particularly among socioeconomically disadvantaged and rural populations. Addressing the observed decline in dietary quality and sociodemographic disparities is crucial for improving the overall population health and well-being.

Keywords: Healthy eating index (HEI)-2015, Diet quality, Hierarchical age-period-cohort (HAPC), Household income and expenditure survey

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*** Corresponding Author:**
Amirhossein Takian, Professor.
Address: *Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran.*
Phone: *+98 (21) 88955569*
E-mail: *dorostim@tums.ac.ir*

Introduction

The healthy eating index (HEI) is a valuable tool in health and nutrition research, providing a measure of diet quality aligned with key recommendations from the Dietary Guidelines for Americans [1]. Although developed for the US context, the HEI-2015—the most current version—has been adapted to assess dietary intake in diverse populations aged 2 years and older, including non-Western settings [2]. The HEI-2015 consists of 13 components that reflect different food groups and key recommendations in the 2015-2020 Dietary Guidelines [3].

The HEI uses a scoring system to evaluate dietary intake patterns. The scores range from 0 to 100. An ideal overall HEI score of 100 reflects that the set of foods aligns with key dietary recommendations from the Dietary Guidelines. This can help identify areas where improvements are needed and monitor changes in dietary patterns over time [4]. The HEI-2015 provides a snapshot of overall diet quality and indicates that the average diet in the United States does not conform to dietary recommendations [3]. Each step closer to a diet that aligns with dietary guideline recommendations can help reduce the risk of developing diet-related chronic diseases, such as heart disease, type 2 diabetes, and cancer [5-7]. The hierarchical age-period-cohort (HAPC) analysis is a statistical method that decomposes trends in behaviors or health outcomes, such as healthy eating, into three distinct components: age, period, and cohort effects. This approach allows researchers to identify the various influences that act on a population over time [8].

Age effects can refer to the behavioral differences between different age groups regarding healthy eating. Period effects represent changes that affect all age groups during a specific period. Cohort effects capture the unique experiences shared by a particular generation throughout their history and social environment.

This study aimed to examine age, period, and cohort effects on dietary quality using the HEI-2015, employing data from the household income and expenditure survey (HIES) conducted by the Statistical Center of Iran. HAPC analysis distinguishes these effects to inform targeted dietary interventions. HAPC analysis of HEI can provide valuable insights into changes in dietary quality over three decades, enabling a more nuanced understanding of the effects of age, period, and cohorts. This analysis can inform strategies for improving dietary policies and programs.

Methods

Sample

Data from 926,339 households in income-expenditure surveys conducted between 1991 and 2020 were analyzed. A total of 665,254 households were included, while 261,085 were excluded due to energy intake values falling outside the normal range (defined as <500 or >3500 kcal for women and <800 or >4200 kcal for men, as outliers) [9-11].

Dietary assessment

This was a repeated cross-sectional study. By applying a set of statistical and nutritional techniques, we converted the HIES data of Iranian society from 1991 to 2020 into household food consumption data. The HIES questionnaire, used for both urban and rural populations, consists of four sections, with section three dedicated to household expenses, including food expenses. We used data from 1991 to 2020 because fewer changes were observed in the questionnaire during this period [12].

HIES data serve as a proxy for food consumption, as direct dietary intake data were unavailable, consistent with methodologies used in similar settings [13-15]. To generalize the sample from each urban and rural area to the entire community, a coefficient or weight was determined for each household based on economic and social criteria [16]. This coefficient, calculated by the Statistical Center of Iran, was used to calculate the HEI.

This study adopted the adult male equivalent (AME) as recommended by the Food and Agriculture Organization (FAO) and World Health Organization (WHO). AMEs represent the energy requirements of an adult male (18-30 years old, moderate physical activity) relative to other household members. Household AME requirements were calculated based on each member's age and sex. To determine the daily intake per AME for each food item, the total amount of the item was divided by the total number of household AMEs. This approach simplifies calculations by converting all household members to a common energy unit (AME) [17, 18].

Furthermore, the FAO's estimated food waste percentages for each food group were incorporated during the consumption step, accounting for food acquired through purchase, gifts, donations, or household production. This methodology provides a more accurate estimate of actual household food consumption [17].

HEI

HEI comprises 13 components, divided into two sections: Adequacy (nine items) and moderation (four items). The adequacy components include foods that should be consumed more for optimal health, while the moderation components include foods that should be limited to maintain good health (Figure 1) [1].

Estimation of individual consumption

The step-by-step process for estimating individual per capita consumption is as follows:

1) Calculation of the amount of food purchased per day (monthly values are provided). 2) Utilizing conversion factors from live animals to carcasses (obtained from the United States Department of Agriculture (USDA) "food yields summarized by different stages of preparation") [19]. 3) Utilizing conversion factors from raw to cooked [19, 20]. 4) Utilizing conversion factors for the net amount of food items (e.g. excluding pineapple skin) [19]. 5) Utilizing waste factors for food items [21]. 6) Removal of void and unnecessary codes, such as rents. 7) Utilizing the AME method [22]. 8) Calculation of energy, macronutrients, and food servings (according to the 13 components of the HEI Score, using NUTRITIONIST IV software adapted to analyze Iranian food consumption). 9) Removal of outlier data (less than 500 or more than 3500 kilocalories for women and less than 800 or more than 4200 kilocalories for men) [11]. 10) Calculation of the HEI Score for individuals. 11) Utilizing household weights and calculating the weighted average of HEI.

Modeling

HAPC analysis

HAPC analysis is a statistical technique used to identify and examine the multifaceted influences of age, period, and cohort on data gathered over time and across various units. In the context of household income-expenditure data, both fixed- and random effects models can be utilized, each with a distinct approach to parameter estimation [14].

Fixed effects model: This model assumes that unobservable variation across units (such as individuals, firms, or countries) remains constant and unaltered over time. It seeks to uncover unique and persistent effects for each unit [12].

Random effects model: This model assumes that unobservable differences between units are random and independent of the explanatory variables. It is well-suited for analyzing data in which variation among units follows a random distribution [12].

In this study, both period (year) and generational (cohort) effects were incorporated as random effects. Periods were defined as one-year intervals, while generational groups (cohorts) were categorized based on five-year increments.

Given the variability of food intake across different time periods and age cohorts, we used the HAPC analysis model proposed by Yang and Land (2006) to examine these changes. In cross-classified random effects modeling (CCREM), the HAPC method is particularly useful as it shows the simultaneous effects of three influential factors, unlike linear regression methods. This method, also known as the Mixed Fixed-Random Effect method,

Period / Cohort	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
< 1911	42.0	43.3	42.7	44.5	41.5	41.6	41.5	41.2	41.0	40.8	42.7	42.5	47.2	45.6	46.5	45.9	47.5	45.2	46.9											
1911-1916	42.5	43.0	43.8	41.9	42.4	41.6	41.5	42.5	40.9	42.0	44.0	42.3	44.2	46.7	47.7	46.5	46.7	43.8	46.8	46.3	47.1	48.0	48.0	47.4						
1916-1921	43.8	44.0	44.8	44.4	41.6	42.0	41.7	42.8	41.1	41.2	43.8	42.1	46.5	46.8	47.4	46.4	47.8	48.0	45.5	47.5	47.0	50.1	49.2	50.7	47.5	49.2	48.1	46.4	49.2	
1921-1926	45.3	44.7	44.5	44.6	42.4	42.0	42.4	42.9	42.4	42.7	43.7	44.1	44.5	46.0	46.5	47.5	46.2	45.8	47.0	48.1	47.8	47.4	48.4	49.6	50.2	48.4	50.4	50.2	49.9	50.3
1926-1931	44.8	44.4	44.5	44.7	42.2	42.0	42.5	42.1	42.4	42.5	43.6	44.0	44.5	46.7	45.8	47.5	47.4	47.3	46.9	48.5	49.0	48.8	48.7	48.4	49.5	51.2	50.5	48.9	50.1	48.7
1931-1936	44.4	44.3	44.5	44.6	42.5	42.3	42.9	43.8	42.9	43.3	44.3	44.4	45.5	46.2	46.4	48.7	47.5	48.6	47.7	48.0	49.2	49.0	49.4	49.5	50.1	50.3	50.9	49.2	50.5	50.6
1936-1941	44.5	44.1	44.6	44.9	42.8	42.5	43.8	43.7	43.2	43.1	44.2	45.3	45.3	46.3	47.7	48.2	47.6	48.1	48.2	49.0	49.7	50.3	49.3	50.4	50.8	51.6	51.4	50.8	51.0	51.4
1941-1946	44.7	44.7	44.3	45.2	43.0	43.6	44.0	44.0	42.9	43.7	44.2	45.2	45.7	46.7	46.4	47.5	48.1	48.3	49.0	49.3	50.0	50.1	50.4	50.3	50.9	51.7	51.9	51.2	50.9	51.5
1946-1951	44.9	44.1	45.1	44.8	43.0	43.7	43.9	44.1	43.4	44.1	45.2	45.8	46.1	47.6	46.6	47.9	48.1	49.0	49.1	49.6	50.6	49.8	50.2	51.3	51.0	51.7	52.5	51.9	51.7	51.7
1951-1956	45.2	44.8	44.7	45.0	42.9	43.1	43.8	44.5	43.6	44.1	45.0	45.7	46.5	47.3	47.5	47.9	48.6	49.3	49.6	49.9	50.6	50.7	50.5	50.9	51.4	52.0	53.0	51.8	51.9	52.1
1956-1961	45.4	44.4	44.7	45.2	43.1	43.4	44.0	44.3	43.5	44.1	45.1	45.5	46.2	46.8	47.1	47.8	48.2	49.0	49.4	50.3	50.6	50.7	50.3	51.7	51.7	52.1	52.6	51.9	52.1	52.3
1961-1966	45.9	45.1	45.7	45.7	43.7	43.6	43.7	44.1	43.8	44.7	44.9	45.9	46.5	47.4	47.5	47.9	48.5	49.2	49.2	50.4	50.4	50.9	50.4	51.6	51.9	52.5	53.0	52.4	52.3	52.2
1966-1971	45.6	45.0	45.0	45.2	43.6	43.5	43.8	44.5	43.7	44.7	45.3	46.2	46.5	47.3	47.2	48.5	48.5	49.2	49.2	49.8	50.7	50.3	50.4	51.3	51.5	52.1	52.7	52.4	52.3	52.1
1971-1976	43.1	44.2	44.7	45.3	42.4	42.3	42.6	43.7	42.6	44.1	45.6	46.1	46.8	47.4	47.0	45.3	47.8	48.8	49.4	49.8	50.3	50.2	50.0	50.8	50.9	51.7	52.1	51.7	51.9	51.6
1976-1981	46.3	44.3	41.3	42.6	42.1	40.0	41.2	41.8	41.1	41.9	42.9	44.8	45.9	46.2	47.3	46.9	48.2	48.9	49.5	49.9	50.1	49.7	49.9	50.8	51.0	51.9	52.0	51.4	51.7	51.4
1981-1986						42.3	43.1	42.3	40.7	40.9	41.8	44.2	43.6	45.5	45.8	47.6	47.5	47.8	48.8	49.6	50.3	50.1	50.0	51.2	51.1	52.0	52.7	52.1	52.0	51.7
1986-1991											42.6	44.6	44.3	42.7	45.0	46.0	43.8	46.0	46.8	48.0	48.9	48.4	49.5	50.5	50.6	51.6	52.4	51.3	51.4	51.3
1991-1996																44.7	46.8	48.5	43.7	43.4	45.7	47.0	46.1	48.4	50.1	50.8	50.9	50.3	50.8	50.2
> =1996																					47.7	49.2	49.4	45.1	47.6	51.5	49.1	48.7	49.5	50.3

Figure 1. Cross table of HEI values for period and cohort

has traditionally been used to study diseases; however, we applied it for the first time to analyze changes in the HEI [14].

We performed the analysis using two models:

1) Model 0: No variables were entered into the model. 2) Model 1: Variables such as the age of the head of the household (representative of the household), the square of the age of the head of the household (to account for nonlinear age effects), household income quartile, place of residence, gender of the head of the household, literacy level of the head of the household, occupational activity status of the head of the household, home ownership, and marital status of the head of the household were included.

To address collinearity, we used principal component analysis to combine correlated household characteristics (Household size, home area, number of literate household members, number of students, and number of employed household members, e.g.) into a smaller number of components, which were then included in the regression model.

The model formulation is as Equation 1 [14]:

1. Yijk=γ0+β1 Age of the head of householdijk+β^2 Age of the head of household2 ijk+β3 Economic statusijk+β4 Gender of the head of householdijk+β5 Place of residence ijk+β6 Literacy of the head of householdijk+β7 Marriage status of the head of householdijk+β8 PCA_factorijk+β9 Homeownership statusijk+β10 Employment activityijk+u0k+v0j+eijk with u0 j~N(0, τu) v0 k ~N(0, τv) eijk~N(0,σ^2)

for

i=1, 2, njk individuals within cohort j and period k; j=1., 19 birth cohorts; k=1., 30 survey years. u=periods, v=Cohorts

To ensure model stability, period effects (annual intervals) and cohort effects (5-year intervals) were modeled as random effects without smoothing, as the large sample size (n=665,254) mitigated overfitting risks. The CCREM addresses the age-period-cohort identification problem by modeling age as a fixed effect and period/cohort as random effects, following Yang and Land (2006) [14] The PCA_factor was derived from less influential variables (household size, home area, number of literate people, number of students, number of employed people) using Principal Component Analysis, retaining components explaining ≥70% of variance to reduce collinearity. The HAPC analysis was implemented using SAS software, version 9.4, PROC MIXED, with the restricted maximum-likelihood (REML) method.

In regression models, variables are sometimes squared to capture nonlinear relationships between the explanatory and dependent variables. For age, this approach allows modeling its effect at different ages, rather than assuming a linear effect across all ages.

Model 1, incorporating the variables mentioned, was estimated and analyzed using REML with the PROC MIXED procedure in SAS software, version 9.4. Charts were created using Microsoft Excel software, version 2016.

Results

The average household size over the 30-year study period was 4.27±1.98. The mean annual household income was 1,338,688,065 Rials (approximately $31,851 at the time of writing). The average age of the household head was 48.88±15.30 years, and the mean residential area was 86.97±51.67 m². Rural households accounted for 43.2% of the sample, and 10.3% of households were female-headed.

The average national HEI score over the 30 years was 48.39±10.25. Figure 2 shows the yearly trend in HEI scores, along with standard deviation bands. The lowest and highest HEI scores were observed in 1995 and 2017, respectively. A declining trend was evident from 2018 onwards. Figure 1 presents raw data; model-based estimates are described in the next paragraphs.

Figure 3 shows average HEI scores across five-year birth cohorts. The lowest scores were observed in cohorts born before 1911, while the highest were among those born between 1981 and 1986. These unadjusted values were later used in the HAPC model to quantify cohort effects.

Figure 1 presents HEI scores across combinations of birth cohorts and survey years. The table reveals that HEI scores were generally low across all generations from 1991 to 2002, improved between 2010 and 2018, and declined again from 2019 onward, returning to levels similar to the early 1990s.

Table 1 summarizes the results of the HAPC models (Models 0 and 1), estimating the fixed and random effects on HEI. Model 1 shows that urban residence (β=2.12), higher income (IQ4), and education (β=3.07) were significantly associated with higher HEI scores.

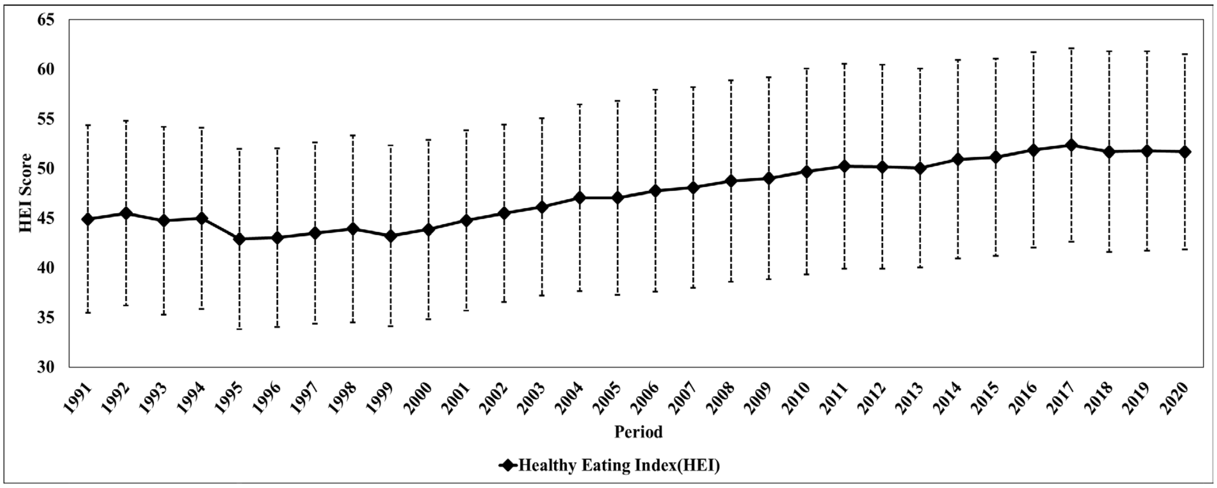

Figure 2. HEI values for periods (±SD)

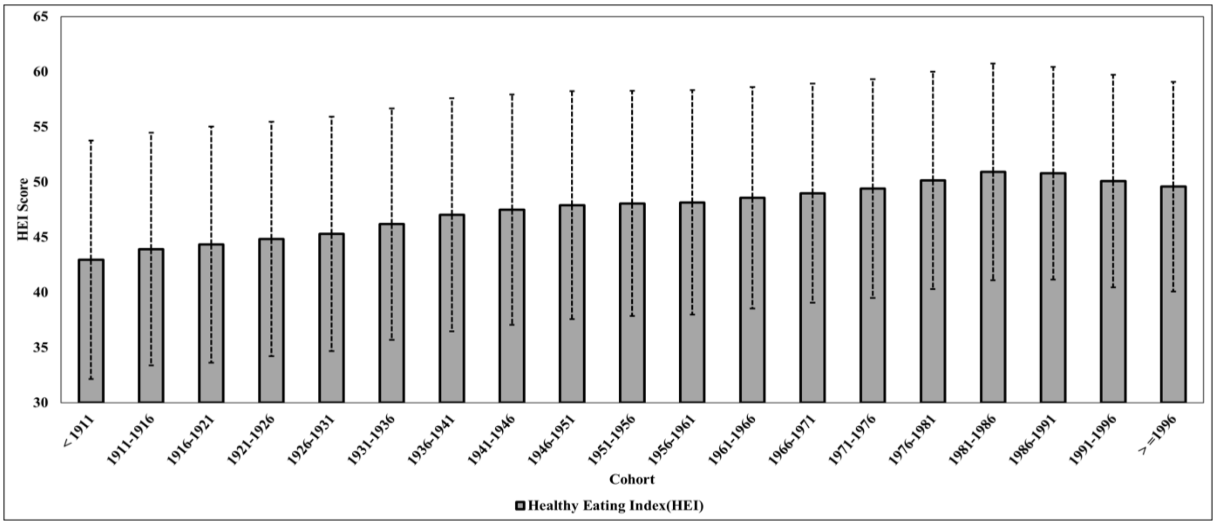

Figure 3. HEI values for cohorts (±SD)

Married and employed household heads also had higher scores. Among age cohorts, those born between 1946 and 1961 had the most favorable dietary quality.

Model 0 reveals significant effects (P<0.01) for all periods except 2004-2007 (P >0.05). Additionally, age cohorts 1939-1936, 1936-1941, 1941-1946, and 1986-1991 do not exhibit significant changes (P>0.05), while the remaining age cohorts demonstrate significant variations (P<0.01).

Model 1, all periods except 2004-2007 exhibit significant effects (P<0.01). However, age cohorts 1921-1926, 1926-1931, 1966-1971, 1971-1976, 1976-1981, 1981-1986, 1986-1991, and ≥1996 do not show significant changes (P>0.05), while the remaining age cohorts demonstrate significant variations (P<0.01) and socioeconomic factors on HEI scores.

Discussion

This study utilized HIES data as a proxy for dietary consumption, a common approach in settings lacking direct dietary intake data [15, 23, 24]. The application of the HAPC model offers a novel approach to analyzing dietary quality trends in Iranian households over 30 years (1991–2020). Unlike traditional linear regression, the HAPC model disentangles age, period, and cohort effects, providing nuanced insights into dietary patterns and informing targeted interventions. This methodology, previously applied to non-communicable diseases [25-27], demonstrates its versatility in nutritional epidemiology [12].

Table 1. HEI HAPC-CCREM of the HEI based on model 0 and 1 according to REML estimation method

Effects			Model 0			Model 1			95% CI	
	Fixed Effects	Parameters	Estimate	SE	P	Estimate	SE	P	Lower	Upper
	Intercept	γ0	46.9451	0.6063	<0.0001	45.8476	0.5156	<0.0001	44.7644	46.9308
	Age of the head of household	β1				0.09802	0.006800	<0.0001	0.08469	0.1113
	Square of the age of the head of household	β2				-0.00069	0.000057	<0.0001	-0.00080	-0.00058
	Gender of the head of household (female=0)	β3				-0.4699	0.06060	<0.0001	-0.5887	-0.3511
	Place of residence (rural=0)	β4				2.1258	0.02455	<0.0001	2.0777	2.1739
IQ	IQ 1	β5				-8.1508	0.03595	<0.0001	-8.2213	-8.0803
	IQ 2	β5				-5.0922	0.03362	<0.0001	-5.1581	-5.0263
	IQ 3	β5				-3.0021	0.03281	<0.0001	-3.0664	-2.9378
	IQ 4 (ref.)	β5				.	.	.	.	.
	Literacy of the head of household (non-literacy=0)	β6				3.0739	0.03096	<0.0001	3.0132	3.1346
	Marriage of the head of household (single=0)	β7				0.1783	0.05581	0.0014	0.06891	0.2877
	PCA_factor	β8				-2.0450	0.01405	<0.0001	-2.0725	-2.0175
	Homeownership status (non_owner=0)	β9				-0.2382	0.02894	<0.0001	-0.2949	-0.1814
	Employment activity (non_activity=0)	β10				0.1762	0.03206	<0.0001	0.1133	0.2390
Random effects (Periods)	1991	u1	-2.3643	0.5799	<0.0001	-1.4900	0.4645	0.0013	-3.5008	-1.2278
	1992	u2	-2.8466	0.5798	<0.0001	-2.0366	0.4643	<0.0001	-3.9830	-1.7102
	1993	u3	-2.6037	0.5823	<0.0001	-1.8974	0.4667	<0.0001	-3.7450	-1.4624
	1994	u4	-2.4063	0.5788	<0.0001	-1.8959	0.4628	<0.0001	-3.5408	-1.2719
	1995	u5	-4.4870	0.5766	<0.0001	-3.7699	0.4603	<0.0001	-5.6171	-3.3569
	1996	u6	-4.4135	0.5784	<0.0001	-3.7072	0.4620	<0.0001	-5.5472	-3.2798
	1997	u7	-3.9738	0.5785	<0.0001	-3.3192	0.4619	<0.0001	-5.1076	-2.8400
	1998	u8	-3.5673	0.5797	<0.0001	-2.8457	0.4630	<0.0001	-4.7035	-2.4312
	1999	u9	-4.2725	0.5776	<0.0001	-3.4875	0.4607	<0.0001	-5.4045	-3.1405
	2000	u10	-3.6460	0.5777	<0.0001	-2.9910	0.4607	<0.0001	-4.7782	-2.5138
	2001	u11	-2.7447	0.5777	<0.0001	-2.1856	0.4606	<0.0001	-3.8769	-1.6125
	2002	u12	-2.0479	0.5771	0.0004	-1.5827	0.4599	0.0006	-3.1791	-0.9168
	2003	u13	-1.4432	0.5786	0.0126	-1.0826	0.4614	0.0190	-2.5772	-0.3092
	2004	u14	-0.5189	0.5786	0.3698	-0.2989	0.4614	0.5171	-1.6529	0.6151
	2005	u15	-0.5204	0.5780	0.3680	-0.3734	0.4608	0.4178	-1.6533	0.6126

Effects			Model 0			Model 1			95% CI	
	Fixed Effects	Parameters	Estimate	SE	P	Estimate	SE	P	Lower	Upper
Random effects (Periods)	2006	u16	0.4645	0.5767	0.4205	0.2068	0.4611	0.6539	-0.6658	1.5948
	2007	u17	0.4892	0.5772	0.3966	0.4399	0.4599	0.3388	-0.6420	1.6205
	2008	u18	1.1583	0.5763	0.0444	0.9186	0.4590	0.0454	0.02880	2.2878
	2009	u19	1.4270	0.5764	0.0133	1.1428	0.4593	0.0128	0.2972	2.5568
	2010	u20	2.0991	0.5763	0.0003	1.7052	0.4592	0.0002	0.9696	3.2285
	2011	u21	2.6347	0.5762	<0.0001	2.2870	0.4592	<0.0001	1.5054	3.7640
	2012	u22	2.5749	0.5762	<0.0001	2.1970	0.4593	<0.0001	1.4456	3.7042
	2013	u23	2.4616	0.5761	<0.0001	1.8110	0.4594	<0.0001	1.3324	3.5908
	2014	u24	3.3575	0.5760	<0.0001	2.6638	0.4595	<0.0001	2.2285	4.4865
	2015	u25	3.5567	0.5760	<0.0001	2.8456	0.4596	<0.0001	2.4279	4.6856
	2016	u26	4.2925	0.5759	<0.0001	3.4897	0.4598	<0.0001	3.1637	5.4213
	2017	u27	4.7956	0.5760	<0.0001	3.9719	0.4600	<0.0001	3.6668	5.9245
	2018	u28	4.1493	0.5759	<0.0001	3.1131	0.4602	<0.0001	3.0206	5.2780
	2019	u29	4.2427	0.5759	<0.0001	3.1556	0.4605	<0.0001	3.1140	5.3715
	2020	u30	4.1524	0.5759	<0.0001	3.0157	0.4608	<0.0001	3.0236	5.2812
Cohorts	<1911	v1	-1.7416	0.2916	<0.0001	-0.6661	0.2276	0.0034	-2.3132	-1.1700
	1911-1916	v2	-1.1527	0.2744	<0.0001	-0.6177	0.2070	0.0028	-1.6905	-0.6149
	1916-1921	v3	-0.8256	0.2369	0.0005	-0.4206	0.1729	0.0150	-1.2899	-0.3612
	1921-1926	v4	-0.3830	0.2134	0.0727	-0.1247	0.1436	0.3851	-0.8012	0.03526
	1926-1931	v5	-0.4833	0.2074	0.0198	-0.03810	0.1285	0.7669	-0.8898	-0.07674
	1931-1936	v6	-0.1421	0.2038	0.4855	0.2983	0.1161	0.0102	-0.5416	0.2573
	1936-1941	v7	0.1957	0.2030	0.3349	0.4894	0.1084	<0.0001	-0.2021	0.5936
	1941-1946	v8	0.3567	0.2026	0.0782	0.3017	0.1029	0.0034	-0.04029	0.7537
	1946-1951	v9	0.6635	0.2017	0.0010	0.4366	0.09871	<0.0001	0.2681	1.0588
	1951-1956	v10	0.8441	0.2005	<0.0001	0.3123	0.09593	0.0011	0.4511	1.2372
	1956-1961	v11	0.8584	0.2001	<0.0001	0.1844	0.09646	0.0559	0.4661	1.2506
	1961-1966	v12	1.0804	0.2000	<0.0001	0.1916	0.09955	0.0543	0.6883	1.4724
	1966-1971	v13	0.9910	0.2002	<0.0001	0.08831	0.1054	0.4023	0.5985	1.3835
	1971-1976	v14	0.6022	0.2007	0.0027	0.09248	0.1132	0.4141	0.2088	0.9956
	1976-1981	v15	0.5110	0.2016	0.0112	0.1163	0.1232	0.3451	0.1160	0.9061

Effects			Model 0			Model 1			95% CI	
	Fixed Effects	Parameters	Estimate	SE	P	Estimate	SE	P	Lower	Upper
Cohorts	1381-1986	v16	0.6587	0.2030	0.0012	0.1836	0.1345	0.1723	0.2608	1.0567
	1986-1991	v17	0.08400	0.2087	0.6873	-0.1038	0.1504	0.4900	-0.3251	0.4931
	1991-1996	v18	-0.8849	0.2384	0.0002	-0.4819	0.1834	0.0086	-1.3522	-0.4177
	≥1996	v19	-1.2325	0.4225	0.0035	-0.2419	0.2834	0.3934	-2.0607	-0.4044
Covariance parameters	Period	τu	9.8590	2.5888	<0.0001	6.2315	1.6393	<0.0001		
	Cohort	τv	0.7216	0.2477	0.0018	0.1362	0.05859	0/0100		
Residual (individual)			95.0393	0.1648	<0.0001	79.7621	0.1383	<0.0001		
-2 Res log likelihood			4917986			4801441				
AIC			4917992			4801447				

Abbreviations: CI: Confidence interval; SE: Standard error; AIC: Akaike information criterion; IQ: Income quartiles.

Our study found a similar upward trend in HEI scores to that observed in the US National Health Study. Scores in our study increased from 43.86 (1999-2000) to 51.86 (2015-2016), showing a statistically significant positive trend. This represents an 8-point increase, compared to a 2-point increase in the US [28].

Nonetheless, our findings differ from a previous Iranian study (2001-2003) that reported a much lower average HEI (approximately 34) [23], probably due to a smaller sample size. Our larger and more recent data suggest an HEI closer to regional averages (approximately 45) [29]. This study examined dietary trends in Iranian households over 30 years (1991-2020). The HEI scores showed an initial rise from 1999 to 2017, indicating improvement in overall diet quality. However, this positive trend reversed after 2018, with HEI scores declining, suggesting a recent decline in dietary quality. The rise in HEI scores from 1999 to 2017 might be linked to public health initiatives promoting healthy eating and balanced diets. The observed decline in HEI scores after 2018 necessitates further investigation to identify contributing factors. This downward trend could be linked to international sanctions and economic shocks in Iran, which increased food prices and reduced access to nutritious imports. [2, 30].

Significant sociodemographic disparities were observed, with higher household income, education, and urban residence associated with better HEI scores, aligning with global evidence [23, 31]. Households with lower incomes and education levels may face barriers to accessing and affording nutritious foods, leading to poorer dietary choices [32].

Additionally, the study found that HEI scores were higher in urban areas than in rural areas. This finding aligns with previous research suggesting that urban residents may have better access to a wider variety of healthy food options and greater exposure to nutrition education programs [23, 29]. In contrast, rural areas may face challenges such as limited availability of fresh produce, longer distances to grocery stores, and fewer resources for nutrition education.

The HAPC model's coefficients for residence, literacy, and income corroborate these findings, highlighting their impact on dietary quality [33]. The female head of household in our study had a positive effect, which is contrary to other studies [34]. The socioeconomic status of female heads of households seems to have been higher than that of males in the years after 2000 [23].

The study's strengths include the large sample size of 665,254 households examined over 30 years, providing robust data for trend analysis and sociodemographic comparisons. Nevertheless, it is important to note that the study relied on self-reported data as a proxy of consumption, which may be subject to recall bias and social desirability.

Conclusion

This study sheds valuable light on dietary trends and sociodemographic factors influencing healthy eating habits in Iranian households. Utilizing 30 years of data and the HAPC model, this study reveals patterns in HEI scores. Although the initial rise in HEI scores from 1999 to 2017 is encouraging, the sharp decline observed after 2018 demands immediate attention and a deeper investigation into its causes. Potential factors such as shifts in food availability, economic constraints, or evolving social norms need to be identified. Understanding these drivers is vital for crafting targeted interventions to reverse this trend and promote long-term healthy dietary habits.

Limitations

Limitations include reliance on HIES as a proxy for consumption, which may introduce recall bias or underestimate actual intake, and the exclusion of 261,085 households due to outliers, potentially affecting generalizability. Although the HEI-2015 was adapted, it may not fully capture Iranian dietary nuances.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Tehran University of Medical Sciences, Tehran, Iran (Code: IR.TUMS.MEDICINE.REC.1400.788). The data used in this study were obtained from the HIES conducted by the Statistical Center of Iran, as mentioned in the text. These data are available to researchers for free and without personal information.

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Authors' contributions

Conceptualization, supervision and guarantors: Ahmadreza Dorosty Motlagh and Amirhossein Takian; Data collection, primary analysis, and manuscript drafting: Omid Emami; Methodology and HAPC analysis: Ehsan Mousa Farkhani; Manuscript review and approval: All authors.

Conflict of interest

The authors declared no conflicts of interest.

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