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Terminal Digit Preference on Blood Pressure Measurements: Its Effect on the Association Between Body Mass Index and Hypertension Among Adult Women

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Hypertension is a serious problem in the Philippines as it (1) afflicts about 21 percent of the adult population; (2) is the fifth leading cause of morbidity; and (3) is a known risk factor for heart, vascular and kidney diseases which are ranked first, second and tenth leading causes of death in the country, respectively[1]. At the same time, there is a growing proportion of the population that has become overweight and/or obese i.e. among adult women alone, overweight prevalence increased from 18 percent in 1993 to 23 percent 1998[2]. Excess body weight causes metabolic changes that can lead to hypertension, and this association has been supported by epidemiologic studies showing positive relationship between body mass index (BMI) (weight (kg)/height (m^2)) and hypertension[3-9]. Very few studies have explored excess body weight in the Philippines, particularly those examining its relationship with BMI.

Indirect measurement of BP is the only practical means of identifying hypertension, and the use of mercury sphygmomanometer remains the gold standard for this type of measurement[10]. However, this method is not free of error. The degree of error is dependent on the accuracy of transmission and interpretation of a signal (Korotkoff sound or pulse wave) from the subject to the device to the observer. Errors can occur at any point in this transmission, but by far the most fallible component is the observer[10]. Among the observer errors, terminal digit preference (rounding off the pressure reading to a digit of his or her choosing) is common. Keary et al[11] reported that even doctors have a 12-fold bias in favor of the terminal digit zero. Terminal digit preference can lead to overestimation or underestimation of actual BP and can distort the distribution of observations. This error can potentially reduce the power of statistical tests - the chance that the study will find a significant association if one is truly present.

One of the problems associated with longitudinal studies that can potentially result to loss of internal and external validity is attrition (loss to follow-up). External validity is compromised when those who remained in the sample is no longer representative of the source population; and internal validity is compromised if attrition results to selection bias - i.e. the probability of remaining in the study is associated with both the exposure and the outcome.

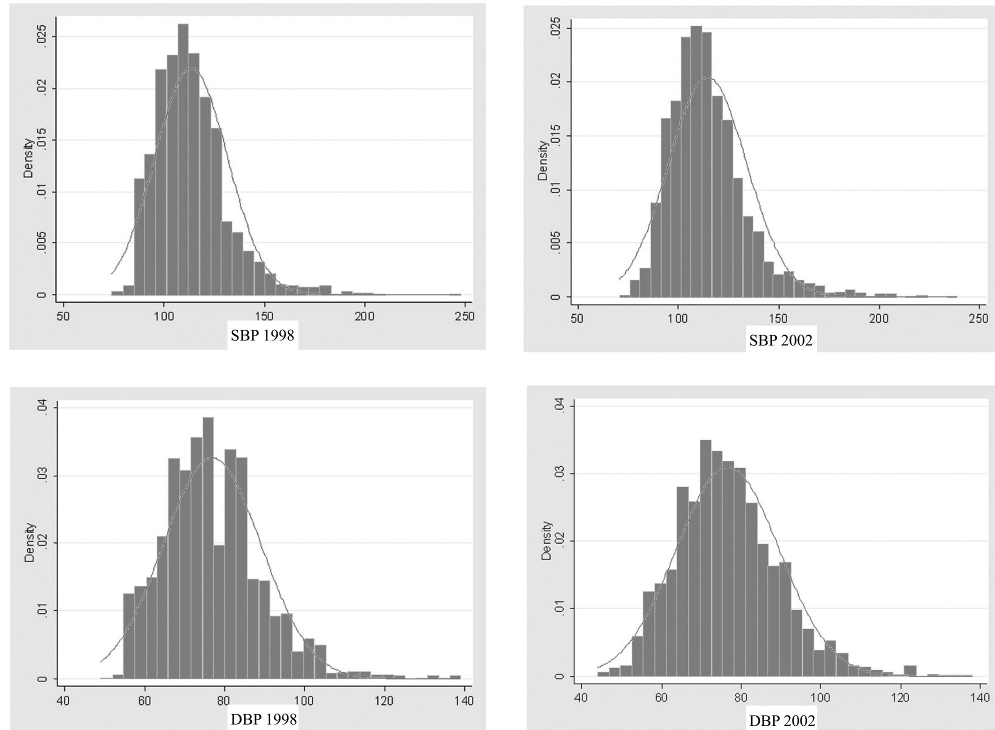
This paper examined the extent of terminal digit (zero) preference in BP measurement and its effect on the estimate of the BMI-hypertension association, along with the effect of attrition as regards to potential selection bias.

MATERIALS AND METHODS

The data source for this study is the Cebu Longitudinal Health and Nutrition Survey (CLHNS). The CLHNS is a community-based sample survey that follows a cohort of mother-child pairs since 1983 in Metro Cebu, the second largest metropolitan area in the Philippines. A stratified, single stage sampling was used to select 33 barangays (smallest administrative unit) - 17 urban and 16 rural barangays. All pregnant women in the selected barangays were initially invited to participate and were included in the survey if they gave birth between May 1, 1983 and April 30, 1984. The baseline interview was conducted among 3,327 women during the 6th to 7th month of pregnancy so that all births, including preterm births, could be identified. Initial refusal rate was low (<3%). Although there have been numerous follow-ups of the CLHNS sample women, this paper included only the participants of the 1998 and 2002 surveys where BP measurements were available.

Blood pressure was measured three times (with at least 2 minutes interval) by trained personnel using a mercury column sphygmomanometer after a 10 minute rest when the woman was seated. The mean of the three BP measurements were used to represent systolic BP (SBP) and diastolic (DBP). To examine the effect of terminal digit preference (particularly at standard definition cut-off points), hypertension was defined in two ways: (1) SBP $\geq$ 140 mmHg or DBP $\geq$ 90 mmHg; and (2) SBP > 140 mmHg or DBP > 90 mmHg, hereon referred to as definition 1 and definition 2, respectively. The same trained personnel obtained weight (kg) and height (cm) measurements to the nearest 0.1 unit using standard adult anthropometric tools. BMI (kg/m2) was calculated as weight in kg divided by the square of height in meters, and BMI change was calculated as 2002 BMI minus 1998 BMI. To appropriately capture BMI change secondary to weight changes, the same height measurements were used to calculate both 1998 and 2002 BMI. The height measurement used was the average height of the two closest measurements looking at those obtained from the baseline, 1998 and 2002 surveys. Data for covariates considered as potential confounders (i.e. age, household income) were obtained from interviews using structured questionnaires. Age was computed as the difference between interview date and birth date and household income included income of all members of the household older than 6 years.

Chi-square, t-tests and multivariate regression models were used for the analyses using STATA version 9.0. In all analyses testing, p-value <0.05 was considered significant. Logistic regression was used to estimate prevalence odds ratios (POR) for the 1998 and 2002 cross-sectional samples and incidence odds ratios (IOR) for the longitudinal samples (women present in both 1998 and 2002 surveys) for each of the hypertension definitions. In addition, since length of exposure can be calculated from the longitudinal samples, incidence rate ratios were also estimated using poisson regression with the robust option. Heckman two-step selectivity model was used to determine the extent of selection bias.



Appendix Figure. Distribution of BP measurements after addition of random number ranging from -5 to +5.

REFERENCES:

1. 2002 FHSIS Updates. Http://doh.gov.ph/data_stat/html/health_statistics.htm Accessed November 2005

2. Food and Nutrition Research Institute (FNRI), Department of Science and Technology. 2001. Philippine Nutrition Facts and Figures. Unicef. ISSN 1655-2911.

3. Brown CD, Higgins M, Donato K, Rohde FC, Garrison R, Obarzanek E, Ernst ND, Horan M. Body mass index and the prevalence of Hypertension. Obes Res. 2000;8:605-619.

4. Himes, C. 2000. Obesity, disease, and functional limitation in later life. Demography: Vol 37-1:73-82

5. Janssen, I, Katzmarzyk, PT, Ross R. Body mass index, waist circumference, and health risk. Arch Intern Med. 2002;162:2074-2079.

6. Dalton M, Cameron AJ, Zimmet PZ, Shaw JE, Jolley D, Dunstan DW, Welborn TA. Waist circumference, waist-hip ratio and body mass index and their correlation with cardiovascular disease risk factors in Australian adults. J of Intern Med.2003; 254:555-563.

7. Canoy D. Luben R, Welch A, Bingham S, Wareham N, Day, N, Khaw, K. Fat distribution, body mass index and blood pressure in 22090 men and women in the Norfolk cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC-Norfolk) study. J of Hypertension. 2004; 22:2067-2074.

8. Mokdad, AH, Ford ES, Bowman BA et al. Prevalence of diabetes, and obesity related health risk factors, 2001. JAMA. 2003;289:76-79.

9. Lloyd-Jones, DM, Sutton-Tyrrell, K, Patel AS, Matthews, KA, Pasternak, RC, Everson-Rose, Sa, Scuteri, A, Chae, CU. Ethnic Variation in hypertension among premenopausal and perimenopausal women, sutdy of women's health across the nation. Hypertension. 2005;46:689-695.

10 Jones, DW, Frolich ED, Grim, CM, Grim CE, Taubert, KA, Mercury sphygmomanometers should not be abandoned: an advisory statement from the Counceil for High Blood Pressure Research, american Heart Association. Hypertension. 2001; 37:185-186.

11. Keary L, Atkins N, O'Brien ET. Terminal digit preference and heaping in office blood pressure measurements. J Hum Hypertension. 1998;12:787-788.

12. Perez, Lorna. Sample Attrition in the Cebu Longitudinal Health and Nutrition Study. Unpublished document.

13. Wen SW, Kramer MS, Hoey J, Hanley JA, Usher, RH. Terminal digit preference, random error, and bias in routine clinical measurement of blood pressure. J Clin Epidemiol. 1993;46(10):1187-93.

14. Hessel PA. Terminal digit preference in blood pressure measurements: effects on epidemiological associations. Int J Epidemiol 1986; 15:122-125.

15. Thavarajah S, White WB, Mansoor GA. Terminal digit bias in a specialty hypertension faculty practice. J of Hum Hypertension. 2003;17:819-822.

16. Grimes DA, Schulz KF. Bias and causal associations in observational research. Lancet 2002; 359:248-52.

RESULTS

Of the 3,327 women interviewed at baseline, 1,989 (59.8%) remained in 1998. All pregnant women (n=51) and those with missing data in any of the variables of interest (n=7) were excluded leaving 1,931 women for the 1998 cross-sectional analysis. In the 2002 survey, 2,102 (63.2%) women participated and of these women 39 were excluded due to pregnancy (n=31) and missing data (n=8) leaving 2,063 women for the 2002 cross-sectional analysis. The 1998 sample was fewer than that of 2002 because of procedural differences in 1998 women were only followed-up if their children were also followed up but in 2002, women were followed-up regardless of whether their children were followed-up or not. About 1,832 women were in both the 1998 and 2002 surveys, creating the base for the longitudinal samples. Since the longitudinal analyses examined incidence, those who were hypertensive in 1998 were also excluded - 369 women excluded if hypertension was defined as SBP $\geq$ 140 mmHg or DBP $\geq$ 90 mmHg leaving 1,463 women for analysis (longitudinal sample 1); and 171 women excluded if hypertension was defined as SBP > 140 mmHg or DBP > 90 mmHg leaving 1,661 for analysis (longitudinal sample 2). Figure 1 illustrates the changes in sample size from baseline to 1998 and 2002 and the main reasons for attrition.[12] Out-migration (outside metro Cebu) accounted for about 84 percent of women lost to follow-up. There were significant differences in the baseline characteristics of women who were lost to-follow-up and those who remained in the study (both 1998 and 2002 surveys) - the latter were older, less educated, less likely from urban areas, and less likely to belong to the lowest quartile of household assets. Average BMI were not significantly different (Table 1).

BMI was normally distributed for both the 1998 and 2002 survey rounds, however terminal digit preference was apparent in the BP measurements (Figure 2), especially for DBP. This observer terminal digit preference was more pronounced in 1998 than 2002. About 63 percent of SBP and 86 percent of DBP ended in zero in 1998 while about 12 percent of SBP and 21 percent of DBP ended in zero in 2002. Nonetheless zero digit preference was not strongly correlated with the magnitude of blood pressure, BMI and other covariates, with correlation coefficients <0.1.

Table 1. Comparison of baseline characteristics: lost to follow-up versus in longitudinal sample[a]

Baseline characteristic	Lost to follow-up	In longitudinal sample	p-value[b]
Mean BMI (SE)	22.17 (0.08)	22.02 (0.06)	0.126
Mean age (SE)	25.49 (0.15)	26.49 (0.14)	0.000
Mean years education (SE)	7.32 (0.08)	6.96 (0.07)	0.002
% urban (SE)	81.10 (1.01)	73.25 (1.04)	0.000
% HH asset quartile 1 (SE)	29.81 (1.18)	21.05 (0.95)	0.000
% HH asset quartile 2 (SE)	23.22 (1.09)	26.48 (1.03)	0.031
% HH asset quartile 3 (SE)	22.22 (1.07)	27.36 (1.04)	0.001
% HH asset quartile 4 (SE)	24.75 (1.11)	25.11 (1.01)	0.812

[a] Longitudinal sample comprised all women who participated in both 1998 and 2002 surveys.
[b] T-test p-value comparing women lost to follow-up versus those who are in the longitudinal sample.

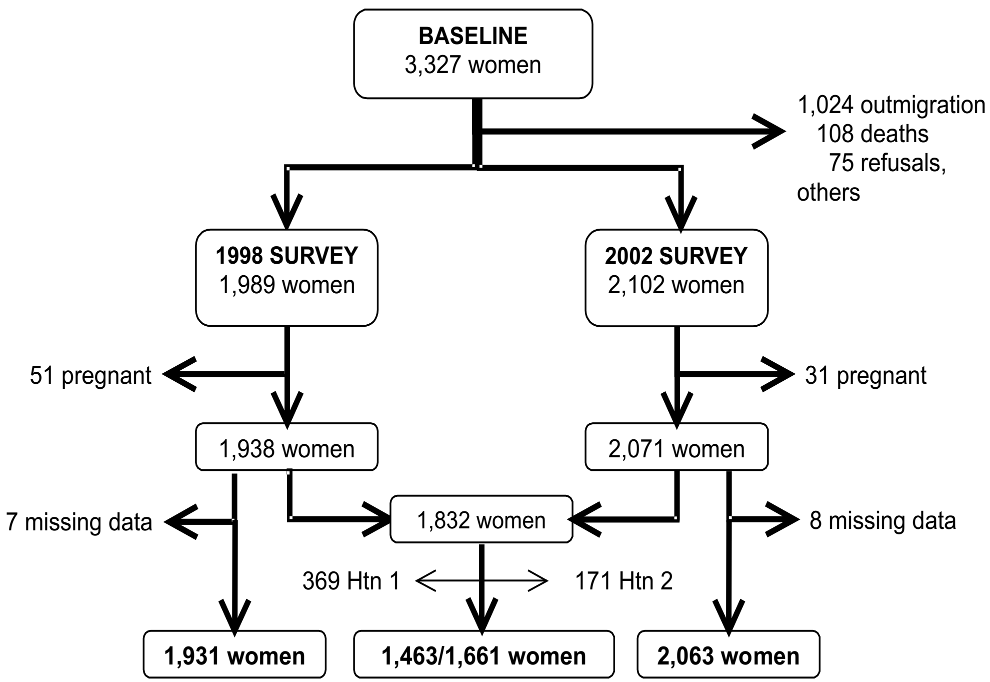


Figure 1. Changes in sample size from baseline survey to 1998 and 2002 surveys.

Selection bias results from non-comparability between groups being studied. This occurs in a cohort study when the exposed and unexposed groups differ in some important respect aside from the exposure[16]. In our data, we explored whether or not those who remained in the study were different from those that were lost to follow-up and whether or not these differences rendered the BMI-hypertension association estimates significantly biased. Results showed that although a substantial proportion of the baseline sample had been lost, the remaining participants were not significantly different from the 'lost' women in terms of factors related to our variables of interest. We can therefore say that our estimates are reliable and that these can be generalized to all women that our baseline sample was set to represent (i.e. women from metro Cebu who gave birth in 1983-84).

As a limitation, the study did not take into account several factors (unmeasured) that can potentially confound and/or modify the BMI-hypertension association estimates. Some the important factors that we have not considered are heredity, sodium intake, comorbidity (i.e. kidney disease), and the use of anti-hypertensive medications. The inclusion of these covariates can potentially affect the magnitude of estimated effect. However, it is not likely that the inclusion of these covariates will change our conclusion as regards to terminal digit (zero) preference and/or selectivity.

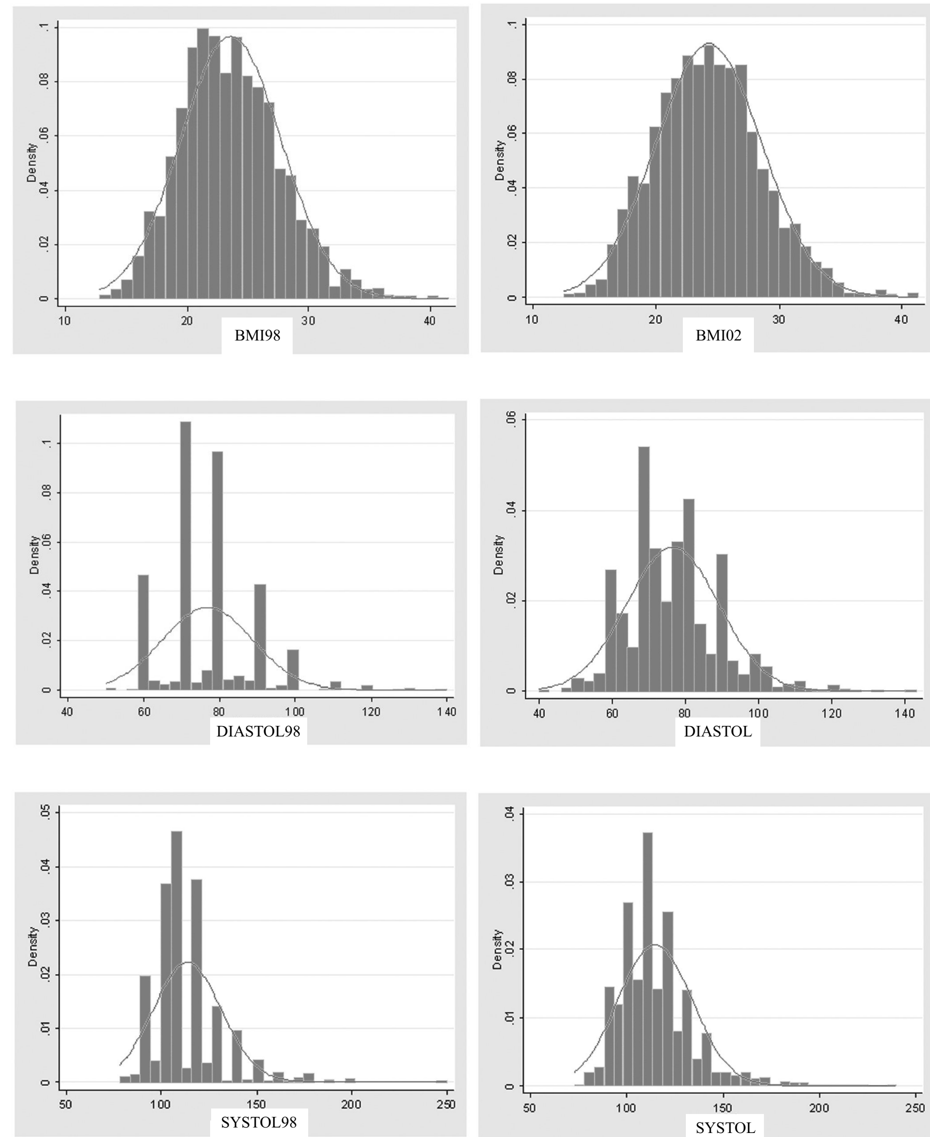
In summary, we found that BMI is positively associated with hypertension prevalence and/or incidence, therefore weight management should be stressed in hypertension prevention efforts among adult women. Although zero digit preference in BP measurement was prevalent in our data (especially in 1998), this appeared to be random and did not affect our estimates of the BMI-hypertension relationship. Attrition did not result to significant selection bias. This study can therefore be said to be internally and externally valid.

DISCUSSION

The results showed that there was terminal digit (zero) preference in both systolic and diastolic blood pressure measurements, with DBP worse than SPB and 1998 worse than 2002. The degree of this observer bias is not substantially different from those reported by other studies mostly conducted in developed countries. The prevalence of terminal digit zero preference in 1998 was comparable to those reported by previous studies within hospitals and in primary care ambulatory settings.[11,13,14]. For example, Wen[13] reported that in their study involving 28,841 pregnant women, 78 percent of SBP measurements were read at zero in Montreal's Royal Victoria Hospital (Canada). Similarly, Hessel[14] reported that about 78.5 percent of SBP and 74.2 percent of DBP readings of examining doctors in an industrial screening program were digit-preferenced. A study by Thavarajah[15] et al in the hypertension specialty clinic of the University of Connecticut Health Center found terminal digit zero preference in 40 percent of the SBP and 23 percent of DBP readings by nurses and 31 percent of SBP and 36 percent of DBP measurements in readings by physicians. The prevalence of zero bias of the 2002 BP measurements taken by trained CLHNS personnel were therefore considerably lower than those reported by most literature where BP measurements were taken by medical staff (i.e. nurses, doctors). Although in the CLHNS data we found consistently higher zero digit prevalence in DBP than SBP measurement, not all the reviewed literature showed the same pattern.

The hypertension prevalence reported by the Philippine Department of Health in 2002 was higher than our estimates. However, in our study, we showed how zero digit preference at cut-off points (SBP 140 mmHg or DBP 90 mmHg) can substantially affect prevalence estimates, to the extent of reversing the trend observed from 1998 to 2002. This stresses the importance of practicing caution in reporting and comparing prevalence estimates from other surveys, especially if we could not determine the magnitude of this bias in these studies.

The zero digit bias observed in this study appeared to be completely random. It was not correlated with the magnitude of BP measurement, with BMI and other covariates considered in the analyses. The addition of a random number ranging from -5 to +5 resulted to a distribution closer to normal (Appendix Figure). This conclusion was also supported by its negligible effect on the relative measures of association (OR, IR) between BMI and hypertension. The effect measure estimates were robust and fairly precise. Misclassification errors resulting from zero digit preference can decrease power therefore making the 12 percent increase in hypertension prevalence odds for each unit increase in BMI reported in this paper possibly more conservative (closer to the null) than the true BMI-hypertension association among women. Hessel[14] reported that digit preferencing did not generally affect estimates of the slopes and intercepts of the relationship between BMI and BP, however the associations showed greater error variance when digit preferenced readings were used compared to non-digit preferenced readings. The direction of the BMI-hypertension association found in our study is consistent with literature.[3-9] The magnitude of association is also comparable with the results of the study conducted by Lloyd-Jones[9] et al using data from the Study of Women's Health Across the Nation (SWAN) among 3,302 perimenopausal and premenopausal women where a BMI-hypertension OR was estimated to be 1.07 (95% CI: 1.06, 1.09). Since we also performed longitudinal analyses looking at incidence, we can postulate that the BMI-hypertension association observed in our sample is most likely causal.



1998 **2002**

Figure2. Distribution of BMI and blood pressure measurements, 1998 and 2002 surveys

Using hypertension definition 1, it appears that hypertension prevalence significantly decreased from 1998 to 2002. However, the opposite was true when hypertension definition 2 was used. Looking at the differences in prevalence by definition (within same survey year), more than 10 percent of 1998 measurements and about 3 percent of 2002 measurements were exactly 140 mmHg for SBP or 90 mmHg for DBP. Average BMI in 1998 was slightly lower than in 2002. Comparing the two longitudinal samples formed by the different definitions, there were no significant differences in the incidence rate of hypertension, as well as in the average BMI, BMI change, age and exposure time (length in months between the surveys) of these women (Table 2).

Multivariate regression analyses showed that BMI was associated with having hypertension among adult women in Cebu, Philippines. Each kg/m^2 increase in BMI was associated with about 12 percent increase in both prevalence odds and incidence odds ($p<0.05$) of having hypertension. The estimated associations were precise with relatively narrow 95% confidence intervals (CI) and remained fairly consistent regardless of the hypertension definition used, with none of the estimated differences reaching 10 percent (Table 3). Incidence rate ratio (IR) using the survey interval width as person-time exposed also showed similar association (IR 1.10, 95% CI 1.06, 1.14 for definition 1 and IR 1.08, 95% CI 1.01, 1.11 for definition 2). Adjusting for more covariates (i.e. urban-rural residence, fat and total energy intake, education) did not result to substantial change in these estimates. No significant multiplicative interactions between and among the exposure variables and covariates were observed.

Although only about 60 percent of the original sample remained in the surveys, selectivity analysis using Heckman two-step model revealed no significant selection bias in the longitudinal data. The inverse mills ratio generated by the model was not significant ($p=0.18$). Figure 3 supported this conclusion. The predicted probabilities estimated by the logistic regression model used to estimate the odds ratios closely approximated the predicted probabilities estimated by the Heckman model .

Table 2. Profile of the respondents

	Survey Year		
	1998	2002	p-value[a]
% hypertensive definition 1 (SE)	19.77 (0.91)	17.18 (0.83)	0.000
% hypertensive definition 2 (SE)	9.03 (0.65)	14.08 (0.77)	0.000
Mean BMI (SE)	23.60 (0.09)	24.23 (0.09)	0.000
Mean age (SE)	42.22 (0.14)	45.38 (0.14)	
Longitudinal sample	**Longitudinal sample 1**	**Longitudinal sample 2**	**p-value[b]**
% hypertensive (SE)	8.61 (0.73)	8.79 (0.69)	0.861
Mean 1998 BMI (SE)	23.23 (0.10)	23.39 (0.10)	0.277
Mean BMI change (SE)	0.82 (0.04)	0.78 (0.04)	0.536
Mean 1998 age (SE)	41.71 (0.16)	41.95 (0.15)	0.258
Mean exposure[c]	37.52 (0.19)	37.39 (0.18)	0.598

[a] T-test p-value comparing 1998 cross-sectional sample with 2002 cross-sectional sample.
[b] T-test p-value comparing longitudinal sample formed by definition 1 (SBP ≥140mmHg or DBP ≥90mmHg) versus longitudinal sample formed by definition 2 (SBP > 140mmHg or DBP > 90mmHg).

Table 3. Estimated effect of BMI and/or BMI change on hypertension: Odds ratios (95% confidence interval)

	Hypertension definition		
	≥140/90	> 140/90	% difference
Cross-sectional sample[a]			
BMI 1998	1.12 (1.09, 1.15)	1.13 (1.09, 1.18)	1.08
BMI 2002	1.12 (1.09, 1.15)	1.10 (1.05, 1.09)	1.86
Longitudinal sample[b]			
BMI 1998	1.12 (1.07, 1.17)	1.09 (1.04, 1.13)	3.04
BMI change	1.10 (0.98, 1.22)	1.02 (0.92, 1.12)	7.63
Without BMI change[b]			
BMI 1998	1.12 (1.07, 1.17)	1.09 (1.04, 1.13)	2.69

[a] Adjusted for age and household income quartile for corresponding year.
[b] Adjusted for 1998 age and 1998 household income quartile.

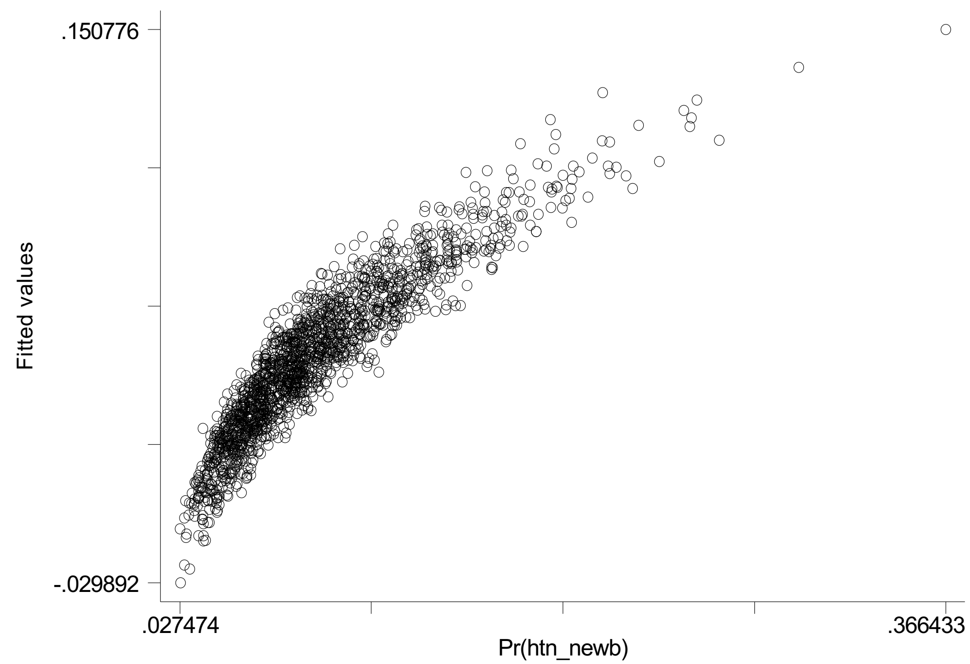


Figure 3. Predicted probabilities of having hypertension estimated using Heckman model (fitted values) versus the predicted probabilities estimated using logistic regression model