Association between body mass index and blood pressure levels across socio-demographic groups and geographical settings: analysis of pooled data in Peru

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Background: Understanding the relationship between BMI and blood pressure requires assessing whether this association is similar or differs across population groups. This study aimed to assess the association between body mass index (BMI) and blood pressure levels, and how these associations vary between socioeconomic groups and geographical settings. **Methods**: Data from the National Demographic Health Survey of Peru from 2014 to 2019 was analyzed considering the complex survey design. The outcomes were levels of systolic (SBP) and diastolic blood pressure (DBP), and the exposure was BMI. Exposure and outcomes were fitted as continuous variables in a non-linear quadratic regression model. We explored effect modification by six socioeconomic and geographical variables (sex, age, education level, socioeconomic position, study area, and altitude), fitting an interaction term between each of these variables and BMI. **Results:** Data from 159,940 subjects, mean age 44.4 (SD: 17.1), 54.6% females, was analyzed. A third (34.0%) of individuals had ≥12 years of education, 24.7% were from rural areas, and 23.7% lived in areas located over 2500 meters above sea level. In the overall sample mean BMI was 27.1 (SD: 4.6) kg/m^2, and mean SBP and DBP were 122.5 (SD: 17.2) and 72.3 (SD: 9.8) mmHg, respectively. In the multivariable models, greater BMI levels were associated with higher SBP (p-value <0.001) and DBP (p-value <0.001). There was strong evidence that sex, age, education level, and altitude were effect modifiers of the association between BMI and both SBP and DBP. In addition to these socio-demographic variables, socioeconomic position and study area were also effect modifiers of the association between BMI and DBP, but not SBP. **Conclusions**: The association between BMI and levels of blood pressure is not uniform on a range of socio-demographic and geographical population groups. This characterization can inform the understanding of the epidemiology and rise of blood

pressure in a diversity of low-resource settings.

1   **Association between body mass index and blood pressure levels across socio-demographic**

2   **groups and geographical settings: analysis of pooled data in Peru**

3

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18

Abstract

Background:

Understanding the relationship between BMI and blood pressure requires assessing whether this association is similar or differs across population groups. This study aimed to assess the association between body mass index (BMI) and blood pressure levels, and how these associations vary between socioeconomic groups and geographical settings.

Methods:

Data from the National Demographic Health Survey of Peru from 2014 to 2019 was analyzed considering the complex survey design. The outcomes were levels of systolic (SBP) and diastolic blood pressure (DBP), and the exposure was BMI. Exposure and outcomes were fitted as continuous variables in a non-linear quadratic regression model. We explored effect modification by six socioeconomic and geographical variables (sex, age, education level, socioeconomic position, study area, and altitude), fitting an interaction term between each of these variables and BMI.

Results:

Data from 159,940 subjects, mean age 44.4 (SD: 17.1), 54.6% females, was analyzed. A third (34.0%) of individuals had ≥12 years of education, 24.7% were from rural areas, and 23.7% lived in areas located over 2500 meters above sea level. In the overall sample mean BMI was 27.1 (SD: 4.6) kg/m^2, and mean SBP and DBP were 122.5 (SD: 17.2) and 72.3 (SD: 9.8) mmHg, respectively. In the multivariable models, greater BMI levels were associated with higher SBP (p-value <0.001) and DBP (p-value <0.001). There was strong evidence that sex, age, education level, and altitude were effect modifiers of the association between BMI and both SBP and DBP. In addition to these socio-demographic variables, socioeconomic position and study area were also effect modifiers of the association between BMI and DBP, but not SBP.

Conclusions:

44   The association between BMI and levels of blood pressure is not uniform on a range of socio-
45   demographic and geographical population groups. This characterization can inform the
46   understanding of the epidemiology and rise of blood pressure in a diversity of low-resource
47   settings.

48

49   **Key words:** blood pressure; body mass index; hypertension; obesity

Introduction

Globally, the number of adults living with raised blood pressure has increased from 594 million in 1975 to 1.13 billion in 2015 [1]; and this condition is responsible for 9.4 million deaths worldwide [2], disproportionally affecting low- and middle-income countries. On the other hand, the alarming increase of body mass index (BMI) during the last decades [3], accompanied by the increase in the prevalence of overweight and obesity, will most likely pair the raise in blood pressure levels.

In Latin America, despite the high prevalence of cardiometabolic risk factors [4], their distribution is not homogenous between countries introducing additional particularities in shaping prevention and control strategies for raised blood pressure across settings. The increases in the levels of blood pressure and BMI are two ongoing global phenomena observed in recent decades, and understanding the patterning of its linkages is required to better counter them. This is of utmost importance as raises in BMI have been predominantly driven by increases in rural areas [5].

BMI has been positively associated with both systolic (SBP) and diastolic (DBP) blood pressure [6, 7]. Although previous studies have described this association, many of these reports arise from high-income countries [8-10], and from Asia and Africa [7, 11], with limited representation from Latin American settings.

Understanding the relationship between BMI and blood pressure requires assessing whether this association is similar or differs across population groups. Peru, a middle-income country located in South America, is a region with pronounced socioeconomic disparities paired with a unique geographical diversity with populations living across a range of low and high-altitude, and rural and urban areas, which can influence how the BMI is associated with blood pressure levels. Therefore, we aimed to assess the association between BMI and both SBP and DBP, and determine whether this association varies between different subgroups of the population.

Methods

Study design and population

Data from Peru's National Demographic Health Survey (ENDES, Spanish acronym) from 2014 to 2019 was utilized in this analysis. The ENDES is a nationally representative population-based survey conducted annually. Since 2014, the ENDES has also included a health questionnaire and blood pressure measurements, on a yearly basis.

The ENDES sampling followed a bietapic approach. In rural areas, the primary sampling units were clusters of 500 to 2000 individuals and the secondary sampling units were the households within each of these clusters. In urban areas, the sampling units were blocks or groups of blocks with more than 2000 individuals and an average of 140 households; the secondary sampling units were also households as in rural settings. Details about the sampling process are described in detail elsewhere [12]. For this analysis we included data from participants aged 20 years and above with complete BMI and blood pressure measurements.

Variables definition

Outcomes:

The outcomes were both SBP and DBP. To guarantee that only plausible measurements were included in analyses, a cut point was used as in previous studies [1]: SBP measurements should be ≥ 70 and ≤ 270 mmHg, whereas DBP measurements should be ≥ 50 and ≤ 150 mmHg. The no-plausible values were dropped from analyses.

Blood pressure was measured using a digital monitor (OMRON, model HEM-713), validated for adult populations [13]. Two types of cuffs were used depending on the arm circumference of participants: standard arm (220 to 320 mm) and thicker arm (330 to 430 mm). Blood pressure measurements were assessed twice with the participant sitting and their right arm resting on a flat surface at the heart level. The first measurement was taken after a resting period of at least five minutes, and the second measurement was taken two minutes thereafter [14]. The average of the two assessments was used in the analysis only if the difference between both measurements did not exceed 10 mmHg. Those exceeding that threshold were dropped from further analyses.

Exposure:

105   BMI (kg/m^2), as a continuous variable, was defined as weight (Kg) divided by height squared

106   (m^2). Participants' weight and height were measured following standard procedures [14], with

107   the subject without shoes. To guarantee that only plausible BMI measurements were included in

108   analyses, a cut point was used as in previous studies [7]: BMI $\geq$10 kg/m^2 and <60 kg/m^2.

109   **Effect modifiers:**

110   A set of socio-demographic and geographical variables were also included as confounders and

111   potential effect modifiers of the association of interest. We included sex (female vs. male); age

112   (as continuous variable, but also categorized as <40, 40-59, and $\geq$60 years); education level (in

113   years, <7, 7-11, and $\geq$12 years), and socioeconomic position (defined in tertiles based on a

114   wealth index). This wealth index was calculated by the National Institute of Statistics and

115   Informatics (INEI, Spanish acronym) based on assets and services that the participant reported

116   having in the household [15]. As geographical variables we considered area (rural vs. urban) and

117   altitude ($\leq$500, 501-2500, and $\geq$2501 meters above the sea level [m.a.s.l.]).

118   **Other variables:**

119   For description of the participants characteristics in our study sample, we also provide

120   information on hypertension, overweight and obesity. The ENDES collected self-reported

121   information about whether the participant had a previous diagnosis of hypertension and if

122   participants were receiving any anti-hypertensive medication. Therefore, hypertension was also

123   defined as SBP $\geq$140 mmHg or DBP $\geq$90 mmHg, or was diagnosed with hypertension [16].

124   Standard BMI thresholds were used to estimate prevalence of overweight and obesity: BMI $\geq$25

125   and <30 kg/m^2 for overweight, and BMI $\geq$30 kg/m^2 for obesity, whereas BMI <25 kg/m^2 was

126   classified as normal.

127   **Statistical methods**

128   Analyses were performed using STATA 13 for Windows (StataCorp, College Station, TX, US).

129   Descriptive statistics and estimates were calculated considering the complex survey design using

130   sample strata, primary sampling units and sampling weights, including the analysis of

131   subpopulation groups [17]. Initially, description of continuous variables was conducted using

132   mean and standard deviation (SD), whereas for categorical variables we used absolute and

133   relative frequencies. Prevalence of hypertension, overweight, and obesity, and their respective

134   95% confidence intervals (95% CI), were also estimated. Comparison between females and

135   males was performed using Chi-squared test and t-test, for categorical and numeric variables,

136   respectively.

137   To assess the association between BMI and blood pressure, a non-linear regression model (more

138   details are provided in the **S1 File**) was built as suggested in literature [18]. An adjusted model

139   was also created including coefficients for categorical variables (i.e. sex, education level,

140   socioeconomic position, study area and altitude), whereas age was included as continuous

141   variable by other studies [1, 3, 4].

142   To explore effect modification, i.e. to evaluate whether the association between BMI and levels

143   of blood pressure vary by specific population groups, i.e. by socio-demographic and

144   geographical variables, an interaction term between each socio-demographic variable and BMI

145   (and its quadratic term) was included (see **S1 File**). When conducting multivariable model

146   stratified by subgroups, we excluded the variable defining that subgroup from the list of potential

147   confounders. Marginal means of blood pressure levels for specified fixed values of socio-

148   demographic variables were calculated from each fitted model and presented as figures (and also

149   tables) to verify variation of the association of interest [19, 20]. Values of BMI higher than 50

150   kg/m^2 were truncated to avoid the impact of few values on results (<0.1% of subjects had values

151   of BMI >50 kg/m^2).

152   Finally, sub-analyses were also conducted to assess the association of interest (overall and by

153   sub-population group) by excluding individuals who reported taking anti-hypertensive

154   medication as this can bias results.

155   **Ethics**

156   The data used in our study is anonymous and freely available to the general public and does not

157   reveal any personal identifiable information, and consequently this study does not represent an

158   ethical risk for participants. The INEI, a Peruvian government organization, is responsible for the

159   annual collection of ENDES data. This institution requested the consent of participants before

160   the survey.

161

162

163 Results

164 Characteristics of the study population

165 Data from a total of 203,880 individuals was available for the analysis utilizing ENDES annual
166 evaluations over the study period. Of them, information from 2,734 (1.3%) pregnant women;
167 15,519 (7.6%) without blood pressure; 3,007 (1.5%) without BMI results, and 34 (<0.1%) with
168 BMI $\geq$60 kg/m^2 were excluded from our analysis. Thus, a total of 159,940 subjects, mean age
169 44.4 (SD: 17.1), 54.6% females, were analyzed. Of note, only a third (34.0%) of individuals had
170 $\geq$12 years of education, 24.7% were from rural areas, and 23.7% lived in areas located over 2500
171 m.a.s.l.

172 Mean BMI was 27.1 (SD: 4.6) kg/m^2 in the overall sample. The prevalence of overweight was
173 41.6% (95% CI: 41.2% - 42.0%), and the prevalence of obesity was 23.5% (95% CI: 23.1% -
174 23.9%). Similarly, mean SBP and DBP were 122.5 (SD: 17.2) and 72.3 (SD: 9.8) mmHg,
175 respectively, whilst the prevalence of hypertension was 21.2% (20.8% - 21.6%).

176 When comparing socio-demographic characteristics by sex, males had higher number of years of
177 education and greater blood pressure levels and hypertension rates compared to females.
178 Conversely, females had higher body mass index and greater obesity rates (**Table 1**).

179 Association between body mass index and blood pressure levels

180 Greater BMI levels were associated with increasing SBP (p-value <0.001) and DBP (p-value
181 <0.001) values in multivariable models (**Fig 1**).

182 The increase of SBP per unit BMI varied from 0.05 to 1.8 mmHg/(kg/m^2), whereas the increase
183 of DBP ranged from 0.09 to 1.13 mmHg/(kg/m^2). Estimates for specific BMI cut points are
184 shown in **Table 2 and Table 3** (by sex), where the highest values of both, SBP and DBP, were
185 reached at BMI of 45 kg/m^2.

186 The association between BMI and SBP differed by different socio-demographic variables (**Fig
187 2**), it was stronger among males (p-value for interaction term <0.001), among older individuals
188 (p-value for interaction term <0.001), those less educated (p-value for interaction term = 0.001),
189 and among those living under 500 meters above sea level (p-value for interaction term = 0.005).
190 On the other hand, all the socio-demographic and geographical variables studied were effect

191   modifiers of the association between BMI and DBP (**Fig 3**): it was stronger among males (p-

192   value for interaction terms <0.001), among older individuals (p-value for interaction term

193   <0.001), better educated (p-value for interaction terms <0.001), those with low socioeconomic

194   position (p-value for interaction terms <0.001), those in urban areas (p-value for interaction

195   terms <0.001), and among those living at high altitude (p-value for interaction terms <0.001).

196   When the analyses were conducted excluding subjects taking anti-hypertensive medication,

197   results and figures were similar to those shown as main results as only about a third (30.4%) of

198   participants with hypertension reported taking antihypertensive pharmacological medication

199   (Details in **S1 to S5 Tables**).

200

Discussion

201

202 Using nationally representative data from Peru, accrued over five years in approximately
203 160,000 subjects, we advance the evidence reported on the association between BMI and blood
204 pressure by exploring the effect of relevant socio-economic health determinants, namely sex,
205 age, education level, socioeconomic position, study area, and altitude, much needed for adequate
206 resource allocation. Whilst the effect modification in the relationship between BMI and DBP was
207 present in all of these subgroups, socioeconomic position and study area were not effect
208 modifiers in the association between BMI and SBP.

209 The global rise of levels of BMI and blood pressure calls for paying attention at particular
210 groups; hence, our results disaggregated by socio-demographic groups show clear patterns of
211 association between SBP and DBP when BMI increases. These results, for countries in
212 transition, can inform tailored prevention and control strategies to counter the rise in levels of
213 blood pressure and BMI, focusing on specific groups to yield higher prevention gains and further
214 population-wide benefits. It is notorious the role of sex, but the peculiarities of area, including
215 living in high altitude areas, as well as education, may be also important. Interventions or
216 treatment allocation to improve BMI and blood pressure may not need different approaches by
217 different socio-demographic variables, but could benefit of gender-based tailoring to maximize
218 its impact.

219 Globally, mean blood pressure levels are higher in African countries, and Peru ranks among the
220 countries with lowest mean blood pressure in the world [1, 4]. Much of the literature on the
221 relationship between BMI and blood pressure arises from Asia and some parts of Africa [8, 11].
222 Importantly, a nationwide study of 1.7 million Chinese adults explored similar relationships
223 between BMI and blood pressure across a diversity of groups [7], with some notorious
224 observations contrasting our findings. Compared to our Peruvian sample, Chinese individuals
225 had approximately 2.5 kg/m^2 units lower than Peruvians (24.7 vs. 27.1 kg/m^2), yet their SBP was
226 14 mmHg higher (136.5 vs. 122.4 mmHg), and DBP was 9 mmHg higher (81.1 vs. 72.2 mmHg).
227 While both studies confirm a relationship between BMI and blood pressure across a range of
228 groups, the trajectories of SBP values in Peruvians range between 100 and 140 mmHg in all the
229 groups studied (**Fig 2**), whereas Chinese SBP values reach up to 150 mmHg and 160 mmHg in
230 some cases [7]. In Latin America, one previous study from Brazil, focused on a single state,

231   analyzed the association between two anthropometric indexes, waist circumference and BMI,

232   and hypertension and found both indexes associated with hypertension, but showed a low

233   sensitivity as predictors [21].

234   Our observations, benefiting from nationwide representative data, are useful not only in

235   describing the patterns of the relationships between BMI and blood pressure, but also in

236   adequately informing policies. Such tailored policies are needed as premature non-avertable

237   mortality from non-communicable diseases decreased slightly or stagnated in most regions, and

238   rose in the region of the Americas [22]. Therefore, characterizing the patterns of the BMI-blood

239   pressure relationship are crucial in the Latin American region, particularly given the high level of

240   heterogeneity in the transition of major cardiovascular risk factors in the region [4].

241   Peru is a middle-income country located in South America, with a fragile and fragmented health

242   care system, with poor response to the challenges of chronic conditions, and for instance, may

243   not be prepared to tackle the burden of increasing BMI and blood pressure levels [23]. A recent

244   manuscript demonstrated an increasing age-standardized prevalence of hypertension in the last

245   years in Peru, whereas the rates of disease awareness and controlled hypertension have declined

246   [24]. Our results demonstrated slightly change in blood pressure estimates in the overall sample

247   and when excluding those with anti-hypertensive medication pointed out the low rates of

248   appropriate treatment and control [25]. Thus, a thoroughly planned and balanced policy would be

249   needed to provide care to those who most needed, including appropriate hypertension diagnosis

250   and treatment.

251   This study benefits from data derived from a nationally representative survey of adult population,

252   with objective measurements, and a robust modeling approach that goes beyond linear

253   associations. In addition, our study expands to disentangle relationships across a diversity of

254   socioeconomic and geographical population groups, much needed to characterize the

255   epidemiology of BMI and blood pressure, and to inform policies. Despite this, we are aware of

256   certain limitations including the cross-sectional nature of the data, together with potential for

257   reverse causality. Given that both, obesity and high blood pressure are established global public

258   health priorities, both require urgent action to prevent their associated complications. Also, the

259   graphical nature of the BMI-blood pressure trajectories should be interpreted with caution as

260   comparisons of levels of blood pressure across BMI groups are not necessarily correct, but rather

261 the result of calculations of blood pressure values given a value of BMI. Whilst we cannot
262 ascertain that a give group has a number of blood pressure units, higher or lower, than other
263 group, the trajectories are useful in identifying potential groups to target action, e.g. males
264 compared to females.

265

Conclusions

267 In conclusion, greater BMI is associated with higher blood pressure levels in Peru, but this
268 association is not uniform across a range of socio-demographic and geographical population
269 groups. These results may contribute to prevention and control strategies to counter the rise in
270 levels of blood pressure and BMI, focusing on specific groups to yield higher prevention gains
271 and further population-wide benefits.

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Acknowledgments

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References

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279   1.   NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in blood pressure from
280   1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19·1
281   million participants. *Lancet* 2017;389(10064):37-55.
282   2.   Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative
283   risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor
284   clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease
285   Study 2010. *Lancet* 2012;380(9859):2224-60.
286   3.   NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index,
287   underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416
288   population-based measurement studies in 128·9 million children, adolescents, and adults.
289   *Lancet* 2017;390(10113):2627-42.
290   4.   NCD Risk Factor Collaboration (NCD-RisC) - Americas Working Group. Trends in
291   cardiometabolic risk factors in the Americas between 1980 and 2014: a pooled analysis of
292   population-based surveys. *Lancet Glob Health* 2020;8(1):e123-e33.
293   5.   NCD Risk Factor Collaboration (NCD-RisC). Rising rural body-mass index is the main
294   driver of the global obesity epidemic in adults. *Nature* 2019;569(7755):260-4.
295   6.   Drøyvold WB, Midthjell K, Nilsen TI, Holmen J. Change in body mass index and its impact
296   on blood pressure: a prospective population study. *Int J Obes (Lond)* 2005;29(6):650-5.
297   7.   Linderman GC, Lu J, Lu Y, Sun X, Xu W, Nasir K, et al. Association of Body Mass Index
298   With Blood Pressure Among 1.7 Million Chinese Adults. *JAMA Netw Open*
299   2018;1(4):e181271.
300   8.   Danon-Hersch N, Chiolero A, Shamlaye C, Paccaud F, Bovet P. Decreasing association
301   between body mass index and blood pressure over time. *Epidemiology* 2007;18(4):493-500.
302   9.   Gelber RP, Gaziano JM, Manson JE, Buring JE, Sesso HD. A prospective study of body
303   mass index and the risk of developing hypertension in men. *Am J Hypertens*
304   2007;20(4):370-7.
305   10.   Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor
306   for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart
307   Study. *Circulation* 1983;67(5):968-77.

308   11. Tesfaye F, Nawi NG, Van Minh H, Byass P, Berhane Y, Bonita R, et al. Association
309   between body mass index and blood pressure across three populations in Africa and Asia. *J*
310   *Hum Hypertens* 2007;21(1):28-37.
311   12. Instituto Nacional de Estadistica e Informatica. *Peru: Encuesta Demografica y de Salud*
312   *Familiar ENDES 2014*. Lima, Peru: INEI; 2015.
313   13. Takahashi H, Yoshika M, Yokoi T. Validation of three automatic devices for the self-
314   measurement of blood pressure according to the European Society of Hypertension
315   International Protocol revision 2010: the Omron HEM-7130, HEM-7320F, and HEM-
316   7500F. *Blood Press Monit* 2015;20(2):92-7.
317   14. Instituto Nacional de Estadistica e Informatica. *Manual de la entrevistadora - Encuesta*
318   *demográfica y de salud familiar*. Lima, Peru: INEI; 2018.
319   15. Rutstein SO, Johnson K. *The DHS wealth index. DHS comparative reports no. 6*. Calverton,
320   Maryland: ORC Macro; 2004.
321   16. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, Jr., et al. The
322   Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and
323   Treatment of High Blood Pressure: the JNC 7 report. *Jama* 2003;289(19):2560-72.
324   17. West BT, Berglund P, Heeringa SG. A closer examination of subpopulation analysis of
325   complex-sample survey data. *Stata J* 2008;8(4):520-31.
326   18. Kerry SM, Micah FB, Plange-Rhule J, Eastwood JB, Cappuccio FP. Blood pressure and
327   body mass index in lean rural and semi-urban subjects in West Africa. *J Hypertens*
328   2005;23(9):1645-51.
329   19. Graubard BI, Korn EL. Predictive margins with survey data. *Biometrics* 1999;55(2):652-9.
330   20. Williams R. Using the margins command to estimate and interpret adjusted predictions and
331   marginal effects. *Stata J* 2012;12(2):308-31.
332   21. Peixoto Mdo R, Benício MH, Latorre Mdo R, Jardim PC. Waist circumference and body
333   mass index as predictors of hypertension. *Arq Bras Cardiol* 2006;87(4):462-70.
334   22. Martinez R, Lloyd-Sherlock P, Soliz P, Ebrahim S, Vega E, Ordunez P, et al. Trends in
335   premature avertable mortality from non-communicable diseases for 195 countries and
336   territories, 1990-2017: a population-based study. *Lancet Glob Health* 2020;8(4):e511-e23.

337   23. Loret de Mola C, Quispe R, Valle GA, Poterico JA. Nutritional transition in children under
338   five years and women of reproductive age: a 15-years trend analysis in Peru. *PLoS One*
339   2014;9(3):e92550.
340   24. Villarreal-Zegarra D, Carrillo-Larco RM, Bernabe-Ortiz A. Short-term trends in the
341   prevalence, awareness, treatment, and control of arterial hypertension in Peru. *J Hum*
342   *Hypertens* 2020;doi.org/10.1038/s41371-020-0361-1.
343   25. Zavala-Loayza JA, Benziger CP, Cárdenas MK, Carrillo-Larco RM, Bernabé-Ortiz A,
344   Gilman RH, et al. Characteristics Associated With Antihypertensive Treatment and Blood
345   Pressure Control: A Population-Based Follow-Up Study in Peru. *Glob Heart*
346   2016;11(1):109-19.
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349   **Figures legend**

350   **Figure 1:** Body mass index and systolic and diastolic blood pressure

351   **Figure 2:** Association between body mass index and systolic blood pressure according to socio-
352   demographic variables

353   **Figure 3:** Association between body mass index and diastolic blood pressure according to socio-
354   demographic variables

355

356

357   **Supporting information**

358   **S1 File.** Statistical approach: Modeling the association between body mass index and blood
359   pressure levels.

360   **S1 Table.** Estimation of blood pressure levels according to body mass index (BMI) by age
361   group.

362   **S2 Table.** Estimation of blood pressure levels according to body mass index (BMI) by education
363   level (in years).

364   **S3 Table.** Estimation of blood pressure levels according to body mass index (BMI) by
365   socioeconomic position.

366   **S4 Table.** Estimation of blood pressure levels according to body mass index (BMI) by study
367   area.

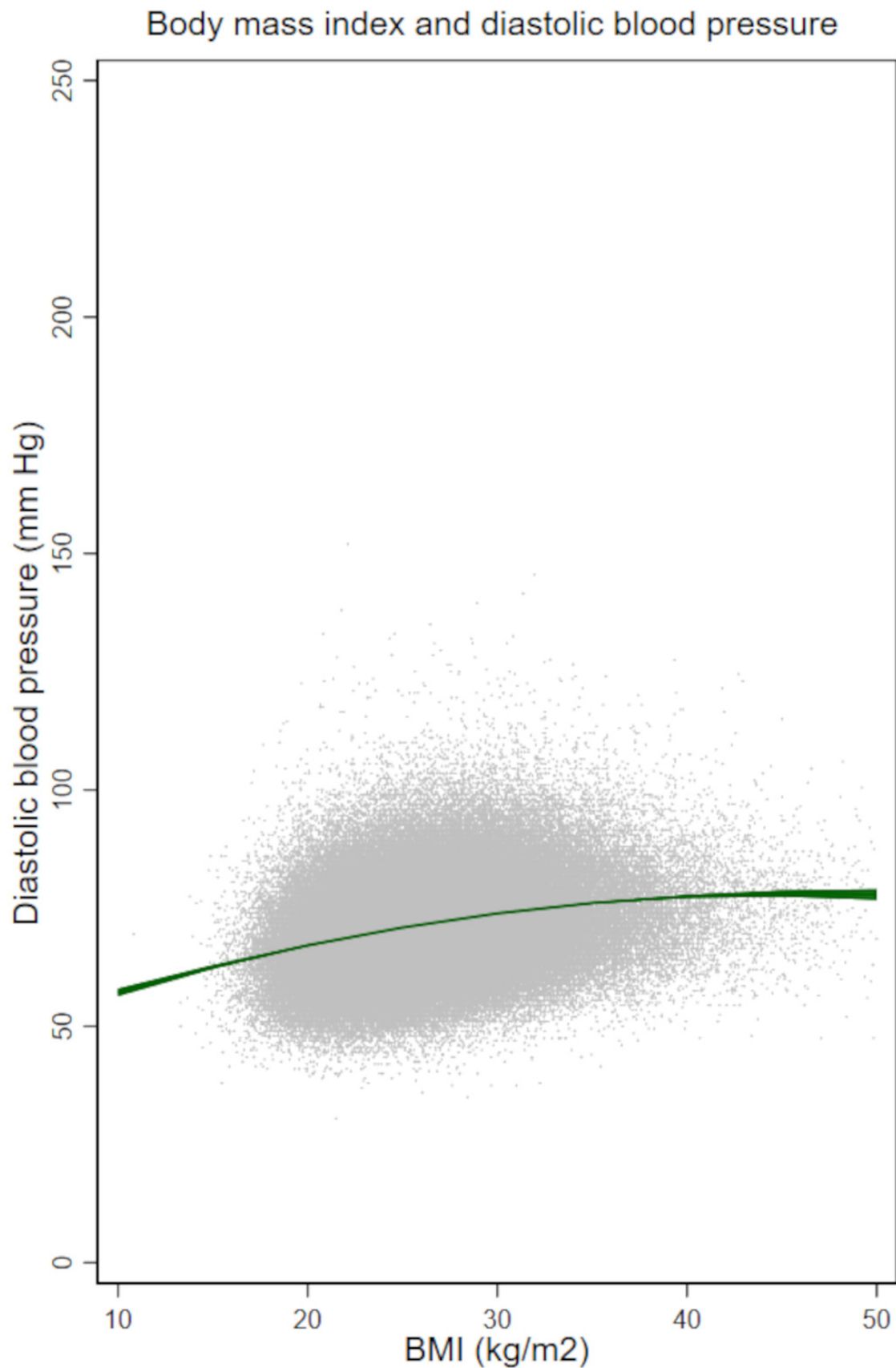368   **S5 Table.** Estimation of blood pressure levels according to body mass index (BMI) by altitude.

369

Figure 1

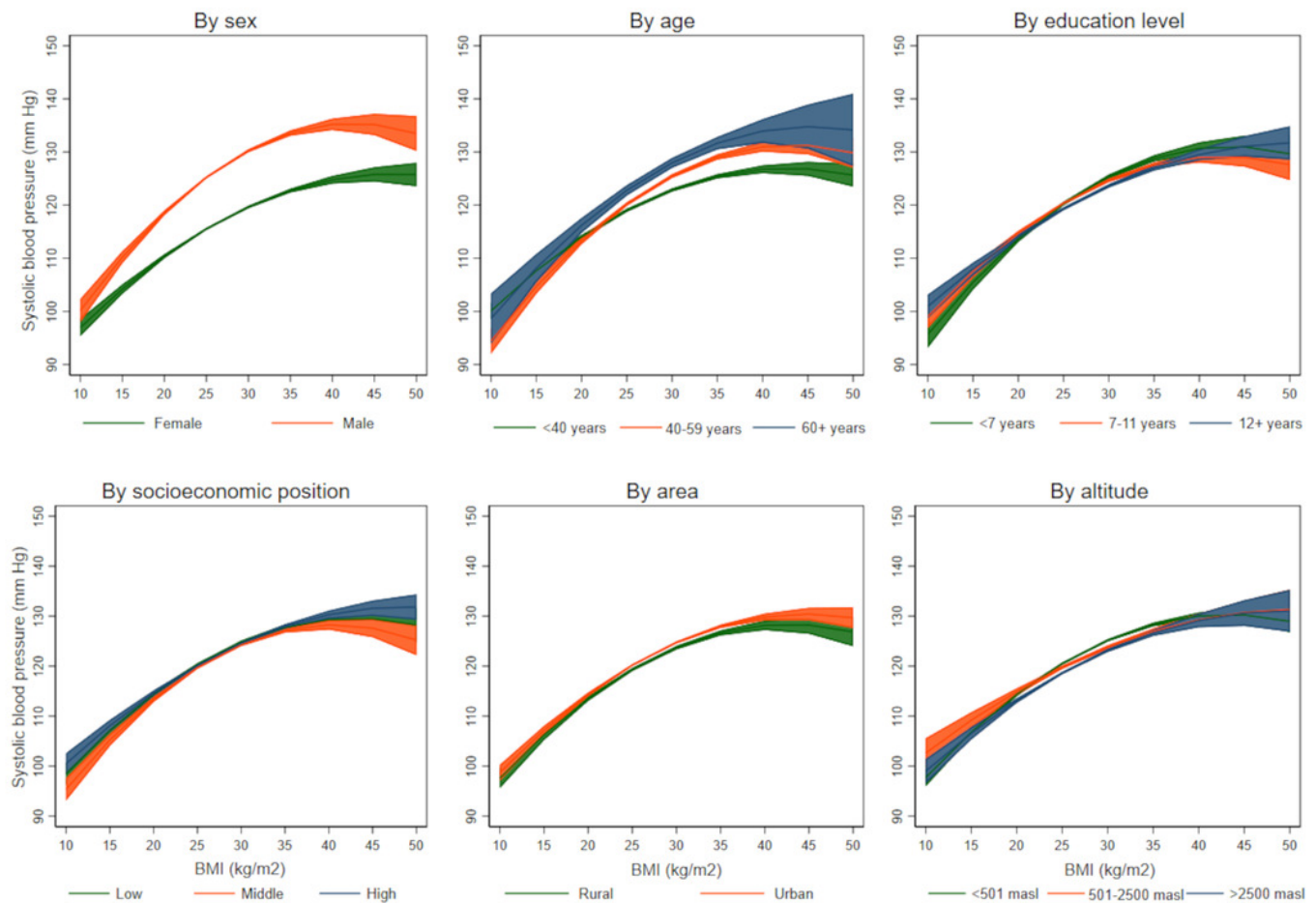Body mass index and systolic and diastolic blood pressure

Body mass index and systolic blood pressure
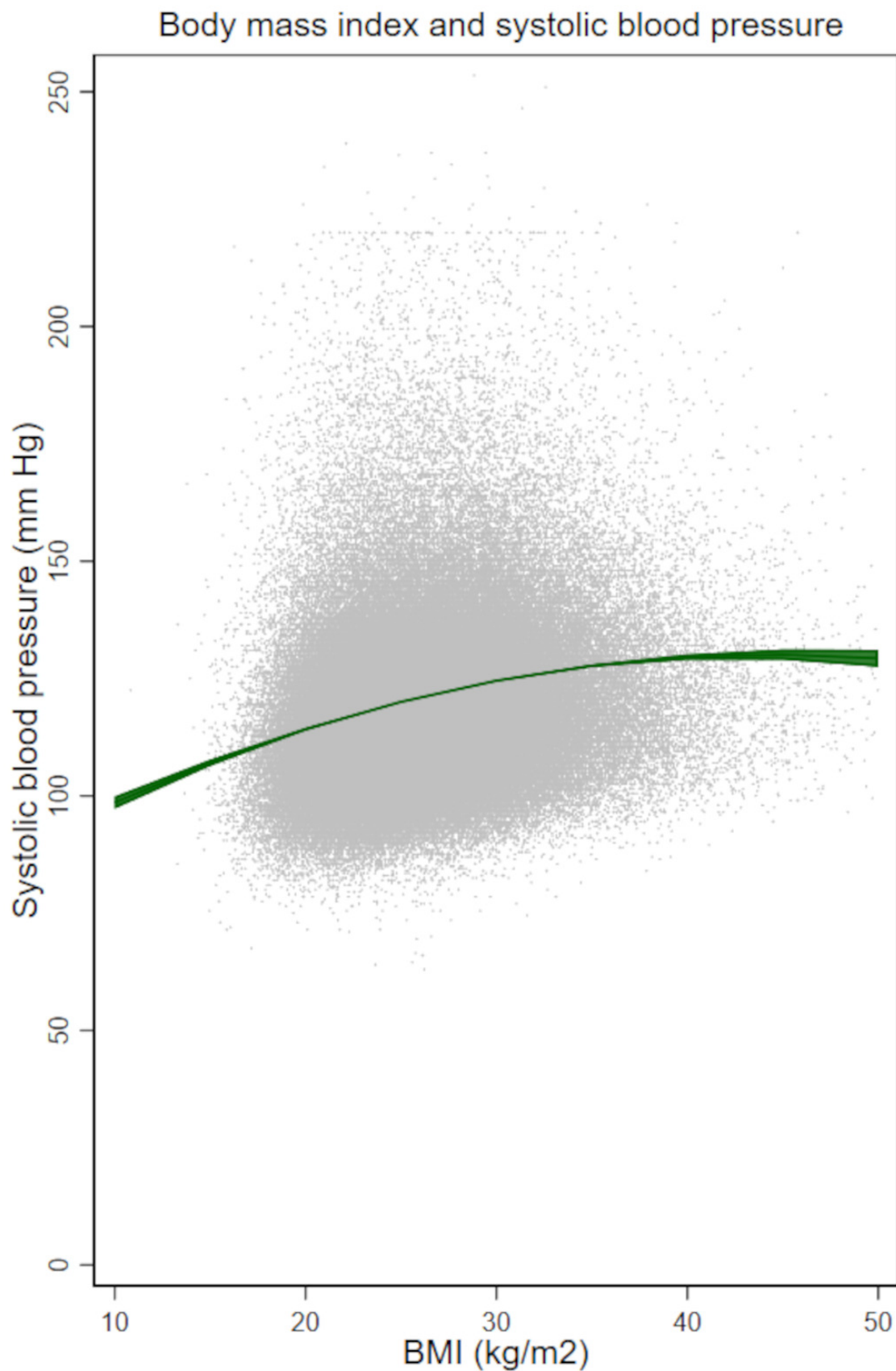
Figure 2

Body mass index and systolic and diastolic blood pressure

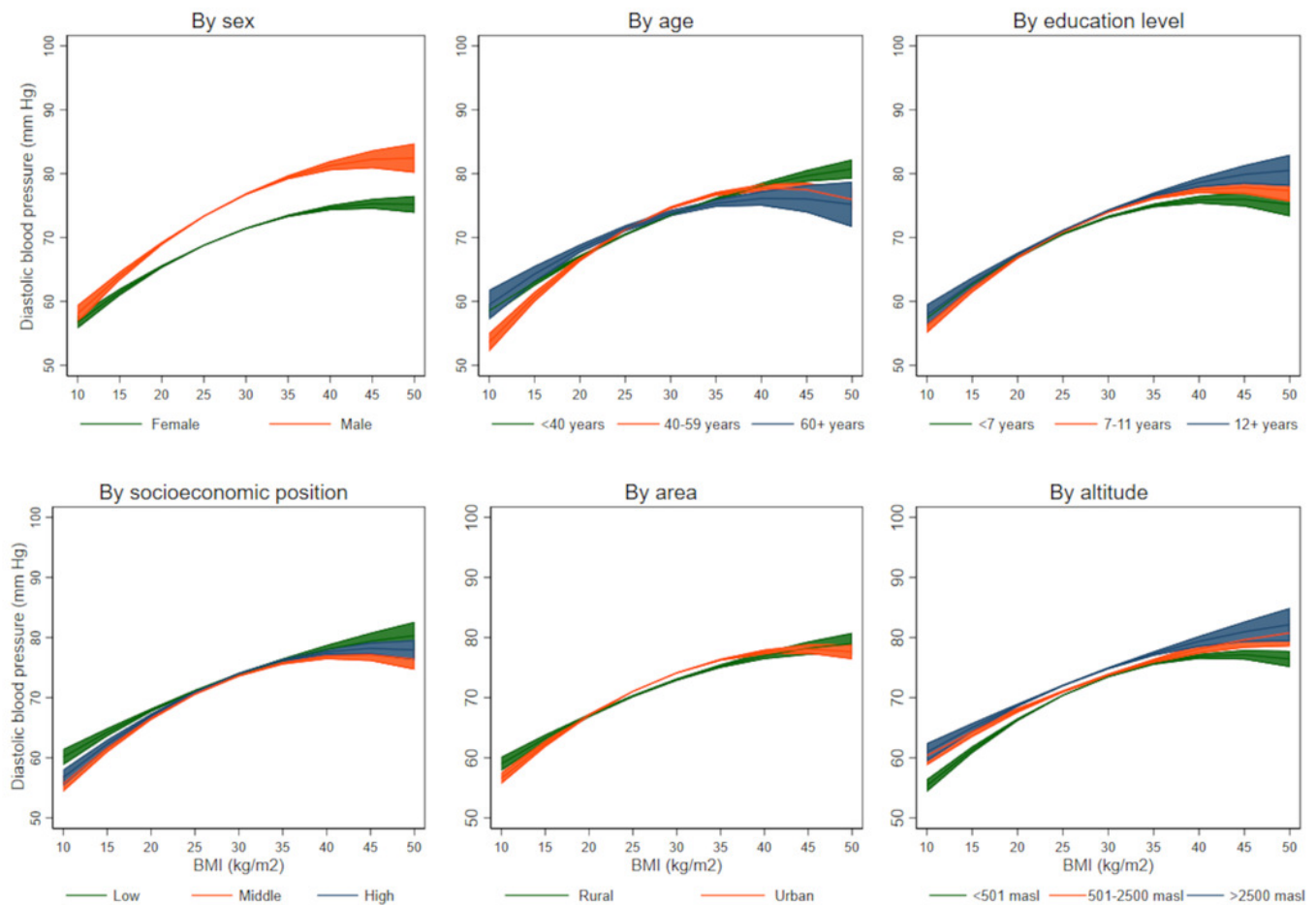Body mass index and diastolic blood pressure

Figure 3

Association between body mass index and systolic blood pressure according to socio-demographic variables

Figure 4

Association between body mass index and diastolic blood pressure according to socio-demographic variables

Table 1(on next page)

Description of the study population by sex comparison considering complex sampling design

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2 **Table 1: Description of the study population by sex comparison considering complex**

3 **sampling design**

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	Females (n = 89,376)	Males (n = 70,538)	p-value
Age			
Mean (SD)	44.3 (16.9)	44.4 (17.2)	0.51
Age (categories)			
<40 years	51,232 (46.5%)	36,727 (45.8%)	0.31
40 – 59 years	24,553 (33.1%)	22,188 (33.5%)	
≥60 years	13,591 (20.4%)	11,623 (20.7%)	
Education level			
<7 years	27,034 (30.4%)	18,093 (23.4%)	<0.001
7 – 11 years	32,046 (36.5%)	30,114 (41.6%)	
≥12 years	24,479 (33.1%)	20,970 (35.0%)	
Socioeconomic position (assets)			
Low	29,107 (23.6%)	24,070 (24.6%)	0.002
Middle	30,201 (30.1%)	23,557 (30.3%)	
High	30,068 (46.3%)	22,911 (45.1%)	
Study area			
Rural	30,142 (24.1%)	25,632 (25.4%)	<0.001
Urban	59,234 (75.9%)	44,906 (74.6%)	
Altitude			
≤500 m.a.s.l.	43,316 (59.9%)	34,757 (61.6%)	<0.001
501 – 2500 m.a.s.l.	17,850 (15.4%)	14,805 (16.0%)	
≥2501 m.a.s.l	28,210 (24.7%)	20,976 (22.4%)	
Body mass index			
Mean (SD)	27.5 (5.0)	26.6 (4.4)	<0.001
Body mass index (categories)			
Normal (<25 Kg/m^2)	30,048 (32.4%)	29,208 (38.0%)	<0.001
Overweight (25 to <30 Kg/m^2)	36,006 (40.4%)	29,276 (43.0%)	
Obese (≥30 Kg/m^2)	23,322 (27.2%)	12,054 (19.0%)	
Blood pressure levels			
Systolic blood pressure, mean (SD)	118.4 (16.7)	127.4 (15.3)	<0.001
Diastolic blood pressure, mean (SD)	70.3 (9.3)	74.7 (9.9)	<0.001
Hypertension			
Yes	13,690 (19.5%)	13,660 (23.2%)	<0.001

5 SD = Standard deviation; m.a.s.l. = meters above the sea level

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Table 2(on next page)

Estimation of blood pressure levels according to body mass index (BMI): in the total sample and excluding those with anti-hypertensive medication

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3   **Table 2:** Estimation of blood pressure levels according to body mass index (BMI): in the total

4   sample and excluding those with anti-hypertensive medication

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BMI (in Kg/m²)	In the overall sample	Only those without antihypertensive medication
	Systolic blood pressure (mm Hg)	
10	98.5 (97.2 – 99.9)	98.5 (97.2 – 99.8)
15	107.0 (106.3 – 107.7)	106.8 (106.1 – 107.5)
20	114.2 (113.9 – 114.5)	113.7 (113.4 – 114.0)
25	120.0 (119.8 – 120.2)	119.4 (119.2 – 119.6)
30	124.5 (124.3 – 124.7)	123.8 (123.6 – 124.0)
35	127.7 (127.4 – 128.0)	126.9 (126.6 – 127.1)
40	129.6 (128.9 – 130.2)	128.6 (128.0 – 129.2)
45	130.1 (129.0 – 131.2)	129.1 (128.0 – 130.2)
50	129.3 (127.4 – 131.2)	128.3 (126.5 – 130.1)
	Diastolic blood pressure (mm Hg)	
10	56.2 (56.4 – 58.0)	57.1 (56.3 – 58.0)
15	62.5 (62.1 – 63.0)	62.4 (62.0 – 62.9)
20	67.1 (66.9 – 67.3)	67.0 (66.8 – 67.1)
25	70.9 (70.8 – 71.0)	70.7 (70.6 – 70.8)
30	73.9 (73.8 – 74.0)	73.7 (73.6 – 73.8)
35	76.1 (75.9 – 76.2)	75.9 (75.7 – 76.1)
40	77.5 (77.1 – 77.8)	77.3 (76.9 – 77.7)
45	78.1 (77.4 – 78.8)	78.0 (77.2 – 78.7)
50	77.9 (76.7 – 79.0)	77.8 (76.6 – 79.0)

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Table 3(on next page)

Estimation of blood pressure levels according to body mass index (BMI) by sex

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2 **Table 3:** Estimation of blood pressure levels according to body mass index (BMI) by sex

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BMI (in Kg/m²)	Females		Males	
	In the overall sample	Only those without antihypertensive medication	In the overall sample	Only those without antihypertensive medication
Systolic blood pressure (mm Hg)				
10	97.0 (95.3 – 98.6)	97.4 (95.8 – 99.0)	100.2 (98.0 – 102.4)	99.6 (97.5 – 101.7)
15	104.2 (103.3 – 105.1)	104.0 (103.2 – 104.9)	110.2 (109.1 – 111.4)	109.8 (108.8 – 110.9)
20	110.4 (110.0 – 110.8)	109.8 (109.4 – 110.2)	118.6 (118.1 – 119.0)	118.3 (117.9 – 118.8)
25	115.5 (115.3 – 115.8)	114.6 (114.4 – 114.8)	125.2 (125.0 – 125.5)	125.0 (124.8 – 125.2)
30	119.7 (119.4 – 119.9)	118.6 (118.3 – 118.8)	130.2 (129.9 – 130.5)	129.9 (129.6 – 130.2)
35	122.7 (122.4 – 123.1)	121.6 (121.2 – 121.9)	133.6 (133.1 – 134.1)	133.1 (132.6 – 133.6)
40	124.8 (124.0 – 125.5)	123.6 (122.9 – 124.4)	135.2 (134.1 – 136.3)	134.4 (133.4 – 135.5)
45	125.8 (124.4 – 127.1)	124.8 (123.5 – 126.2)	135.2 (133.2 – 137.2)	134.1 (132.1 – 136.0)
50	125.8 (123.5 – 128.0)	125.1 (122.9 – 127.3)	133.5 (130.2 – 136.8)	131.9 (128.8 – 135.1)
Diastolic blood pressure (mm Hg)				
10	56.8 (55.7 – 57.8)	57.0 (55.9 – 58.0)	58.1 (56.7 – 59.5)	57.7 (56.3 – 59.0)
15	61.5 (60.9 – 62.0)	61.5 (60.9 – 62.0)	64.0 (63.3 – 64.7)	63.7 (63.0 – 64.4)
20	65.5 (65.2 – 65.7)	65.3 (65.0 – 65.6)	69.1 (68.8 – 69.4)	68.9 (68.6 – 69.2)
25	68.8 (68.7 – 68.9)	68.5 (68.4 – 68.7)	73.3 (73.2 – 73.5)	73.2 (73.1 – 73.4)
30	71.4 (71.3 – 71.6)	71.1 (71.0 – 71.3)	76.8 (76.6 – 77.0)	76.7 (76.5 – 76.9)
35	73.4 (73.2 – 73.6)	73.1 (72.9 – 73.3)	79.4 (79.1 – 79.8)	79.3 (78.9 – 79.6)
40	74.7 (74.2 – 75.1)	74.5 (74.0 – 74.9)	81.2 (80.5 – 82.0)	81.0 (80.2 – 81.8)
45	75.3 (74.5 – 76.1)	75.2 (74.4 – 76.1)	82.2 (80.8 – 83.7)	81.9 (80.4 – 83.3)
50	75.2 (73.8 – 76.5)	75.3 (73.9 – 76.7)	82.4 (80.1 – 84.7)	81.8 (79.5 – 84.1)

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