Original Article

Zero and Five End-Digit Preference and Blood Pressure Quality of Care Revisited

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Abstract

Background: To determine the rate of zero and five end-digit preference (EDP) for systolic and diastolic blood pressures (SBP and DBP, respectively) and risk factors amongst a representative sample of Iranian adults in the year 2011

Methods: Data gathered from 7997 Iranian adults aged 25–70 were extracted from the database of the sixth Survey of Surveillance of Risk Factors of Non-communicable Diseases, which surveyed a total of 11,864 individuals aged 6 to 70 years. Multilevel multiple logistic regression was used to identify the independent factors associated with zero or five EDP.

Results: The prevalence of three serial zero or five EDP for SBP and DBP were 18.5% (95% CI: 11.3%–25.7%). SBP ≥140 mmHg (OR = 0.78; 95% CI: 0.65–0.95), DBP ≥90 mmHg (OR = 0.71; 95% CI: 0.58-0.88), and a positive family history of diabetes (OR = 0.77; 95% CI: 0.66–0.9) were found as protective factors against zero or five EDP in blood pressure recording the male gender (OR = 1.18; 95% CI: 1.04–1.35) was found to be its independent risk factor.

Conclusion: Sex, SBP, DBP and family history of diabetes were found to be the main independent determinants of EDP in our country which underscores the importance of assessing the many patient-related factors in the studies involving EDP as part of BP monitoring in public health care.

Keywords: Iran, prevalence, risk factors, surveillance of risk factors of non-communicable diseases (SuRFNCD), zero and five end-digit preference

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Introduction

Although precise measurement of blood pressure (BP) is well-known as an important factor in reducing the burden of cardiovascular disease, low-quality measurement of BP remains a challenging problem.[1–4] BP measurement is subject to numerous, and occasionally inevitable errors, considering the various factors that might affect the measuring process. While technical issues pertaining to the application of measuring devices or the personnel performing the measurement should rightly be regarded as the main source of inaccuracy, one common source of bias is zero and five end-digit preference (EDP). Widely used as an indicator of the quality of BP measurement, EDP is well recognized as a factor that can affect the management of healthy individuals as well as patients with cardiovascular diseases. Although it is not certain whether EDP contributes to underreporting or overestimation of clinical hypertension, results emerging from the recent cluster-randomized controlled trial of oscillometric vs. manual sphygmomanometer for blood pressure management in primary care (CRAB)[5] and endovascular treatment for small core and proximal occlusion ischemic stroke (ESCAPE)-ancillary blood pressure measurement study (ESCAPE-ABPMS)[6] trials confirm that systematic and/or random rounding up of BP values is practiced more often than rounding down these measurements.

It has been suggested that the disparity, in terms of calibrated measurement, between automated devices and manual sphygmomanometers may play a defining role in terminal digit preference.[6,7] However, subject characteristics such as sex, race and body composition along with the BP index measured, whether it is the systolic blood pressure (SBP) or the diastolic blood pressure (DBP), have also been credited a correlation with terminal digit bias.[8] Rather surprisingly, EDP in BP measurements appears to be highly prevalent among both specialized and primary care physicians and the non-physicians[8]; thus, previous theoretical training may not represent a protective factor against inaccurate and biased BP measurement.[9]

High-quality and trusted BP monitoring is particularly important since the concept of EDP increases the chance of missing individuals with BPs just above the strictly set cut-off points, thus increasing the cardiovascular morbidity and mortality

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associated with diagnostic delay and mismanagement. Regarding the importance of this issue, it has been shown that moving the hypertension detection threshold from more than 140 mmHg to at least 140 mmHg results in nearly doubled rate of hypertension, from 13.3% to 25.9%.[10] As such, the health hazards associated with EDP are concerning and new strategies should be implemented to target the main contributing factors of increased EDP.

Considering the significant prevalence and effects of EDP in the primary care,[11] general practice[6] and hypertension[12] and diabetes[8] clinics, the need for population-based studies on EDP is prominent. Assessment of BP values measured in apparently healthy and at-risk adult population could potentially help identify covariates associated with higher prevalence of EDP. Herein, we aimed to evaluate the EDP prevalence and its significant determinants in the database from the sixth Survey of Surveillance of Risk Factors of Non-communicable Diseases (SuRFNCD-2011).

Patients and Methods

Study population

Data gathered from 7997 Iranian adults aged 25–70 were extracted from the SuRFNCD-2011 depository, as commissioned by the Iranian Center for Disease Control and Prevention. SuRFNCD 2011 is the latest in a series of nationwide household surveys, starting with SuRFNCD-2005,[13] which has been conducted on nationally representative non-hospitalized and non-institutionalized population in Iran. SuRFNCDs datasets remain largely analogous in terms of their protocol for physical examination, methodology adopted for laboratory investigations and their sample populations being socio-demographically representative of the Iranian population, proportionate to the population size of all 31 Iranian provinces. The SuRFNCD-2011 protocol has been described in details in previous studies.[14,15] Briefly, according to the World Health Organization (WHO) stepwise approach to surveillance (STEPS) guidelines, a four-step multi-stage probability cluster random sampling scheme was conceived to generate a dataset comprising 11,864 surveyed individuals aged between 6 and 70 years.

The questionnaire, initially proposed by the WHO, and the reliability and validity of the Persian version of the questionnaire have been reported in previous studies.[14–16] The questionnaire was completed for each subject through a face-to-face interview by trained staff from 51 medical schools across the country. The study received ethics approval of the Center for Disease Control and Prevention of Iran and all participants gave verbal informed consent prior to enrollment. All procedures described here were conducted in accordance with the guidelines and standards laid down in the current revision of the Declaration of Helsinki.

Measurements of study parameters

Interviews were based on a validated Persian version of the 'WHO STEPS chronic disease risk factor surveillance' questionnaire, mainly including demographic information, behavioral risk factors and physical measurements. Weight and height of participants were determined in light clothing and without shoes. For this purpose, a portable stadiometer (Seca Model 207 Germany) and a portable calibrated balanced scale (Seca Model 710 Germany) were used. Body mass index (BMI) was calculated as body weight (kg) divided by the square of the subject's height (meter). Three measurements, made 5-minutes apart constituted the standard protocol for BP measurement as quantified by a calibrated Omron M7 sphygmomanometer (HEM-780-E, Kyoto, Japan). A major methodological difference from the previous reports of SuRFNCD is our incorporation of every three serial BP measurements into the EDP repeated measurement analysis to ensure the validity of the findings as well as to substantially increase the power of the study.[17,18] Self-reported history of diabetes in the first-degree relatives was also recorded. Education was categorized into four categories based on the years studied in school.

Terminology and definitions inventory

We categorized BMI of included subjects based on the WHO and National Heart, Lung, and Blood Institute (NHLBI) recommendations into underweight (<18.5 Kg/m^2), normal (18.5–24.9 Kg/m^2), overweight (25–29.9 kg/m^2) and obese (≥30 Kg/m^2).[19] Based on the *Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure*, subjects with SBP ≥ 140 mmHg, DBP ≥ 90 mmHg or subjects currently using any medications for hypertension were considered to have hypertension.[20] Hypertension awareness was marked as positive by answering "yes" to the question: Q: *"Has a doctor or other health worker ever measured/checked your blood pressure?"* Diabetes awareness was defined as choosing "yes" on the answer sheet when being asked either of the following questions: Q1:*"During the past year, have you had your blood glucose checked/had a blood glucose test?"* and Q2:*"During the past year, has a doctor or other health worker told that you had diabetes?"*. In addition, participants were questioned regarding their cardiovascular status by answering the question: "*Has a doctor or other health worker ever told that you had a cardiovascular disease (e.g., myocardial infarction, angina pectoris etc.)?"*. A modification of the previously disclosed method[21] determined the socioeconomic status (SES) of our individuals into the following levels: poor, moderate and decent. In this method, a factor analysis via principal component extraction method on home assets is performed. To evaluate the individuals' assets, participants were asked about the *location of their house* and whether they own *separate bathroom*, *kitchen*, *vacuum cleaner*, *personal computer*, *fridge* and *washing machine*. Subsequently, the three levels of SES were determined based on the tertiles of the variable "highest weighted component asset index with an acceptable explanation of total variation".

Statistical design framework

Considering the cluster design effects, complex sample survey analyses were employed using the free statistical software R 3.1.2.[22] Chi-Square Goodness of Fit test was used to determine whether the distribution of terminal numbers in SBP and DBP values violates the uniformity assumption that frequency for each end digit (i.e., from 0 to 9) equals to the expected 10%. Pearson Chi-Square analysis was performed to test for between-group difference of EDP rates across the three measurements of SBP and DBP. To underline the systematic recording bias rather than the random effect on EDP error in BP measurements, we defined EDP as '*the separate occurrence of zero or five end digits on each of the three consecutive BP measurements'*. The same terminology was applied in the subsequent analysis of EDP risk factors. Based on this definition and the null hypothesis of 20% expected frequency for BP numbers ending in zero or five terminal digits on each of the three occasions, the expected prevalence for EDP recording of BP (three) measurements equals to 0.8%. Using the package lme4[23] and based on significant findings from bivariate associations, multilevel logistic regression consisting of three levels (measure, cluster and province) was constructed to model the effective risk factors on zero and five EDP binary outcome variables (SBP, DBP and both). Likelihood Ratio test and Akaike information criterion (AIC) were used to determine the number of appropriate levels in the multilevel logistic regression. Using this logistic model, we calculated the odds ratio (OR) and its 95% confidence Interval (CI) for each independent variable. In addition, the simultaneous effect of the variables was assessed in a separate multilevel multiple logistic regression analysis, including variables with P-values less than 0.10. For variables with positive collinearities, one representative factor was entered into the multivariate models. The backward model selection was used to derive the statistically significant risk factors from the analysis. In each step of the backward model selection, variables with the highest *P*-values were withdrawn from the model and re-analysis was performed. This procedure was continued until there were no variables with P-values more than or equal to 0.10.

Results

Individual distribution of 0 to 9 end digits for the three measurements of SBP and DBP is demonstrated in Table 1. For each SBP measurement, a significant irregularity (*P* value < 0.001) in terminal digit distribution is detected as characterized with higher rates for 0 [prevalence (95% CI): 24.9% (19.4%–30.3%) for the first measurement, 24.6% (19.1%–30.1%) for the second measurement and 28.8% (23.7%–33.9%) for the third measurement] and 5 (11.4% to 13.6%) terminal numbers. A similar deviation from the uniform DBP EDP distribution is observed with zero and five EDP rates ranging from 24.0% to 28.2% and 12.6% to 14.2%, respectively. The frequency of SBP and DBP values with terminal digits of 0 and 5 significantly increased from the first to the third BP measurements (*P* values for SBP and DBP < 0.001, Table 1).

The observed frequency of three serial 0 or 5 EDP was calculated to be 18.5% (95% CI: 11.3%–25.7%) for SBP and 18.5% (95% CI: 11.3%–25.7%) for DBP, which is significantly different from the expected 0.8% EDP frequency for both SBP and DBP (P values for both SBP and DBP < 0.001). The probability for either or both of the SBP and DBP readings ending in 0 or 5 terminal digits on each of the three independent BP measurements was calculated at 21.5% (vs. 1.6% expected, 95% CI: 14.3%–28.7%) and 15.5% (vs. 0.64% expected, 95% CI: 8.4%–22.6%), respectively. Table 2 summarizes the prevalence of 0 or 5 EDP for systolic, diastolic and either of the systolic or diastolic BPs according to different strata of various demographic and clinical variables in the entire surveyed population.

Table 3 presents the results of bivariate analyses on the

Table 1. Distribution of end digits preference for systolic and diastolic blood pressure measurements.

End digit	First measurement		Second measurement		Third measurement		*P*-Value
	Percentage	95% CI	Percentage	95% CI*	Percentage	95% CI*	
Systolic Blood pressure (%)							
0	24.9	19.4 – 30.3	24.6	19.1 – 30.1	28.8	23.7 – 33.9	<0.0001
1	8.5	7.6 – 9.4	8.3	7.3 – 9.3	7.7	6.7 – 8.7	
2	8.6	7.6 – 9.6	8.8	7.4 – 10.2	9.0	8.1 – 10.0	
3	7.9	6.7 – 9.0	7.3	6.5 – 8.2	6.3	5.6 – 7.1	
4	7.3	6.3 – 8.4	7.2	6.2 – 8.3	6.1	5.1 – 7.0	
5	11.4	10.0 – 12.7	13.3	11.6 – 15.0	13.6	12.1 – 15.1	
6	7.2	6.1 – 8.2	7.3	6.3 – 8.2	6.6	5.8 – 7.4	
7	7.9	7.1 – 8.7	7.9	6.8 – 8.9	6.5	5.6 – 7.3	
8	9.1	8.1 – 10.2	8.4	7.4 – 9.4	8.4	7.2 – 9.5	
9	7.3	6.3 – 8.3	6.9	5.9 – 8.0	7.1	6.0 – 8.1	
***P*-Value**	**<0.0001**		**<0.0001**		**<0.0001**		
Diastolic Blood pressure (%)							
0	24.0	18.4 – 29.6	25.0	19.6 – 30.4	28.2	22.9 – 33.5	<0.0001
1	7.8	6.8 – 8.8	7.4	6.6 – 8.2	6.9	5.9 – 7.9	
2	8.9	7.8 – 9.9	9.0	8.0 – 10.1	8.1	7.1 – 9.1	
3	8.5	7.5 – 9.5	8.0	7.0 –9.0	7.6	6.5 – 8.6	
4	7.9	7.0 – 8.9	7.3	6.4 – 8.1	7.0	6.1 – 7.9	
5	12.6	11.3 – 13.9	13.0	11.4 – 14.7	14.2	12.7 – 15.7	
6	7.9	7.0 – 8.7	7.4	6.5 – 8.2	6.6	5.8 – 7.4	
7	7.6	6.7 – 8.5	7.7	6.7 – 8.6	7.2	6.4 – 8.1	
8	7.4	6.5 – 8.3	7.8	6.6 – 8.9	7.4	6.4 – 8.3	
9	7.4	6.4 – 8.4	7.4	6.4 – 8.3	6.9	6.0 – 7.7	
***P*-Value**	**<0.0001**		**<0.0001**		**<0.0001**		

*, Design effect considered in the calculation of the 95% confidence interval (CI); Total samples: 7997 subjects.

Table 2. Inflated BP by characteristics of the subjects.

Characteristics		*n* (%)	Systolic blood pressure (%)	Diastolic blood pressure (%)	Any blood pressure (%)
Sex	Male	3201 (40.0)	20.0	20.1	23.4
	Female	4796 (60.0)	17.4	17.5	20.2
Age	25-44	3666 (45.8)	18.5	18.8	21.9
	45-65	3537 (44.2)	18.8	18.6	21.5
	65+	794 (9.9)	16.8	17.1	19.8
Education	Illiterate	2405 (30.1)	19.0	18.5	21.4
	<6	1926 (24.1)	19.0	18.7	21.8
	6-12	2665 (33.3)	17.7	17.9	21.1
	>12	1001 (12.5)	18.2	20.0	22.4
Area	Urban	5640 (70.5)	18.0	18.2	21.1
	Rural	2357 (29.5)	19.6	19.3	22.5
BMI (kg/ m^2)	Normal	264 (3.3)	18.5	18.8	21.8
	Underweight	2674 (33.4)	24.6	26.5	29.2
	Overweight	3022 (37.8)	18.4	18.5	21.3
	Obese	2037 (25.5)	17.6	17.2	20.4
Systolic BP	<140	6159 (77.0)	19.5	19.8	22.8
	^{3}140	1838 (23.0)	14.9	14.4	17.2
Diastolic BP	<90	6413 (80.2)	19.5	19.5	22.7
	^{3}90	1584 (19.8)	14.1	14.6	16.7
Measured BP	No	5542 (69.3)	20.0	20.2	23.7
	Yes	2455 (30.7)	17.8	17.8	20.6
HTN	No	5028 (62.9)	19.6	19.8	23.0
	Yes	2969 (37.1)	16.5	16.4	19.0
Diabetes Family history	No	2154 (26.9)	19.4	19.7	22.8
	Yes	5843 (73.1)	15.8	15.5	18.1
Sugar measured	No	3593 (44.9)	18.7	18.8	21.9
	Yes	4404 (55.1)	18.1	18.2	21.0
Diabetes told	No	940 (11.8)	18.6	18.8	21.8
	Yes	7057 (88.2)	17.1	16.8	19.4
History of CVDs	No	688 (8.6)	18.5	18.7	21.7
	Yes	7309 (91.4)	17.9	16.7	19.9
SES	Poor	2563 (32.0)	19.8	19.4	22.6
	Moderate	2850 (35.6)	17.6	17.8	20.4
	Good	2584 (32.3)	18.1	18.5	21.7

BM = body mass index; BP = blood pressure; CVD = cardiovascular diseases; HTN = hypertension; SES = socioeconomic status.

correlations between demographic and clinical risk factors and the prevalence of zero or five EDP. Sex, age, SBP, DBP, Hypertension, Family history of diabetes and diabetes awareness were variables significantly associated with either systolic or diastolic EDP. In the final multilevel multivariable model (resulted from our backward elimination), Male gender (OR = 1.18; 95% CI: 1.04–1.35), SBP ≥ 140 (OR = 0.78; 95% CI: 0.65–0.95), DBP ≥ 90 (OR = 0.71; 95% CI: 0.58–0.88) and a positive family history of diabetes (OR = 0.77; 95% CI: 0.66–0.9) were found to be the independent factors associated with zero or five EDP in rounding of systolic or diastolic BP (Table 4).

Discussion

In this nationally representative observational study, EDP prevalence ranging from 24% to 28.8% and 11.4% to 15% for 0 and 5 terminal digits, respectively, are reflective of inaccurate BP recording in our country. Such high rates of EDP were found

Table 3. Analysis of risk factors with zero and five end digit Preference of BP Value.

Characteristics	Systolic Blood Pressure				Diastolic Blood Pressure				any Blood Pressure			
	Odds ratio	95% CI	*P*†	*P* of Variable*	Odds ratio	95% CI	*P*†	*P* of Variable*	Odds ratio	95% CI	*P*†	*P* of Variable*
Sex												
Female	*ref*				*ref*				*ref*			
Male	1.26	1.07 - 1.47	0.004	0.004	1.27	1.09 - 1.48	0.003	0.003	1.24	1.07 - 1.42	0.004	0.004
Age												
25-44	*ref*				*ref*				*ref*			
45-65	0.86	0.73 - 1.01	0.062	0.138	0.79	0.67 - 0.93	0.005	0.020	0.8	0.69 - 0.93	0.004	0.012
65+	0.85	0.65 - 1.11	0.226		0.87	0.67 - 1.14	0.311		0.82	0.64 - 1.04	0.106	
Education												
Illiterate	*ref*				*ref*				*ref*			
<6	1.13	0.91 - 1.4	0.265	0.435	1.19	0.96 - 1.48	0.110	0.008	1.16	0.96 - 1.42	0.133	0.075
6-12	1.11	0.9 - 1.35	0.335		1.16	0.95 - 1.43	0.148		1.17	0.97 - 1.4	0.108	
>12	1.24	0.95 - 1.62	0.121		1.59	1.22 - 2.06	0.001		1.38	1.08 - 1.76	0.011	
Area												
Urban	*ref*				*ref*				*ref*			
Rural	0.85	0.67 - 1.07	0.160	0.160	0.80	0.63 - 1.01	0.060	0.060	0.88	0.71 - 1.09	0.248	0.248
BMI (kg/ m^2)												
Normal	*ref*				*ref*				*ref*			
Underweight	1.29	0.83 – 2	0.253	0.233	1.55	1.02 - 2.36	0.042	0.215	1.45	0.97 - 2.15	0.068	0.240
Overweight	1.11	0.92 - 1.33	0.272		1.08	0.9 - 1.29	0.429		1.03	0.87 - 1.22	0.697	
Obese	1.22	0.99 - 1.5	0.057		1.11	0.9 - 1.36	0.340		1.12	0.93 - 1.35	0.247	
Systolic BP												
<140	*ref*				*ref*				*ref*			
≥140	0.77	0.63 - 0.94	0.011	0.011	0.69	0.57 - 0.85	<0.001	<0.001	0.74	0.62 - 0.89	0.001	0.001
Diastolic BP												
<90	*ref*				*ref*				*ref*			
≥90	0.63	0.51 - 0.78	<0.001	<0.001	0.69	0.56 - 0.85	<0.001	<0.001	0.67	0.55 - 0.81	<0.001	<0.001
Measured BP												
No	*ref*				*ref*				*ref*			
Yes	0.91	0.77 - 1.09	0.304	0.304	0.88	0.74 - 1.04	0.132	0.132	0.87	0.74 - 1.02	0.085	0.085
HTN												
No	*ref*				*ref*				*ref*			
Yes	0.82	0.69 - 0.96	0.017	0.017	0.77	0.65 - 0.91	0.002	0.002	0.76	0.66 - 0.89	<0.001	<0.001
Diabetes Family history												
No	*ref*				*ref*				*ref*			
Yes	0.93	0.77 - 1.11	0.403	0.403	0.81	0.67 - 0.97	0.021	0.021	0.84	0.71 - 0.99	0.034	0.034
Sugar measured												
No	*ref*				*ref*				*ref*			
Yes	1.03	0.88 - 1.21	0.724	0.724	1	0.85 - 1.17	0.953	0.953	0.98	0.84 - 1.14	0.782	0.782
Diabetes told												
No	*ref*				*ref*				*ref*			
Yes	0.85	0.66 - 1.09	0.196	0.196	0.76	0.59 - 0.98	0.032	0.032	0.78	0.62 - 0.98	0.034	0.034
History of CVDs												
No	*ref*				*ref*				*ref*			
Yes	1.15	0.88 - 1.51	0.302	0.302	0.97	0.74 - 1.28	0.828	0.828	0.99	0.77 - 1.27	0.933	0.933
SES		—				—				-		
Poor	*ref*	—			*ref*	—			*ref*	-		
Moderate	1.01	0.82 - 1.24	0.937	0.989	1.12	0.91 - 1.37	0.298	0.466	0.97	0.8 - 1.17	0.729	0.812
Good	1.02	0.82 - 1.26	0.880		1.14	0.91 - 1.41	0.250		1.03	0.84 - 1.25	0.807	

BMI = body mass index; BP blood pressure; CI = confidence interval; CVD = cardiovascular diseases; HTN = hypertension; SES = socioeconomic status. † P-value for the comparison of the level of variable with its reference level. * P-value for the effect of variable (all levels together). Effect of demographic factors on end digit preference of zero and five; bivariate analysis

Table 4. Final model based on backward elimination* to evaluate the effective risk factors on zero and five end digit preference of diastolic blood pressure in three serial measurements.

Characteristics	Systolic Blood Pressure			Diastolic Blood Pressure			Any Blood Pressure		
	Odds ratio	95% CI	*P*†	Odds ratio	95% CI	*P*†	Odds ratio	95% CI	*P*†
Sex									
Female	*ref*			*ref*			*ref*		
Male	1.26	1.05 - 1.45	0.009	1.18	1.03 - 1.35	0.013	1.18	1.04 - 1.35	0.012
Systolic BP									
<140	*ref*			*ref*			*ref*		
³140	--	---	---	0.69	0.56 - 0.86	0.001	0.78	0.65 - 0.95	0.013
Diastolic BP									
<90	*ref*			*ref*			*ref*		
³90	0.64	0.52 - 0.79	<0.001	0.79	0.63 - 0.98	0.0.31	0.71	0.58 - 0.88	0.001
Diabetes Family history									
No	*ref*			*ref*			*ref*		
Yes	—	—	—	0.76	0.64 - 0.89	0.001	0.77	0.66 - 0.9	0.001

BP = blood pressure; CI = confidence interval; OR = odds ratio; Ref = reference; SES = socioeconomic status
* all the effect entered in the first model has the P-value less than 0.100, the variable with highest p-value excluded from the model until there was no variable with $P \geq 0.100$).
† Considered as any systolic or diastolic blood pressure has zero and five end digit preference in three serial measurements.

in three consecutive SBP and DBP readings measured by trained primary health care professionals. These findings suggest that repeated measures of BP by educated health-care professionals lack certain quality in BP monitoring. Since the decision on whether an individual requires primary/additional therapy is made based on the average of five to six BP readings,[24] these findings suggest that there might be a neglect in the initiation/augmentation of BP-lowering therapy.

A review of the current literature reveals that the prevalence of zero terminal digit rounding varies greatly from 22.2–40.8% for SBP and 21.8–53.6% for DBP at the Hypertension Division of Mayo Clinic[12] to around 81% in China[25] to nearly 100% in Nigeria.[26] Our finding of a relative high frequency of EDP is particularly concerning given the meticulous instructions on the premium-quality and trusted BP measurement as outlined in the SuRFNCD-2011 preface and detailed program.

Here, we have examined the impact of diverse demographic and clinical variables on EDP prevalence at a national level. In the multilevel multivariate logistic regression analysis, we identified male gender to be a risk factor for either systolic or diastolic EDP, and SBP ≥ 140, DBP ≥ 90 and a positive family history of diabetes to be protective factors against EDP in either SBP or DBP measurements. Previous independent groups found inconsistent determinants of zero and five terminal digit frequency among the general population and in specialized care settings. Lebeaua and colleagues found no significant associations between any of the general practitioners' characteristics and patient-related factors with the group-divided prevalence of EDP and concluded that EDP habits are only device-related.[6] Populations studied in specialized clinical-based researches typically consist of a selected group of homogenous patients with comparable baseline characteristics in terms of demographic and clinical data. In such surveys, common risk factors of EDP may be confined to observer and device-related factors. On the other hand, as demonstrated in the present study, EDP assessment on more heterogeneous primary-care grounds and particularly in population-based surveys can identify more patient-related predictors of EDP. We believe that the lower risk of EDP in our subjects with higher SBP and DBP readings and the self-reported family history of diabetes is partially related to the subconsciously over-conservative approach of health-care professionals towards the at-risk population and/or their more passive behavior in apparently healthy groups when recording their BP measurements.

Contrary to the results of previous studies,[12] the significance of EDP is highlighted in the present survey by a nearly uniform distribution of odd and even terminal SBP and DBP digits excluding the two distinct peaks at the digits 0 (24.0%–28.8% vs. 10% expected) and 5 (11.4%–14.2% vs. 10% expected). EDP definition of three serial zero or five digit endings was another strength of this study as this terminology more accurately addresses the true rate of systematic recording bias and is beneficial for reliable detection of EDP risk factors.

Recent studies have shown a downward trend in the prevalence of rounding terminal digits at the two extremes of BP that are of little clinical significance, while EDP rates around the treatment targets continue to rise[27] As this is the first nationwide report on EDP prevalence and associated risk factors, longitudinal trend analysis of the terminal digit frequency across SuRFNCD reports was not possible. From 2005 onwards, oscillometric BP measurement has been a mainstay of the national SuRFNCD surveys. As studies have identified an association between the emergence of automated BP measuring devices with lower rates of EDP,[6] it will be interesting to reflect on the alterations in systolic and diastolic EDP over time. Thus from an epidemiologic perspective, it is pivotal to maintain consistency with the use of automated BP recording devices across the current and succeeding SuRFNCD reports. Adoption of such strategy enables health care policy makers to design preventative and educational approaches, based on true and comparable estimates of EDP determinants and their impact on the increased cardiovascular disease burden.

Limitations

In the present study, characteristics such as family history of hypertension, diabetes and chronic diseases, sugar consumption, and history of cardiovascular diseases were assessed on the basis of the subjects' self-reports which suggests the possibility of recall bias. Moreover, considering the observational nature of the study, elimination of selection bias is not always complete. Eventually, some potential confounders might have been missed in this survey.

In conclusion, our findings demonstrate a relatively high prevalence of EDP despite a high-level of training and strict national guidelines on recording BP measurements in a large representative population of Iranian adults. Repeated-measure analysis separately confirms the increasing prevalence of EDP across the three measurements of SBP and DBP. Sex, SBP, DBP and the family history of diabetes were found to be the main independent determinants of EDP in our country which underscores the importance of assessing the many patient-related factors in the studies involving EDP as part of BP monitoring in public health care.

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Conflict of interest

The authors declared no competing of interest.

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