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Rising trends of obesity and abdominal obesity in 10 years of follow-up among Tehranian adults: Tehran Lipid and Glucose Study (TLGS)

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Abstract

Objective: Some recent studies have shown stablity or declining trends in obesity while others still report increasing trends. The present study aimed to investigate the trends of obesity and abdominal obesity in Tehranian adults during a median follow-up of 10 years.

Design: Prospective cohort study.

Setting: Community-based data collection from the Tehran Lipid and Glucose Study (TLGS).

Subjects: Participants from four phases of the TLGS from 1999 to 2011 (n 10 368), aged ≥20 years.

Results: The crude prevalence of obesity and abdominal obesity increased from 23·1 % and 47·9 % at baseline to 34·1 % and 71·1 % at the end of follow-up, respectively. Generalized estimating equation (GEE) models were used to analyse the correlated data and calculate the relative risks (RR). Risks of obesity and abdominal obesity increased over the whole study period for men (RR = 1·62; 95 % CI 1·49, 1·76 and RR = 1·46; 95 % CI 1·41, 1·52, respectively) and women (RR = 1·24; 95 % CI 1·19, 1·29 and RR = 1·22; 95 % CI 1·18, 1·27, respectively). These rising trends were observed in all subgroups regardless of age, marital status and educational level.

Conclusions: Trends of obesity and abdominal obesity are increasing in Tehranian adults during a decade of follow-up in both genders and in all study subgroups. These results underscore the still growing obesity epidemic in the capital of Iran, calling for urgent action to educate people in lifestyle modifications and the need for effective preventive and educational strategies on obesity.

Keywords
Obesity
Abdominal obesity
Trend
Sociodemographic
GEE

Obesity as a major health issue is closely related to morbidity and mortality from non-communicable diseases(1). In recent decades the prevalence of obesity has been growing rapidly worldwide, turning it into an epidemic(2). Studies show that the prevalence of obesity in the Eastern Mediterranean region is one of the highest in the world(3) and Middle East countries are among the leading ones in terms of mean BMI(4). Although recently some studies have reported stability or leveling off in trends of obesity in the USA and some other countries(5–7), this does not constitute a cessation of the epidemic, and longitudinal studies still report increasing obesity trends in the adult population of most countries worldwide(8–12). Furthermore, the increasing rate of obesity is a major concern in most developing countries and they require special attention in this regard(13).

Most studies investigating obesity trends are based on cross-sectional survey data(14–16). Cross-sectional studies and synthetic cohorts (i.e. linking age groups across cross-sectional data at different time points) that are often used for these purposes lack the ability to show the dynamics and these data may not be comparable over time(12,17). Despite these limitations, sufficient longitudinal data are generally not available and more longitudinal studies are needed to overcome these obstacles.

In addition to genetic and lifestyle factors, many sociodemographic and socio-economic indices are closely

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related to obesity. Cross-sectional literature abounds on unequal prevalence of obesity in subgroups of age, gender, marital status, income, education level and cigarette smoking[3,18]. A significant relationship is also proposed in most studies assessing the temporal trends of obesity in different subgroups of socio-economic status[19–21]. However, some other studies suggest that socio-economic status has exerted minimal influence on changes in BMI over time and it seems that because of the obesogenic environment, these associations, though important, may have been weakened over past decades[11,22].

We previously reported an increasing trend of obesity and abdominal obesity in both genders in the first three phases of the Tehran Lipid and Glucose Study (TLGS) with a median follow-up of 6·6 years[23]. Considering the need for updated longitudinal data, the present study was designed to determine the trends of obesity and abdominal obesity in different subgroups of Tehranian adults over a 10-year follow-up using generalized estimating equations (GEE).

Materials and methods

Study participants and design

The TLGS was designed to determine the risk factors of non-communicable diseases among the Tehranian urban population and to develop population-based measures to prevent and improve these risk factors[24]. The design of the TLGS included four components: phase I, a cross-sectional prevalence study of cardiovascular risk factors; and phases II, III, and IV, prospective ongoing follow-up studies for 10 years. A multistage, stratified, cluster random sampling technique was used to select 15 005 people, aged 3 years or older, and under coverage of three medical health centres from district 13 of Tehran, the capital of Iran. The district is located in the centre of Tehran and the distribution of age and other demographic factors in its population is representative of the overall population of Tehran and is compatible with that in the Iranian population. All members of each family, including those without risk factors, were invited for baseline measurments during phase I of the study and were followed in subsequent phases. The interval between every two assessments was approximately 3·6 years: phase I, 1999–2001; phase II, 2002–2005; phase III, 2006–2008; and phase IV, 2009–2011. Details of the study have been published elsewhere[24]. From this population, only individuals ≥20 years old were selected from phase I and were followed to phase IV. Data on 10 368 participants (mean age of 43·5 years) in phase I, who had at least one further measurement in later phases, were used for analysis in GEE clusters that compensated for the absent information in each phase.

Measurements and definitions

Information regarding age, sex, smoking, marital status and educational level was collected using standard questionnaires. Smoking was defined according to WHO guidelines[25]. In our questionnaire, smoking was categorized into yes/no groups; 'yes' defined participants who smoked cigarettes (daily or occasionally or ex-smokers) and 'no' defined non-smokers. Marital status was categorized as married and non-married (including widowed and divorced). Educational level was defined based on last official educational degree achieved by the individual and was categorized as primary and secondary level, high school level and university level.

Weight was measured using a digital electronic weighing scale (Seca 707, range 0·1–150 kg; Hanover, MD, USA) with an accuracy of up to 100 g (the machine was regularly checked for precision after every ten measurements) and height was determined using a tape meter stadiometer according to standard protocols. Waist circumference (WC) was measured by trained personnel at the level of the umbilicus using an unstretched tape meter, without any pressure to body surface, and was recorded to the nearest 0·1 cm. Instruments and methods used for anthropometric measurements were the same at baseline and follow-ups. BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m^2). Obesity was defined as BMI ≥ 30·0 kg/m^2 and subcategories of obesity were defind as follows: class I as 30·0 ≤ BMI < 34·9 kg/m^2; class II as 35·0 ≤ BMI < 39·9 kg/m^2; and class III as BMI ≥ 40·0 kg/m^2[26]. WC of ≥ 89 cm in men and ≥91 cm in women were considered as cut-off points for abdominal obesity, based on national cut-offs[27]; although other WC cut-offs also exist for different Iraninan populations, we used the ones proposed by Delavari *et al.*[27] since they are the only ones representative of the whole nation, with the largest sample size and are widely used in similar studies.

Statistical analysis

All continuous variables are expressed as means and standard deviations, and categorical covariates are expressed as percentages. ANCOVA and logistic regression tests were used to compare age-adjusted differences between the two sexes within each phase for continuous and dichotomous variables, respectively.

Tests of interactions were checked considering time trends and obesity/abdominal obesity for subgroups of age, marital status, smoking and educational level. If the interaction terms were significant, the results were analysed and reported in those subgroups separately. Considering that the responses were dependent, the GEE model with auto-regressive working correlation structure, through log-link function with binomial errors, was used to estimate the relative risk of responses in the age, marital status and educational level subgroups[28]. Relative risks (RR) and 95 % confidence intervals were computed. In the present study, obesity and abdominal obesity were considered as responses, separately.

All analyses were performed using the statistical software packages SPSS version 16 and SAS version 9·1 for

Windows; the significance level was set at $P<0.05$ (two-tailed).

Results

The GEE analysis was performed on data of 10 368 participants (4397 males) aged ≥20 years from phase I, who had the information required in at least one of four study phases. The number of crude observations was 10 368, 6246, 6663 and 6217 in phases I, II, III and IV, respectively. The baseline characteristics of those who were lost to follow-up in phase IV were compared with those who remained in the study; there were no clinically significant differences between these two groups regarding age, sex, BMI, marital status and educational level (data not shown).

Basic characteristics of participants in phases I and IV of the study are presented for men and women separated into different age groups (Tables 1 and 2). In the whole study population, the crude prevalence of obesity and abdominal obesity increased from 23·1 % and 47·9 % at baseline to 34·1 % and 71·1 % at the end of follow-up, respectively. The crude prevalence of obesity increased from 14·4 % at baseline to 23·1 % in phase IV for men and from 29·5 % to 42·0 % for women. There was also an increase, at the end of follow-up, in the prevalence of abdominal obesity from 52·8 % at baseline to 78·1 % for men and from 44·4 % to 66·1 % for women. Sex-specific mean BMI and WC values, and also prevalences of obesity and abdominal obesity in each phase of the study, are presented in Table 3.

The RR for obesity and abdominal obesity in different subgroups and in each phase are presented in Tables 4 and 5 for men and women, respectively. Sex-specific tests of interaction were statistically significant for subgroups of age, marital status and educational level ($P<0.001$ for all), but not for smoking. Evaluating the trends using GEE showed that risk of obesity and abdominal obesity increased in both sexes. The total age-adjusted RR for obesity were 1·18, 1·23 and 1·36 in phases II, III and IV compared with baseline, and corresponding values were 1·21, 1·19 and 1·34 for abdominal obesity. Compared with baseline, an increase of 62 % and 46 % in the risk of obesity and abdominal obesity was observed in men at the end of the follow-up, respectively. The risk of obesity and abdominal obesity also increased by 24 % and 22 % in women, respectively. The highest increase in risk of obesity and abdominal obesity was observed in the 20–39 years age group for men (105 % and 74 %, respectively) and also for women (53 % and 79 %, respectively). Non-married men and married women were at increased risk of obesity compared with their counterparts regarding marital status. Regarding educational level, the highest increase in obesity and abdominal obesity was observed in those with high school educational level in both men and women (except for abdominal obesity in men that was higher in those with university educational level). At the end of the study, there was also an increasing trend of obesity and abdominal obesity in all subgroups of age, marital status and educational level, when compared with baseline values.

Table 1 Basic characteristics of study participants at baseline and the end of the study by age group (men), Tehran Lipid and Glucose Study (TLGS), 1999 to 2011

	Phase I (baseline)				Phase IV (end of follow-up)			
Variable	20–39 years (*n* 1999)	40–59 years (*n* 1469)	≥60 years (*n* 929)	Total (*n* 4397)	20–39 years (*n* 463)	40–59 years (*n* 1244)	≥60 years (*n* 866)	Total (*n* 2573)
BMI (kg/m^2)								
Mean	25·2	26·4	26·1	25·8	27·5	27·7	26·7	27·3
SD	4·3	3·8	3·9	4·1	4·6	4·0	4·0	4·2
WC (cm)								
Mean	88·4	92·4	93·5	91·0	97·0	98·1	97·8	97·8
SD	11·8	10·2	10·7	11·2	11·5	10·5	10·4	10·6
Obesity* (%)	12·7	16·4	14·9	14·4	24·2	25·3	19·1	23·1
Abdominal obesity* (%)	44·4	57·6	61·1	52·8	73·2	80·3	77·5	78·1
Smoking (%)								
Smoker	36·6	48·6	42·1	41·8	52·2	52·2	41·3	48·5
Non-smoker	63·4	51·4	57·9	58·2	47·8	47·8	58·7	51·5
Marital status (%)								
Married	61·8	98·6	97·4	81·6	80·1	95·7	95·4	92·8
Non-married	38·2	1·4	2·6	18·4	19·9	4·3	4·6	7·2
Educational level (%)								
Primary and secondary	8·3	27·4	63·8	24·7	3·5	12·2	49·2	22·2
High school	54·7	36·5	15·2	41·5	9·3	15·9	16·1	14·7
University	37·0	36·1	21·0	33·8	87·2	71·9	34·7	63·1

WC, waist circumference.
Values are expressed as mean and standard deviation or as percentages.
*Obesity, BMI ≥ 30·0 kg/m^2; abdominal obesity, WC ≥ 89 cm[27].

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Table 2 Basic characteristics of study participants at baseline and the end of the study by age group (women), Tehran Lipid and Glucose Study (TLGS), 1999 to 2011

	Phase I (baseline)				Phase IV (end of follow-up)			
Variable	20–39 years (*n* 2963)	40–59 years (*n* 2138)	≥60 years (*n* 870)	Total (*n* 5971)	20–39 years (*n* 798)	40–59 years (*n* 1805)	≥60 years (*n* 1041)	Total (*n* 3644)
BMI (kg/m^2)								
Mean	25·5	29·5	28·4	27·3	27·4	30·2	30·9	29·8
SD	5·5	4·7	4·9	5·5	4·7	5·0	18·7	10·7
WC (cm)								
Mean	82·6	93·7	95·7	88·9	88·5	96·3	100·9	95·8
SD	11·4	11·4	10·8	12·7	10·7	11·5	11·1	12·1
Obesity* (%)	18·3	42·4	35·7	29·5	23·3	46·3	49·2	42·0
Abdominal obesity* (%)	23·7	59·5	69·1	44·4	39·6	68·7	82·8	66·1
Smoking (%)								
Smoker	3·4	6·6	6·8	5·0	7·3	8·0	6·6	7·4
Non-smoker	96·6	93·4	93·2	95·0	92·7	92·0	93·4	92·6
Marital status (%)								
Married	76·3	88·3	61·5	78·4	89·6	87·1	58·2	79·4
Non-married	23·7	11·7	38·5	21·6	10·4	12·9	41·8	20·6
Educational level (%)								
Primary and secondary	11·8	53·3	87·0	32·2	4·3	26·0	74·9	31·4
High school	56·4	23·2	6·1	40·8	9·7	21·7	12·6	16·8
University	31·8	23·5	6·9	27·0	86·0	52·3	12·5	51·8

WC, waist circumference.
Values are expressed as mean and standard deviation or as percentages.
*Obesity, BMI ≥ 30·0 kg/m^2; abdominal obesity, WC ≥ 91 cm[27].

Table 3 Prevalence and trends of obesity and abdominal obesity for Tehranian adults, Tehran Lipid and Glucose Study (TLGS), 1999 to 2011

	Men				Women			
	Phase I	Phase II	Phase III	Phase IV	Phase I	Phase II	Phase III	Phase IV
Age (years)								
Mean	44·7	49·0	50·3	53·1	42·4	46·5	48·3	50·9
SD	14·7	14·7	14·1	13·9	13·5	13·4	13·0	12·8
BMI (kg/m^2)								
Mean	26·0	26·7	27·1	27·3	27·7	28·8	28·9	29·8
SD	4·0	4·0	4·1	4·2	5·0	4·8	4·9	10·7
WC (cm)								
Mean	90·9	95·1	96·4	97·8	88·9	92·0	91·2	95·8
SD	11·2	10·5	10·3	10·6	12·7	12·5	12·8	12·0
Obesity* (%)	14·4	18·8	21·0	23·1	29·5	37·9	37·4	42·0
Class I	85·6	85·5	84·6	83·0	74·7	72·8	68·7	66·9
Class II	12·3	12·3	12·7	13·2	20·9	22·3	24·3	24·6
Class III	2·1	2·2	2·7	3·8	4·4	4·9	7·0	8·5
Abdominal obesity† (%)	52·8	67·8	73·7	78·1	44·4	54·7	50·8	66·1

WC, waist circumference.
Values are expressed as mean and standard deviation or as percentages.
*Obesity, BMI ≥ 30·0 kg/m^2; class I, 30·0 ≤ BMI < 34·9 kg/m^2; class II, 35·0 ≤ BMI < 39·9 kg/m^2; class III, BMI ≥ 40·0 kg/m^2.
†Abdominal obesity: WC ≥ 89 cm in men and ≥91 cm in women[27].

Discussion

To our knowledge, the present study is the first one on trends of obesity and abdominal obesity in the region with a decade of follow-up. Our results showed an overall increase in trends of obesity and abdominal obesity in both genders and different study subgroups in the urban adult Tehranian population over a 10-year follow-up. Using a GEE model, the overall risk of obesity and abdominal obesity increased by 36 % and 34 % at the end of study, respectively. This increase was more dramatic in younger age groups and in men.

Most studies addressing obesity trends are based on cross-sectional data and, in contrast to longitudinal studies, lack the ability to genuinely represent the dynamics of the problem over time periods. The trends of obesity vary worldwide and the literature shows conflicting results. Data from developing countries and the Middle East indicate that increasing trends of obesity are still a major health problem in these areas[13]. In concordance with our

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Table 4 Relative risks of obesity and abdominal obesity in different study subgroups in phases I to IV* (men), Tehran Lipid and Glucose Study (TLGS), 1999 to 2011

		Phase II		Phase III		Phase IV	
	Phase I	RR	95 % CI	RR	95 % CI	RR	95 % CI
Total							
Obesity	1	1·23†	1·15, 1·22	1·46†	1·36, 1·57	1·62†	1·49, 1·76
Abdominal obesity	1	1·30†	1·26, 1·35	1·40†	1·36, 1·46	1·46†	1·41, 1·52
Age							
20–39 years							
Obesity	1	1·38†	1·24, 1·55	1·73†	1·53, 1·95	2·05†	1·78, 2·36
Abdominal obesity	1	1·41†	1·32, 1·50	1·59†	1·47, 1·71	1·74†	1·62, 1·88
40–59 years							
Obesity	1	1·21†	1·09, 1·34	1·38†	1·24, 1·53	1·48†	1·33, 1·66
Abdominal obesity	1	1·27†	1·21, 1·34	1·35†	1·28, 1·42	1·43†	1·35, 1·51
≥60 years							
Obesity	1	1·05	0·95, 1·16	1·12	0·98, 1·26	1·18†	1·03, 1·34
Abdominal obesity	1	1·21†	1·15, 1·28	1·28†	1·20, 1·36	1·27†	1·19, 1·35
Marital status							
Married							
Obesity	1	1·22†	1·14, 1·30	1·42†	1·32, 1·52	1·55†	1·43, 1·69
Abdominal obesity	1	1·27†	1·23, 1·32	1·34†	1·30, 1·39	1·40†	1·35, 1·46
Non-married							
Obesity	1	1·10	0·82, 1·45	1·34	1·00, 1·85	1·95†	1·36, 2·81
Abdominal obesity	1	1·36†	1·18, 1·57	1·63†	1·38, 1·91	1·68†	1·42, 2·00
Educational level							
Primary and secondary							
Obesity	1	1·15†	1·01, 1·31	1·31†	1·15, 1·51	1·30†	1·12, 1·52
Abdominal obesity	1	1·17†	1·11, 1·24	1·21†	1·14, 1·29	1·22†	1·14, 1·31
High school							
Obesity	1	1·50†	1·20, 1·88	1·69†	1·33, 2·14	1·92†	1·51, 2·44
Abdominal obesity	1	1·35†	1·22, 1·49	1·40†	1·27, 1·54	1·48†	1·34, 1·62
University							
Obesity	1	1·29†	1·15, 1·45	1·56†	1·38, 1·76	1·80†	1·58, 2·05
Abdominal obesity	1	1·36†	1·27, 1·46	1·51†	1·41, 1·61	1·59†	1·48, 1·70

RR, relative risk; WC, waist circumference.
*Obesity, BMI ≥ 30·0 kg/m^2; abdominal obesity, WC ≥ 89 cm in men and ≥91 cm in women; marital status, married and non-married (including widowed and divorced); Phase I was considered as the reference category.
†All comparisons are adjusted for age and $P < 0·05$ is considered statistically significant.

results, numerous studies have reported an increasing trend of obesity in different parts of the world either in cohort studies[9–12] or by comparing multiple cross-sectional surveys over time[15,16,29]. In Iran, Esteghamati *et al.*[30] showed increasing secular trends of overweight and obesity among Iranian adults over an 8-year period, during which the overall prevalence of obesity increased from 13·6 % in 1999 to 22·3 % in 2007 with an OR of 1·08 per year[30]. However, the latter study compared data from three independent cross-sectional studies with different urban and rural populations, and possibly with different socio-economic backgrounds. Interpreting and extrapolating these kinds of data face multiple limitations since it does not represent a longitudinal trend in a single representative population. On the other hand, several studies have reported stability or levelling off in trends of obesity specifically in Europe and the USA[6,7,31]. Although concerns about generalizability of both categories of these studies exist, the different composition of study populations, variations in socio-economic status and also implementation of preventive strategies in some countries could partly explain these differences. It is also noteworthy that interpretation of these studies is largely dependent on the type of statistical method applied, choice of statistical models and consideration of possible publication biases as well[5].

Together with the epidemic of general obesity (measured by BMI), the prevalence of abdominal obesity (measured by WC) is also increasing, however with different patterns[10,32]. It is suggested that abdominal obesity is a better indicator for risk of type 2 diabetes, CVD and all-cause mortality, so addressing this index in obesity studies is important[33]. Our results indicated a higher prevalence of abdominal obesity compared with obesity, and this is in agreement with previous TLGS data and the current literature[23,32]. Low physical activity, sedentary lifestyle, changes in diets and higher energy intake are suggested to play key roles in this shifting trend towards abdominal obesity[34]. In our study, the prevalence of obesity and abdominal obesity followed an increasing trend in the last 10 years; this trend was more dramatic in men and the youngest age group (20–39 years), a finding in agreement with previous reports in Tehran which had stressed the alarming rates in men and younger age groups[23,35]. Regarding abdominal obesity, our results were in contrast to those of another study conducted in northern Iran reporting a slight decline in trends of abdominal obesity in an urban male and female

Table 5 Relative risks of obesity and abdominal obesity in different study subgroups in phases I to IV* (women), Tehran Lipid and Glucose Study (TLGS), 1999 to 2011

		Phase II		Phase III		Phase IV	
	Phase I	RR	95 % CI	RR	95 % CI	RR	95 % CI
Total							
Obesity	1	1·15†	1·11, 1·19	1·14†	1·09, 1·18	1·24†	1·19, 1·29
Abdominal obesity	1	1·12†	1·09, 1·16	1·01	0·97, 1·04	1·22†	1·18, 1·27
Age							
20–39 years							
Obesity	1	1·35†	1·25, 1·46	1·35†	1·24, 1·46	1·53†	1·38, 1·68
Abdominal obesity	1	1·24†	1·13, 1·36	1·09	0·98, 1·22	1·79†	1·61, 2·00
40–59 years							
Obesity	1	1·15†	1·10, 1·20	1·12†	1·07, 1·18	1·23†	1·16, 1·29
Abdominal obesity	1	1·17†	1·12, 1·22	1·01	0·96, 1·06	1·26†	1·20, 1·32
≥ 60 years							
Obesity	1	1·15†	1·08, 1·23	1·20†	1·12, 1·29	1·32†	1·22, 1·42
Abdominal obesity	1	1·08†	1·03, 1·14	1·08†	1·02, 1·14	1·19†	1·13, 1·26
Married							
Obesity	1	1·16†	1·12, 1·20	1·11†	1·07, 1·16	1·23†	1·17, 1·29
Abdominal obesity	1	1·12†	1·08, 1·17	0·99	0·95, 1·03	1·22†	1·17, 1·28
Non-married							
Obesity	1	1·07	0·97, 1·17	1·13†	1·02, 1·24	1·14†	1·02, 1·27
Abdominal obesity	1	1·12†	1·03, 1·22	1·07	0·98, 1·18	1·21†	1·10, 1·33
Educational level							
Primary and secondary							
Obesity	1	1·15†	1·09, 1·21	1·20†	1·13, 1·27	1·29†	1·21, 1·38
Abdominal obesity	1	1·19†	1·13, 1·24	1·12†	1·06, 1·18	1·24†	1·18, 1·32
High school							
Obesity	1	1·59†	1·38, 1·83	1·49†	1·29, 1·72	1·63†	1·40, 1·90
Abdominal obesity	1	1·69†	1·49, 1·93	1·49†	1·29, 1·70	1·87†	1·64, 2·13
University							
Obesity	1	1·34†	1·26, 1·43	1·36†	1·27, 1·45	1·47†	1·36, 1·60
Abdominal obesity	1	0·92	0·83, 1·01	0·77	0·70, 0·85	1·14†	1·04, 1·25

RR, relative risk; WC, waist circumference.
*Obesity, BMI ≥ 30·0 kg/m^2; abdominal obesity, WC ≥ 89 cm in men and ≥91 cm in women; marital status, married and non-married (including widowed and divorced); Phase I was considered as the reference category.
†All comparisons are adjusted for age and $P < 0·05$ is considered statistically significant.

population between 2006 and 2010[36]; however, that study was based on two cross-sectional data sets that face problems for comparing the trends, used different WC cut-offs (north American and European cut-offs of 102 cm and 88 cm in men and women, instead of national cut-offs) and the results were an exception when compared with other similar studies in Iran. Furthermore, Tehran is a metropolitan city with different levels of population diversity and environmental risk factors compared with smaller towns in the country. Similar to ours, several studies have reported that the prevalence of abdominal obesity is growing using a cohort design[10,37] or multiple cross-sectional surveys[32,38]. Niu *et al.*[37] used longitudinal data from the China Health and Nutrition Survey (CHNS) from 1997 to 2009 and reported that the prevalence of abdominal obesity increased from 17·3 % to 39·4 % during a 12-year follow-up; in that study abdominal obesity (WC ≥ 90 cm for men and ≥80 cm for women) was more prevalent in Chinese women at baseline, but the increasing trends were observed in both genders and all age groups. On the other hand, Tanamas *et al.*[10] showed in a 12-year longitudinal study that the mean BMI and WC increased in Australian adults and most prominently in those who were younger at baseline; the incidence of obesity and abdominal obesity also increased in both sexes, but was more prominent in women. The root causes behind these sex differences are unclear and need more investigations; but the higher trends of abdominal obesity in Tehranian men compared with women may in part be because, in recent years: women's awareness of their health and body has increased; women are getting more educated and involved in social activities; and last but not least, most of the public educational programmes have targeted women, somehow overlooking the male population. These factors may have implemented changes in Tehranian women's diet and lifestyle in recent years. Despite the increasing trend of abdominal obesity observed in most related studies, comparing these results in various populations is problematic because definitions and cut-off points for diagnosing abdominal obesity, and also the nature of the data used (cohort *v.* multiple cross-sectional), vary in different studies.

Socio-economic status and factors like smoking, educational level and marital status are regarded as important variables associated with obesity, particularly in women; however, these associations are complex and dynamic[18,39]. In our study, the rates of obesity and abdominal obesity increased during the study period in all subgroups, regardless of age group, educational level and marital status, although the extent was different. Similar to our results, several studies have reported that during the epidemic, obesity prevalence increased in all subgroups and socio-economic indicators exerted minimal effect on these growing trends[11,40]. Recently, in a large sample of Chinese adults, Du *et al.*[38] reported that the increasing trends of obesity and abdominal obesity exist in all population subgroups of age, sex and education. Also Prättälä *et al.*[19] reported differences in BMI increase at various educational levels according to outcome, but similar to us they also reported that the increasing trend is present at all educational levels. Although Torrance *et al.*[41] found that obesity trends varied with educational level and smoking, more recent evidence suggests that the association between these factors and obesity has been weakened in recent decades, concurrent with the dramatic increase in obesity prevalence[11,22]. In our study women with high school educational level had the highest trend of obesity and abdominal obesity and the trend was less dramatic in the higher educational level. However, in men this pattern was more complex and those with higher educational levels had higher trends of obesity and abdominal obesity. These findings are in line with most studies on education and obesity that show an inverse association in women, but inconclusive and complex associations in men[19,42]. It is supposed that women with higher education are more concerned about their body shape and how they look compared with men[42], so they may more actively engage in healthy eating and weight-control programmes. Regading marital status we found that married women and unmarried men had higher rates of obesity and abdominal obesity in our follow-up. Most studies show that marriage and weight gain are positively associated; however, these associations may differ based on gender, ethnicity and other socio-economic factors[43,44]. In Iranian women, marriage may be accompanied with less concern about body shape, less physical activity and also childbearing; all may affect their body weight in the long term[43]. On the other hand, Iranian men may have different dietary patterns and less healthy diets before marriage; lack of support from a spouse may also lead to less concern about body shape in unmarried men. However, one should also consider the dynamic nature of factors like marriage and educational level and the role of other environmental and socio-economic factors in interpretation of these findings. Since we used baseline information of participants in the present study we cannot conclude on these subjects or test the aforementioned hypotheses.

Lack of physical activity is another culprit in the obesity epidemic. Studies show that both leisure-time physical activity and occupational physical activity can be inversely associated with obesity[45]. Lifestyle patterns are changing and with modernization, the global trend is towards a decrease in physical activity that also plays an important role in trends of obesity and abdominal obesity[46]. Taken together, it seems that the dynamic roles of lifestyle changes and different socio-economic factors form a complex network to affect obesity trends. Modern life with advances in the food industry, easier and faster access to larger food volumes and also major lifestyle changes are making the world we live in more and more 'obese-friendly' and this obesogenic environment is a major contributor to the obesity epidemic.

The present study has several strengths and limitations. Being the first large population-based study in Iran and the Middle East with a 10-year follow-up is the main study strength. We also used measured values for weight, height and WC in order to diagnose obesity and abdominal obesity as opposed to self-reported measures, which could lead to underestimation of BMI and obesity[47]. The other strength of the study is that we used country-specific cut-offs for WC in defining abdominal obesity. We also used GEE as a more flexible and robust model for handling longitudinal data, allowing us to use all available data and better dealing with missing values. Regarding limitations, we did not take into account some factors like physical activity, dietary habits and economic status in our study. Furthermore, TLGS is a population-based study on Tehranian residents and although Tehran is a metropolitan city with a wide range of population variety, these data may not be representative of all the Iranian population.

Conclusion

In conclusion, our study shows that in a representative adult Tehranian population, the trends of obesity and abdominal obesity are fast increasing in both men and women and in different social groups. Moreover, the dramatic increase of obesity and abdominal obesity in men and younger age groups merits special consideration. These alarming trends challenge current health priorities to provide urgent and effective prevention and education strategies targeting the whole population, not just a specific educational level or social group.

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The Research Ethics Committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, approved this study that was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

References

1. Whitlock G, Lewington S, Sherliker P *et al.* (2009) Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet* **373**, 1083–1096.
2. Roth J, Qiang X, Marban SL *et al.* (2004) The obesity pandemic: where have we been and where are we going? *Obes Res* **12**, Suppl. 2, 88S–101S.
3. Musaiger AO (2011) Overweight and obesity in Eastern Mediterranean region: prevalence and possible causes. *J Obes* **2011**, 407237.
4. Yusuf S, Hawken S, Ounpuu S *et al.* (2005) Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case–control study. *Lancet* **366**, 1640–1649.
5. Rokholm B, Baker JL & Sorensen TI (2010) The levelling off of the obesity epidemic since the year 1999 – a review of evidence and perspectives. *Obes Rev* **11**, 835–846.
6. Sundquist J, Johansson SE & Sundquist K (2010) Levelling off of prevalence of obesity in the adult population of Sweden between 2000/01 and 2004/05. *BMC Public Health* **10**, 119.
7. Flegal KM, Carroll MD, Kit BK *et al.* (2012) Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA* **307**, 491–497.
8. Matsushita Y, Takahashi Y, Mizoue T *et al.* (2008) Overweight and obesity trends among Japanese adults: a 10-year follow-up of the JPHC Study. *Int J Obes (Lond)* **32**, 1861–1867.
9. Murdock D, Salit J, Stoffel M *et al.* (2013) Longitudinal study shows increasing obesity and hyperglycemia in Micronesia. *Obesity (Silver Spring)* **21**, E421–E427.
10. Tanamas SK, Shaw JE, Backholer K *et al.* (2014) Twelve-year weight change, waist circumference change and incident obesity: the Australian diabetes, obesity and lifestyle study. *Obesity (Silver Spring)* **22**, 1538–1545.
11. Reas DL, Nygard JF, Svensson E *et al.* (2007) Changes in body mass index by age, gender, and socio-economic status among a cohort of Norwegian men and women (1990–2001). *BMC Public Health* **7**, 269.
12. von Ruesten A, Steffen A, Floegel A *et al.* (2011) Trend in obesity prevalence in European adult cohort populations during follow-up since 1996 and their predictions to 2015. *PLoS One* **6**, e27455.
13. Hossain P, Kawar B & El Nahas M (2007) Obesity and diabetes in the developing world – a growing challenge. *N Eng J Med* **356**, 213–215.
14. Berghofer A, Pischon T, Reinhold T *et al.* (2008) Obesity prevalence from a European perspective: a systematic review. *BMC Public Health* **8**, 200.
15. Neovius K, Johansson K, Kark M *et al.* (2013) Trends in self-reported BMI and prevalence of obesity 2002–10 in Stockholm County, Sweden. *Eur J Public Health* **23**, 312–315.
16. Marques-Vidal P, Paccaud F & Ravasco P (2011) Ten-year trends in overweight and obesity in the adult Portuguese population, 1995 to 2005. *BMC Public Health* **11**, 772.
17. Levy DT, Mabry PL, Wang YC *et al.* (2011) Simulation models of obesity: a review of the literature and implications for research and policy. *Obes Rev* **12**, 378–394.
18. Hajian-Tilaki KO & Heidari B (2007) Prevalence of obesity, central obesity and the associated factors in urban population aged 20–70 years, in the north of Iran: a population-based study and regression approach. *Obes Rev* **8**, 3–10.
19. Prättälä R, Sippola R, Lahti-Koski M *et al.* (2012) Twenty-five year trends in body mass index by education and income in Finland. *BMC Public Health* **12**, 936.
20. Molarius A, Seidell JC, Sans S *et al.* (2000) Educational level, relative body weight, and changes in their association over 10 years: an international perspective from the WHO MONICA Project. *Am J Public Health* **90**, 1260–1268.
21. Devaux M & Sassi F (2013) Social inequalities in obesity and overweight in 11 OECD countries. *Eur J Public Health* **23**, 464–469.
22. Zhang Q & Wang Y (2004) Trends in the association between obesity and socioeconomic status in US adults: 1971 to 2000. *Obes Res* **12**, 1622–1632.
23. Hosseinpanah F, Barzin M, Eskandary PS *et al.* (2009) Trends of obesity and abdominal obesity in Tehranian adults: a cohort study. *BMC Public Health* **9**, 426.
24. Azizi F, Rahmani M, Emami H *et al.* (2000) Tehran Lipid and Glucose Study: rationale and design. *CVD Prev* **3**, 242–247.
25. World Health Organization (1998) *Guidelines for Controlling and Monitoring the Tobacco Epidemic*. Geneva: WHO.
26. Tsigos C, Hainer V, Basdevant A *et al.* (2008) Management of obesity in adults: European clinical practice guidelines. *Obes Facts* **1**, 106–116.
27. Delavari A, Forouzanfar MH, Alikhani S *et al.* (2009) First nationwide study of the prevalence of the metabolic syndrome and optimal cutoff points of waist circumference in the Middle East: the national survey of risk factors for noncommunicable diseases of Iran. *Diabetes Care* **32**, 1092–1097.
28. Zeger SL, Liang KY & Albert PS (1988) Models for longitudinal data: a generalized estimating equation approach. *Biometrics* **44**, 1049–1060.
29. Boylan EA, McNulty BA, Walton J *et al.* (2014) The prevalence and trends in overweight and obesity in Irish adults between 1990 and 2011. *Public Health Nutr* **17**, 2389–2397.
30. Esteghamati A, Khalilzadeh O, Mohammad K *et al.* (2010) Secular trends of obesity in Iran between 1999 and 2007: National Surveys of Risk Factors of Non-communicable Diseases. *Metab Syndr Relat Disord* **8**, 209–213.
31. Howel D (2011) Trends in the prevalence of obesity and overweight in English adults by age and birth cohort, 1991–2006. *Public Health Nutr* **14**, 27–33.
32. Li C, Ford ES, McGuire LC *et al.* (2007) Increasing trends in waist circumference and abdominal obesity among US adults. *Obesity (Silver Spring)* **15**, 216–224.
33. Bigaard J, Frederiksen K, Tjonneland A *et al.* (2005) Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *Int J Obes (Lond)* **29**, 778–784.
34. Koh-Banerjee P, Chu NF, Spiegelman D *et al.* (2003) Prospective study of the association of changes in dietary intake, physical activity, alcohol consumption, and smoking with 9-y gain in waist circumference among 16 587 US men. *Am J Clin Nutr* **78**, 719–727.
35. Hosseinpanah F, Barzin M, Amiri P *et al.* (2011) The trends of metabolic syndrome in normal-weight Tehranian adults. *Ann Nutr Metab* **58**, 126–132.
36. Veghari G, Sedaghat M, Banihashem S *et al.* (2012) Trends in waist circumference and central obesity in adults, northern Iran. *Oman Med J* **27**, 50–53.
37. Niu J & Seo DC (2014) Central obesity and hypertension in Chinese adults: a 12-year longitudinal examination. *Prev Med* **62**, 113–118.
38. Du T, Sun X, Yin P *et al.* (2013) Increasing trends in central obesity among Chinese adults with normal body mass index, 1993–2009. *BMC Public Health* **13**, 327.

39. Monteiro CA, Moura EC, Conde WL *et al*. (2004) Socioeconomic status and obesity in adult populations of developing countries: a review. *Bull World Health Organ* **82**, 940–946.
40. Lahti-Koski M, Seppanen-Nuijten E, Mannisto S *et al*. (2010) Twenty-year changes in the prevalence of obesity among Finnish adults. *Obes Rev* **11**, 171–176.
41. Torrance GM, Hooper MD & Reeder BA (2002) Trends in overweight and obesity among adults in Canada (1970–1992): evidence from national surveys using measured height and weight. *Int J Obes Relat Metab Disord* **26**, 797–804.
42. Wardle J, Waller J & Jarvis MJ (2002) Sex differences in the association of socioeconomic status with obesity. *Am J Public Health* **92**, 1299–1304.
43. Janghorbani M, Amini M, Rezvanian H *et al*. (2008) Association of body mass index and abdominal obesity with marital status in adults. *Arch Iran Med* **11**, 274–281.
44. Sobal J, Rauschenbach B & Frongillo EA (2003) Marital status changes and body weight changes: a US longitudinal analysis. *Soc Sci Med* **56**, 1543–1555.
45. King GA, Fitzhugh EC, Bassett DR Jr *et al*. (2001) Relationship of leisure-time physical activity and occupational activity to the prevalence of obesity. *Int J Obes Relat Metab Disord* **25**, 606–612.
46. Ng SW & Popkin BM (2012) Time use and physical activity: a shift away from movement across the globe. *Obes Rev* **13**, 659–680.
47. Nyholm M, Gullberg B, Merlo J *et al*. (2007) The validity of obesity based on self-reported weight and height: implications for population studies. *Obesity (Silver Spring)* **15**, 197–208.