Path analysis for determining health factors in Indonesia

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Abstract. Health status of a population plays an important role in developing a country. A better health can promote economic growth and foster development of the country. The aim of this study was to investigate relationships among age, sex, weight, height, smoking behavior, and blood pressure on health status of adults in Indonesia. The path analysis was constructed using the secondary data of the fifth wave of the Indonesian Family Life Survey in 2014/2015. This survey was a large national survey with representing about 83% of the Indonesian population. The sample comprised 24,263 adults aged older than 17 years. The hypothesized model suggested that age, sex, weight, height, and smoking behavior had an effect on blood pressure and that all variables influenced health status. All path coefficients were statistically significant. The age, gender, and weight variables had positive relationships with blood pressure while in the opposite direction to the height and smoking behavior. The blood pressure, age, and smoking behavior had negative relationships with health status while in the opposite direction to the sex, weight, and height. Short male respondents who ever smoked and had high blood pressure were reported to have poor health status as age increased and weight decreased.

1. Introduction

The Human Development Index (HDI) was developed by the United Nations Development Program (UNDP) in 1990 and published periodically in the annual Human Development Report (HDR) report. The HDI is an important indicator for measuring success in efforts to build the quality of human life. A ranking of development of a region/country can be determined by the HDI. In 2017, Indonesia HDI was 70.81 and categorized in the high human development [34].

According to World Health Organization (WHO), health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Some factors that influence population’s health include 10% of the physical environment, 20% of clinical health, 30% of health behaviours, and 40% of social and economic factors [23]. From the fifth wave of the Indonesian Family Life Survey (IFLS-5) which were conducted in 2014/2015, the majority to the health status of Indonesian populations were in high condition with the scale of 7 out of 9. The IFLS is an on-going longitudinal survey in Indonesia and a representative of 83% of the Indonesian population which contains over 30,000 individuals living in 13 provinces [30].

Researches on path analysis of factors affecting health have been done by many scientists. Eduardo [29] studied about determining the health variables associated with the quality of life and mental health. The research variables included smoking behaviour, physical activity at leisure, mental health,
eating behaviour of fruits and vegetables, body mass index, and arterial hypertension. Meyer et al. [24] investigated effects of socioeconomic status (SES), neighborhood safety, and physical activity on mental health and self-rated health (SRH) using path analysis. Resnick et al. [12] used path analysis for investigating factors that influence behavior of older adults in the United States of America. Their study suggested that age, gender, and mental and physical health have an effect on self-efficacy and outcome expectations, and all these variables influence exercise behavior. Ye et al. [27] used path analysis to identify several direct and indirect factors influencing health skills and behaviors in adolescents. The variables in this study included socio-demographic variables were age, gender, school performance, student classification, prestigious school, region, and monthly pocket money; health knowledge variables are general knowledge, knowledge on infectious diseases, and health concept. Rosen et al. [25] used path analysis for examining the impacts of technology on four areas of ill-being psychological issues, behavior problems, attention problems and physical health among children.

The relation between demographic variables such as age, gender, weight, height, and health status has been examined extensively [6, 14, 17, 18, 22]. Cockerham et al. [1] study showed that elderly people tend to consider their health more positive than younger people. Verbrugge [3] explained that the differences in health status between men and women were basically based on their lifestyles, levels of stress, and perceptions on treating life conditions. Song [26] analyzed the correlation of blood pressure with height and weight in Korean adolescents and the result showed that the blood pressure of men or women had a stronger correlation to weight in comparison with height. The blood pressure increased with age in men and women. Bourgeois et al. [31] reported that height was associated with blood pressure and the magnitude increased with greater age. They used multiple linear regression model to test the hypothesis that included age, body mass index (BMI), percentage of body fat, and height. Li et al. [32] studied the association between cigarette smoking and blood pressure. They used analysis of covariance tests to compare systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and pulse pressure (PP) among the smoking groups, while adjusting for age, BMI, alcohol drinking and ethnicity, and they found that the blood pressure were lower in current smokers in comparison with nonsmokers and former smokers. Imamura et al. [8] used forward stepwise multiple regression analysis and they found that the cigarette smoking is negatively associated with blood pressure. The aim of this study is to investigate those factors age, gender, weight, height, smoking behavior, and blood pressure to the health status among adults in Indonesia.

2. Methods

2.1. Data

The data for empirical analysis were taken from the fifth wave of Indonesian Family Life Survey (IFLS-5) in 2014/2015. The survey collected information on individual, household, and community level data using multistage stratified sampling [30]. The original sampling frame was based on households from 13 Indonesian provinces that were selected to maximize the representativeness of the study population and represented approximately 83% of the Indonesian population in 1993. The IFLS-5 data are open for public users with a prior registration on the IFLS website [33]. The selected sample was 24,263 adults aged from 18 until 95 years.

2.2. Measure

The health status were measured using a scale of 1 to 9 where 1 was defined as ‘much worse’, 5 as ‘about the same’ and 9 as ‘very good’. The interviewer reported the participant health status by comparing the participant health in general to the health status of other people of the same age and sex. The socio-demographic measures included age and sex (0: female or 1: male). The health variables measures included weight, height, smoking behavior, blood pressure, and health status. For smoking behavior, the wording of the question was ‘Have you ever chewed tobacco smoked a pipe, smoked self-rolled cigarettes, or smoked cigarettes/cigars?’ with no (0) or yes (1) respond. The blood pressure was taken by first measurement on the left arm if possible.
2.3. Path Analysis

A path analysis is a statistical technique which provides possible causal relationships either direct or indirect among a set of variables. The path analysis is started by developing a diagram with arrows connecting variables and indicating casual flow or the direction of cause-and-effect. Each path indicates two variables connected by either arrows (lines, usually straight, with an arrowhead on one end) or wires (lines, usually curved, with no arrowhead), or slings (with two arrowheads). The variables can be categorized into one of two types: those that are without a direct cause (exogenous) and those with a direct cause (endogenous). In regression, the exogenous variables are sometimes called as predictors or independent variables or explanatory variables. The endogenous variables are called as dependent or response variables. Figure 1 shows a simple path diagram with two exogenous ($X_1$ and $X_2$) and two endogenous ($Y_1$ and $Y_2$). In the path diagram, single-headed arrows represent direct influences, while wires or slings represent covariance/correlations.

The general steps of the path analysis are developing a theoretically based model, all information from literature review, scientific reports, previous research are collected and then formulate hypotheses. The next step is constructing a path diagram of casual relationships and then converting the path diagram into a set of structural and measurement models, then choosing the input matrix type and estimating the proposed model, and then evaluating the model and interpreting the model [9].

2.4. Data Analysis

A total of 24,263 participants aged 18-95 years with complete data on all variables of interests were used to investigate relationships among demographics variables and health variables. Descriptive statistics and correlation were used to describe the characteristics of the sample and to assess the relationships among variables. The path model form can be expressed in the following 2 endogenous variable regression equations:

$$BP_i = \beta_0^{BP} + \beta_A^{BP} A_i + \beta_S^{BP} S_i + \beta_W^{BP} W_i + \beta_H^{BP} H_i + \beta_{SB}^{BP} S B_i + \epsilon_i^{BP}$$

$$HS_i = \beta_0^{HS} + \beta_A^{HS} A_i + \beta_S^{HS} S_i + \beta_W^{HS} W_i + \beta_H^{HS} H_i + \beta_{SB}^{HS} S B_i + \epsilon_i^{HS}$$

(1)

where $BP_i$ represents the $i$th blood pressure, $A_i$ represents the $i$th sex where 1 for male and 0 for female, $W_i$ represents the $i$th weight, $H_i$ represents the $i$th height, $S B_i$ represents the $i$th smoking behaviour where 1 for yes and 0 for no, $HS_i$ represents the $i$th health status, $\epsilon_i^{BP}$ represents the error in the approximation of the $i$th blood pressure, $\epsilon_i^{BP} \sim N(0, \sigma_{BP}^2)$, and $\epsilon_i^{HS}$ represents the error in the approximation of the $i$th health status, $\epsilon_i^{HS} \sim N(0, \sigma_{HS}^2)$. It is assumed that the covariances between two errors are zero. The regression parameters with the superscript of $BP$ are constants referred to as the model regression coefficients corresponding to the blood pressure endogenous, while the superscript of $HS$ for the health status endogenous.

A path analysis using maximum likelihood estimation in R version 3.5.1 with lavaan package was performed to identify factors associated with blood pressure and health status. The chi-square statistics, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) covariance were used to estimate model fit. The chi-square with larger probability indicates the better fit of the model to the
data [5, 8]. A TLI and CFI of > 0.90 are considered good fit between the hypothesized model and the observed data [11]. A RMSEA of < 0.10 is considered good and < 0.05 is very good [10]. A SRMR of < 0.08 is considered a good fit [11].

3. Results
Socio-demographics and health information for the 24,263 participants are represented in Table 1. The average age of the participants was 38.06, with 50% young adults (ages 18-35 years), 39% middle-aged adults (ages 36-55 years), and 11% older adults (ages older than 55 years). About half the participants (53%) were male. The average body weight of the adult female was 57.56 kg (SD = 10.82 kg); for the adult male 59.97 kg (SD = 11.02 kg). The average height of adult female was 152.44 cm (SD = 5.35 cm); for the adult male 162.94 cm (SD = 5.85 cm). Of the 24,263 participants, 10,082 (42%) reported smoking cigarettes where the adult males smoked nearly three times as much as females. The average blood pressure of the adult female was 125.83 mmHg (SD = 21.80 mmHg); for the adult male 131.13 mmHg (SD = 19.02 mmHg). The average blood pressure for adult smokers (130.81 mmHg) was higher than adult nonsmokers (127.07). There was statistically significant difference in health status among gender (F = 64.02, p < 0.0001) where the adult males had higher health status than adult females. Surprisingly, the average health status for the adults were the same (6.9) for those who ever smoked and never smoked.

Table 1 shows the bivariate correlations among variables. All variables were significantly related to health status. With exception of height, all variables were significantly related to blood pressure. The Pearson correlation between male and smoking was about 0.74, which indicated that there was a high positive relationship between the variables. There was a moderate positive between male and height (r = 0.68). The Pearson correlation between height and smoking (r = 0.49) and between age and blood pressure (r = 0.46) were indicating low positive relationship between the variables, and other Pearson correlations were reported very low.

Table 1. Descriptive statistics and correlations for path analysis variables (n = 24,263): Indonesia Family Life Survey, 2014/2015.

| Variable  | Mean ± SE | 1 | 2   | 3 | 4  | 5  | 6  | 7  |
|-----------|-----------|---|-----|---|----|----|----|----|
| 1: Age    | 38.06 ± 0.09 | 1.00 | ... | ... | ... | ... | ... | ... |
| 2: Male   | 0.53 ± 0.08  | 0.09**** | 1.00 | ... | ... | ... | ... | ... |
| 3: Weight | 58.83 ± 0.07 | 0.04**** | 0.11**** | 1.00 | ... | ... | ... | ... |
| 4: Height | 157.98 ± 0.05 | -0.13**** | 0.68**** | 0.33**** | 1.00 | ... | ... | ... |
| 5: Smoking| 0.42 ± 0.00  | 0.12**** | 0.74**** | 0.02**** | 0.49**** | 1.00 | ... | ... |
| 6: Blood pressure | 128.62 ± 0.13 | 0.46**** | 0.13**** | 0.21**** | -0.01 | 0.09**** | 1.00 | ... |
| 7: Health | 6.91± 0.01 | -0.09**** | 0.05**** | 0.06**** | 0.09**** | 0.02** | -0.06**** | 1.00 |

Note: Ranges of variables: age (18-95 years), weight (40-104.2 kg), height (140.0-179.3 cm), blood pressure (67-244 mmHg), health (1-9).

The major assumptions of the path analysis which are essentially based on the assumptions of the multiple regression which include uncorrelated errors, equal errors variances, and normal distribution of errors. The data in this study are non-time series, so to test for independent errors can be done by looking at plots of the residuals and independent variables. All plots of the residuals and continuous independent variables (not shown here) show that the residuals fairly consistent fall around zero indicating the independent assumptions are satisfied. The sample size in this study is sufficiently large (> 200), hence the violation of the normality assumption should not cause major problems [20]. West et al. [7] proposed an absolute skewness value > 2 as a reference departure from normality. Absolute skewness of the residuals of the linear regression for blood pressure and health are 1 and 2, respectively. The skewness value indicates that the errors have a normal distribution. Homocedasticity for each linear regression model was assessed by creating a residuals plot (fitted values versus standardized residuals). All residual plots show the fairly consistent spread of residuals which indicates the homogeneity assumptions are fulfilled.
In the path model setup, there were 7 variables where 2 variables were endogenous and 5 variables were exogenous. The model was defined as a recursive model since there were no feedback loops. All covariance terms in the all-variable matrix were \(7 \times (7+1)/2 = 28\). There were 18 model parameters for the covariance matrix which contained 11 direct path, 2 residual variances, and 5 variances of the exogenous variables. Therefore, the path model was over-identified by t-rule [5].

Two different path models were tested. The path diagram with respective standardized path coefficients for both models were shown in Figure 2. All model indices for selecting the best fit model were compared and summarized in Table 2. The modified model was chosen as the final model based on CFI, TLI, RMSEA, SRMR, AIC and BIC. The final model results indicated an excellent model fit with \(\chi^2 (2, n = 24.263) = 46.252, p < 0.0001\), CFI = 0.999, TLI = 0.990, RMSEA = 0.030, 90% confidence interval around RMSEA of between 0.023 and 0.038, and SRMR = 0.011. Moreover, all conclusions were drawn by using the modified model.

### Table 2. Model comparisons

| Model     | \(\chi^2(\text{df})\) \(p\) | CFI | TLI | RMSEA | 90% CI for RMSEA | SRMR | AIC | BIC |
|-----------|------------------------|-----|-----|-------|------------------|------|-----|-----|
| Hypothesized | 40950.685(10), \(< 0.0001\) | 0.162 | 0.000 | 0.411 | 0.407, 0.414 | 0.205 | 909816.922 | 910019.340 |
| Modified   | 46.252(2), \(< 0.0001\) | 0.999 | 0.990 | 0.030 | 0.023, 0.038 | 0.011 | 868928.490 | 869195.681 |

All coefficients on the modified model were statistically significant at the 0.05 level of significance. The results were shown on Table 3. The intercepts and their standard errors for each variable which were not shown on the path diagram were \(\hat{\beta}_{BP} = 138.033 (3.352), \hat{\beta}_{HS} = 5.991 (0.266), \hat{\beta}_{A} = 38.065 (0.087), \hat{\beta}_{S} = 0.528 (0.003), \hat{\beta}_{W} = 58.832 (0.071), \hat{\beta}_{H} = 157.983 (0.049), \hat{\beta}_{SB} = 0.416 (0.003). The interpretation of multivariate regression results for \(BP\) were (1) \(\hat{\beta}_{BP} = 138.033\), the value of \(BP\) when all predictors are zero \((A = 0, S = 0, W = 0, H = 0, SB = 0)\); (2) \(\hat{\beta}_{AP} = 0.644\), the slope for \(A\) predicting \(BP\) which indicates that for every one-unit increase in \(A\) (holding \(S, W, H, SB\) constant), \(BP\) increases by 0.644; (3) \(\hat{\beta}_{SP} = 8.096\), males have a higher blood pressure on average than females (holding \(A, W, H, SB\) constant); (4) \(\hat{\beta}_{WP} = 0.415\), the slope for \(W\) predicting \(BP\) which indicates that for every one-unit increase in \(W\) (holding \(A, S, H, SB\) constant), \(BP\) increases by 0.415; (5) \(\hat{\beta}_{HP} = -0.392\), the slope for \(H\) predicting \(BP\) which indicates that for every one-unit increase in \(H\) (holding \(A, S, W, SB\) constant), \(BP\) decreases by 0.392; and (5) \(\hat{\beta}_{BP} = -1.630\), the respondents who ever smoked have a lower blood pressure on average than those who never smoked (holding \(A, S, W, H\) constant). The interpretation of multivariate regression results for \(HS\) were (1) (1) \(\hat{\beta}_{HS} = 5.991\), the value of \(HS\) when all predictors are zero \((BP = 0, A = 0, S = 0, W = 0, H = 0, SB = 0)\); (2) \(\hat{\beta}_{HS} = -0.003\), the slope for \(BP\) predicting \(HS\) which indicates that for every one-unit increase in \(BP\) (holding \(A, S, W, H, SB\) constant), \(HS\) decreases by 0.003; (3) \(\hat{\beta}_{HS} = -0.007\), the slope for \(A\) predicting \(HS\) which indicates that for every one-unit increase in \(A\) (holding \(BP, S, W, H, SB\) constant), \(HS\) decreases by 0.007; (3) \(\hat{\beta}_{HS} = 0.142\), males have a higher health status on average than females (holding \(BP, A, W, H, SB\) constant); (4) \(\hat{\beta}_{WS} = 0.007\), the slope for \(W\) predicting \(HS\) which indicates that for every one-unit increase in \(W\) (holding \(BP, A, S, H, SB\) constant), \(HS\) increases by 0.007; (5) \(\hat{\beta}_{HS} = 0.007\), the slope for \(H\) predicting \(HS\) which indicates that for every one-unit increase in \(H\) (holding \(BP, A, S, W, SB\) constant), \(BP\) decreases by 0.007; and (5) \(\hat{\beta}_{BP} = -0.081\), the respondents who ever smoked have a lower health status on average than those who never smoked (holding \(BP, A, S, W, H\) constant). The residual variance for \(BP\) is \(\sigma^2_{BP} = 310.178\) and \(R^2\) for \(BP\) is 0.260; while for \(HS\) \(\sigma^2_{HS} = 1.859\) and \(R^2 = 0.017.\)
The results found that age, sex, weight, height and smoking behavior had direct and indirect effects on health status, while blood pressure had only direct effect on health status. These results could be useful for individuals to help improving health status in Indonesia, especially for males and smokers.

**Direct effects**

The blood pressure had a negative relationship to health status, high blood pressure can damage the health and may lead to bleeding in the eye, blurred vision, and complete loss of vision [21]. The age variable had a negative relationship to health status in contrast to blood pressure, which suggested that increasing age will directly lead to a decline of individual’s health status. Consistent with other studies [3, 16, 28], male sex was found to relate with higher blood pressure and health status, which indicated lower blood pressure and health status for female. The findings for the unstandardized path coefficient of age to blood pressure showed a positive value. The weight variable had a positive relationship to blood pressure and health status, similarly to the height. These results were consistent with findings from previous studies [26]. Respondents who ever smoked in the smoking behaviour variable showed direct negative relationships to blood pressure and health status [2, 7]. The effect of nicotines on cigarettes could cause some stimulations of adrenal hormones in the heart-stimulating and increase blood pressure [4]. According to a report by the World Health Organization (WHO), a smoker has a 20 times greater risk of death due to lung cancer than non-smokers.

**Indirect effects**

The modified path model given on Figure 2 (b) indicated that male sex and weight had positive indirect effect on health status through their impacts on blood pressure. The association of health status and blood pressure with male sex were much greater than with weight. Consistent with this study, male with poor physical health were found only among the obese, while for female’s physical health deteriorated with increasing body mass index [19]. The indirect effect for smoking behaviour on health status through blood pressure was negative which suggested that the health status of respondents who ever smoked with low blood pressure was much poor than for those never smoked [15]. The blood pressure, age, and smoking behavior had negative indirect effects on health status through their impacts on blood pressure. The increase blood pressure with age affected on poor health status, and in contrast with height. As has been previously reported [13] blood pressure increased between 55 and 68 years of age and inversely related to lung function.

**Figure 2.** (a) Hypothesized model with unstandardized path coefficients; (b) Modified model with unstandardized path coefficients; and ***p < 0.001, **p < 0.01.

4. Discussion

The results found that age, sex, weight, height and smoking behavior had direct and indirect effects on health status, while blood pressure had only direct effect on health status. These results could be useful for individuals to help improving health status in Indonesia, especially for males and smokers.
Table 3. Path coefficients based on the final model

| Outcome variables | R²  | Predictors          | Unstandardized coefficient estimate | SE  | p-value         | Standardized coefficient estimate |
|-------------------|-----|---------------------|-------------------------------------|-----|----------------|-----------------------------------|
|                   |     | Age                 | 0.644                               | 0.011 | < 0.001        | 0.424                             |
| Blood pressure    | 0.260| Sex                 | 8.096                               | 0.418 | < 0.001        | 0.197                             |
|                   |     | Weight              | 0.415                               | 0.012 | < 0.001        | 0.223                             |
|                   |     | Height              | -0.392                              | 0.023 | < 0.001        | -0.147                            |
|                   |     | Smoking behaviour   | -1.630                              | 0.348 | < 0.001        | -0.039                            |
|                   |     | Blood pressure      | -0.003                              | 0.001 | < 0.001        | -0.045                            |
| Health status     | 0.017| Age                 | -0.007                              | 0.001 | < 0.001        | -0.064                            |
|                   |     | Sex                 | 0.142                               | 0.031 | < 0.001        | 0.051                             |
|                   |     | Weight              | 0.007                               | 0.001 | < 0.001        | 0.055                             |
|                   |     | Height              | 0.007                               | 0.002 | < 0.001        | 0.039                             |
|                   |     | Smoking behaviour   | -0.081                              | 0.026 | 0.002          | -0.029                            |

5. Conclusion
The final model suggesting that age, sex, weight, height, and smoking behavior had direct and indirect effects on health status, while blood pressure only had a direct effect on health status. All path coefficients of the final model were statistically significant, and the model accounted 26% of the variance in blood pressure and 1.7% of the health status. The results found that the short male respondents who ever smoked and had high blood pressure were reported to have poor health status as age increased and weight decreased. Preventing poor health status and high blood pressure by quitting smoking and maintaining weight can increase life expectancy.

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