

Path analysis to examine the effects of sociodemographic and health conditions on the incidence of falls in older adults

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Abstract

Background: Factors associated with the incidence of falls among older adults have been studied and evaluated to assess the magnitude of this issue in the field of public health. This is conducted by developing a model of relationships between independent and dependent variables based on theoretical frameworks.

Objective: To analyze a structural model explaining the relationships between sociodemographic factors, health conditions, and the incidence of falls.

Methods: An observational study with a cross-sectional design was conducted. The sample consisted of older adults aged ≥ 55 years, both male and female, in Surabaya. A multiple-stage sampling technique was employed, with a total sample size of 240 older adults.

Results: Sociodemographic variables, namely age and sex, had direct effects, with path coefficients of $P1 = 0.198$ (p-value < 0.05) and $P2 = 0.208$ (p-value < 0.05), respectively. Age and sex are non-modifiable variables that directly influence the aging process. The path coefficients also indicated indirect effects of age and sex on falls. This suggests that modifiable factors, such as BMI and physical exercise, may help prevent falls (although the results were not statistically significant, p-value > 0.05). The overall path diagram model indicates that health conditions in older age are important. Controlling BMI and engaging in regular physical exercise are identified as modifiable variables.

Conclusion: Minimizing the risk of falls is associated with non-modifiable variables, particularly self-care practices.

Keywords: Path Analysis; Sociodemographic Factors; Health Conditions; Falls; Older Adults

1. Introduction

The relationship between two variables can be categorized into three types, one of which is an asymmetrical relationship. The essence of an asymmetric relationship lies in the assumption that one variable can influence another.¹ In this study, a relational model is developed to examine the association between subject characteristics and health conditions among older adults at risk of falling by analyzing the relationships among variables. These variables are examined through statistical calculations using path analysis. Path analysis is a method used to trace the mechanisms through which independent variables influence dependent variables, with an emphasis on the underlying system of relationships.²

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The risk of falling is more prevalent among individuals who have entered older age. This is due to declining physical and mental conditions, as well as environmental factors that are either unsupportive or unfamiliar. The causes of falls are multifactorial, involving intrinsic and extrinsic factors, as well as factors that are difficult to identify. The consequences may be prolonged (including joint changes, fractures, skin infections, and other complications).^{3,4}

Several variables, such as age and sex, are non-modifiable factors that have a direct influence on the incidence of falls. In contrast, physical exercise, Body Mass Index, BMI, and comorbid conditions are modifiable factors that can contribute to self-protection (prevention) against falls.⁵ Physical function serves as a biomarker of healthy aging.⁶

Dietary intake can influence an individual's health status, determining susceptibility to disease.^{6,7} Inadequate nutrient intake may contribute to an increased risk of falling. Certain diseases, such as neurological disorders and memory impairment, may also trigger fall risk. This occurs due to changes in the nervous system, including slower response and prolonged reaction time. In addition to age-related factors, lack of or insufficient physical exercise can negatively affect health conditions (e.g., increased susceptibility to illness and inability to control body weight), ultimately increasing the risk of falls.^{8,9}

Based on the aforementioned background, it is identified that the analysis of relationships between independent and dependent variables, both directly and indirectly influencing falls among older adults, requires further investigation. Falls among older adults constitute an important phenomenon from a public health perspective. Therefore, determining causal relationships may be used to predict the effects of sociodemographic factors and health conditions on the risk of falling.

The objectives of this study are: (1) to identify sociodemographic factors, including age and sex, health conditions including BMI and physical exercise, as well as the incidence of falls; and (2) to establish a structural model of the relationships between independent variables (age, sex, BMI, physical exercise) and the incidence of falls.

This study is expected to provide the following benefits: (1) to offer important information regarding the variables examined; (2) to conduct evaluations related to the health of older adults; and (3) to contribute to the advancement of knowledge in the field of public health through the application of statistical methods to provide scientific evidence.

2. Materials and Methods

2.1. Design

This study is an observational study conducted using a cross-sectional design, meaning that information regarding the variables examined in relation to the incidence of falls was obtained through a single observation. A quantitative analytical approach was employed to explain the relationships between independent and dependent variables.

2.2. Sample

The sample consisted of older adults aged ≥ 55 years, both male and female, residing in the city of Surabaya. The sampling technique used was multiple-stage sampling. First, the city of Surabaya was divided based on administrative regions, and districts were selected randomly. Second, from the selected districts, sub-districts were randomly chosen. Third, from the selected sub-districts, individuals were randomly selected. The total sample size was 240 older adults.

2.3. Measurement

Data collection was carried out through interviews using a structured questionnaire. The survey was conducted by visiting the homes of selected respondents. Interviews were then conducted to obtain information on sociodemographic factors, including age and sex; health conditions, including Body Mass Index, BMI and physical exercise; as well as history of falls.

Variables and Operational Definitions. The variables examined in this study include:

- Age is the length of life calculated based on the most recent birthday (in years).
- Sex is a characteristic inherent to individuals, clearly categorized as male or female. This variable was further treated as a dummy variable.
- Body Mass Index, BMI is a measure of body mass based on the ratio of body weight to height (kg/m^2).
- Physical exercise are activities performed regularly and consistently to maintain optimal health (hours/week).

- History of fall is the frequency of slipping and/or falling events experienced within the past 12 months (number of occurrences).

2.4. Statistical analysis

After data collection was completed, the data were re-examined to verify their accuracy and completeness. Subsequently, the data were analyzed using path analysis with SPSS software.

The basis of this path analysis is to examine the relationships between independent and dependent variables. The relationships in question are asymmetric (causal relationships), based on several assumptions: (1) the older an individual is, the greater the risk of falling; (2) as individuals age, their physical condition declines, and without control of other variables (such as regular physical exercise and weight management), the risk of falling increases; and (3) all individuals entering older age, regardless of sex are at risk of falling.

The steps in conducting path analysis are as follows:²

- Model specification: formulation of the theoretical model in the form of equations or diagrams.
- Model identification and parameter estimation: the theoretical model is estimated using observational data, and model parameters are statistically estimated from the data.
- Model fit: the estimated model parameters are used to predict the relationships among the variables under study.
- Model respecification: identification of the effects of independent variables on dependent variables. The relationships among variables are expressed in the form of structural equations. These structural equations are constructed by calculating direct effects, indirect effects, and total effects among variables. These index values are determined based on path coefficients.

3. Results and Discussion

3.1. Characteristics and Health Conditions of Older Adults

The mean age of older adults was 65.89 years, which falls within the senescence stages.¹⁰ The female group was older on average than the male group. At this advanced age (senescence period), individuals are more likely to fall into categories such as having severe illnesses,^{10,11} disabilities, living alone, and experiencing social isolation.

The average duration of physical exercise among older adults was one hour per week for males, whereas females engaged in less than one hour per week. Males tended to spend more time on physical exercise compared to females. However, this level of physical activity remains far below health recommendations for older adults. For individuals aged over 65 years, physical exercise should be performed regularly, with the duration depending on the type of activity.¹³ Insufficient physical activity can affect various organs, such as the heart, lung capacity, and muscle elasticity. Consequently, as the aging process progresses, health conditions tend to decline, susceptibility to disease increases, and immune function weakens. Regular physical exercise can contribute to long-term physical fitness.¹³

Body Mass Index, BMI is an anthropometric measure used to assess body size. It is useful for evaluating body composition and its association with health, particularly in determining whether it has direct or indirect effects on personal safety (risk of falling). Table 1. shows no difference in mean BMI between males and females. The average BMI for both groups was 22.76, which falls within the normal weight category.¹⁵

The average incidence of falls in both male and female groups was less than once per year. However, the frequency of falls was slightly higher among females than males.

Table 1 Sociodemographic Factors and Health Conditions of Older Adults

Variables	Male (n= 87)	Female (n= 153)
	Mean	Mean
Age (years)	64.82	66.50
Physical exercise (hours per week)	1.0	0.61
BMI (kg/cm ²)	22.47	22.93
Falls (past 12 months – number of occurrences)	0.14	0.60

Figure 1. illustrates differences in the graphical patterns between male and female groups. The graphs depict the incidence of falls according to age, Body Mass Index, BMI, and physical exercise. In the male group, both physical exercise and the incidence of falls show fluctuating patterns across age. In contrast, in the female group, physical exercise appears to reduce the risk of falls; however, the risk increases again at older ages. The trend lines indicate sharp decreases and increases, particularly beyond the age of 69 years. BMI appears to reduce the risk of falls among females. However, at ages above 69 years, higher BMI is associated with an increased risk of falling.

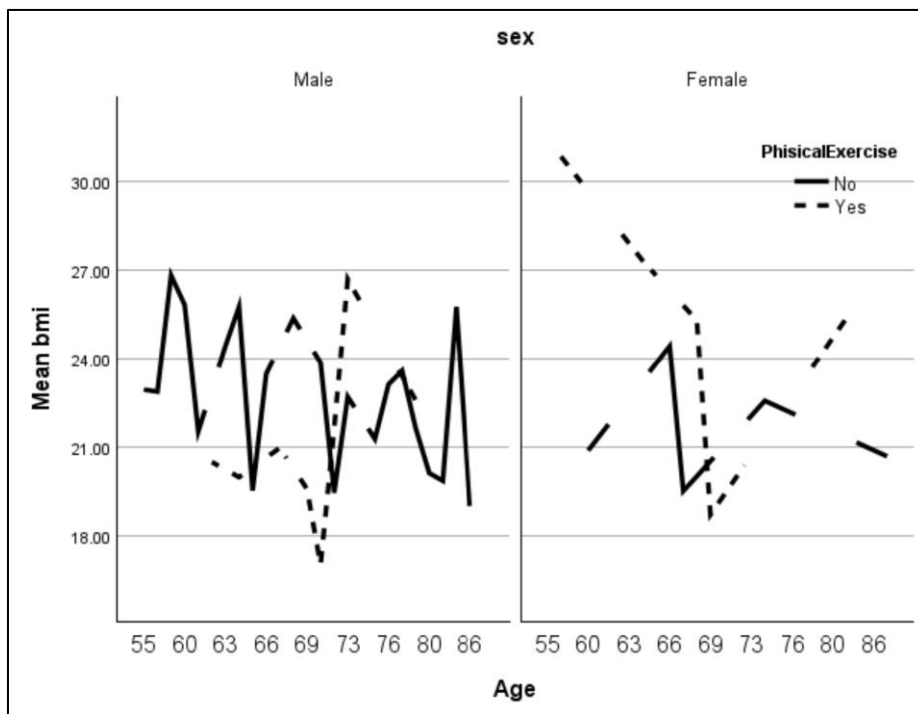


Figure 1 Incidence of falls according to age, BMI, and physical exercise in male and female groups

3.1.1. Structural model of the relationships between independent and dependent variables

Path analysis was conducted to examine both direct and indirect effects on the variables under study. This analysis employed multiple linear regression, with the following step:

Model development based on conceptual or theoretical consideration

- Age, sex, BMI, and physical exercise have direct effects on the incidence of falls.
- BMI is influenced by age, sex, and physical exercise.
- Sex has a direct effect on physical exercise.

Based on these theoretical relationships among variables, a model can be constructed in the form of a path diagram (figure 2.) as follows:

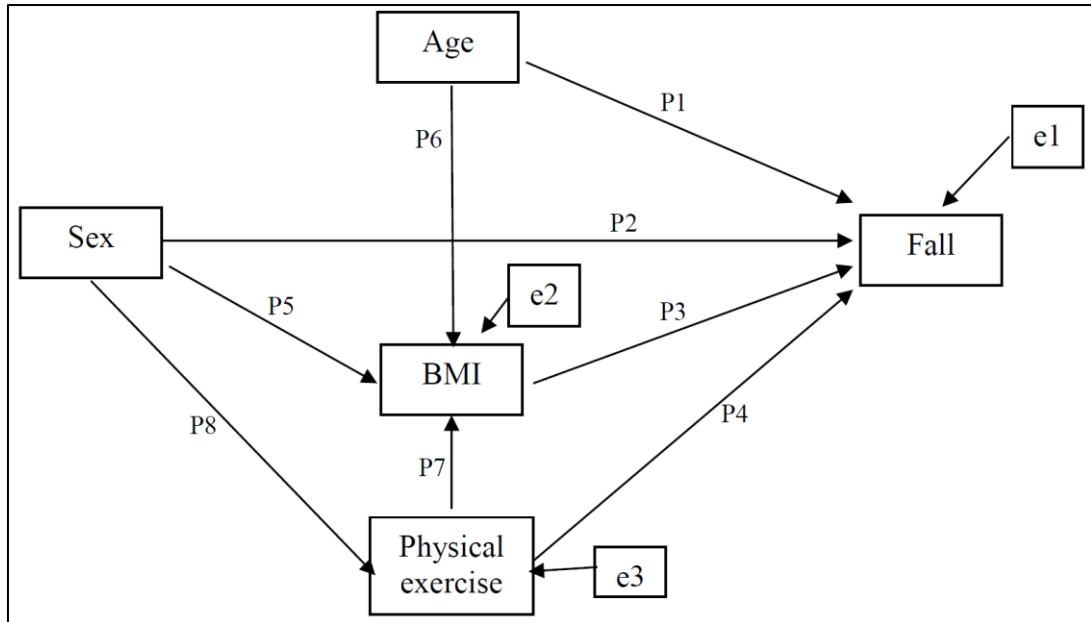


Figure 2 Model in the form of a path diagram and path coefficients

Within the path diagram, there are direct effects, indirect effects, and total effects. The coefficient P_i represents the direct effect coefficients.

- The direct effects of age, sex, BMI, and physical activity on falls= P_1, P_2, P_3, P_4
- The indirect effect of age on falls through BMI= $P_6 \times P_3$
- The indirect effect of sex on falls through BMI= $P_5 \times P_3$
- The indirect effect of sex on falls through physical exercise= $P_8 \times P_4$
- The total effect of age on falls= $P_1 + (P_6 \times P_3)$
- The total effect of sex on falls= $P_2 + (P_5 \times P_3)$

Based on the results of this model, the relationships are then expressed in the form of equations, forming a system of simultaneous equations (structural model). Three equation models are proposed:

- Model 1: $\text{Fall} = \alpha_1 + \alpha_2 \text{ age} + \alpha_3 \text{ BMI} + \alpha_4 \text{ physical exercise} + \alpha_5 \text{ sex}$
- Model 2: $\text{BMI} = \alpha_1 + \alpha_2 \text{ age} + \alpha_3 \text{ physical exercise} + \alpha_4 \text{ sex}$
- Model 3: $\text{Physical exercise} = \alpha_1 + \alpha_2 \text{ sex}$

Subsequently, regression analysis was performed using the Ordinary Least Squares, OLS approach, applied separately to each equation. The results of the analysis, based on the standardized beta coefficients, are as follows:

- $Z_{\text{Fall}} = 0.198 Z_{\text{age}} + 0.039 Z_{\text{BMI}} + 0.026 Z_{\text{Physical exercise}} - 0.208 Z_{\text{sex}}$
- $Z_{\text{BMI}} = -0.235 Z_{\text{age}} - 0.082 Z_{\text{Physical exercise}} - 0.078 Z_{\text{sex}}$
- $Z_{\text{Physical exercise}} = 0.108 Z_{\text{sex}}$

Based on these models of influence, a path model can be constructed, referred to as path analysis, in which the error effects are determined as follows:

$$p_{ei} = \sqrt{1 - R^2}$$

$$p_{e1} = \sqrt{1 - 0.090} = 0.950, p_{e2} = \sqrt{1 - 0.068} = 0.965, p_{e3} = \sqrt{1 - 0.012} = 0.994$$

3.2. The path diagram is presented as follows

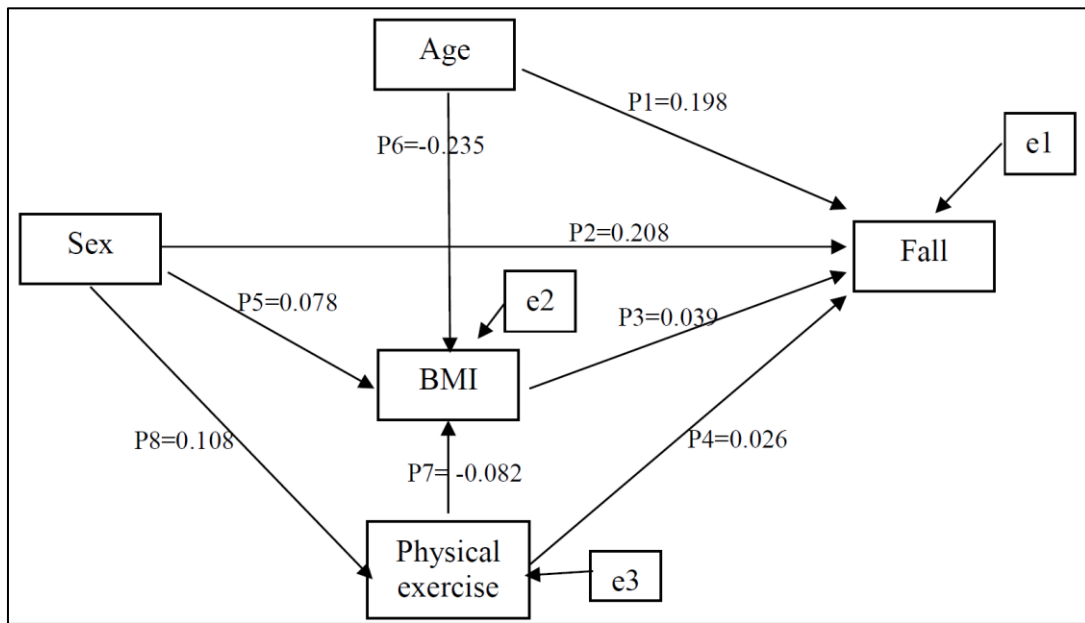


Figure 3 Path diagram illustrating the relationships among variables

3.2.1. The validity of the constructed path model was assessed as follows:

Coefficient of determination, $R_m^2 = 1 - (0.95)^2(0.965)^2(0.994)^2 = 0.1697$. This indicates that the proportion of variance in the data explained by the model is 16.97%. In other words, 16.97% of the information contained in the data can be accounted for by the model (the coefficient of determination is relatively small). The remaining 83.03% is attributed to other factors or errors.

Trimming theory: based on this approach, the supporting paths are identified by p-values <0.05. The results indicate that age and sex have direct effects on the incidence of falls. The interpretation shows that both age and sex exert direct influences on fall occurrence, as indicated by the thicker paths in the diagram. Older age has a direct effect on falls, with a path coefficient of $P1 = 0.198$. Sex also has a direct effect on falls, with a path coefficient of $P2 = 0.208$.

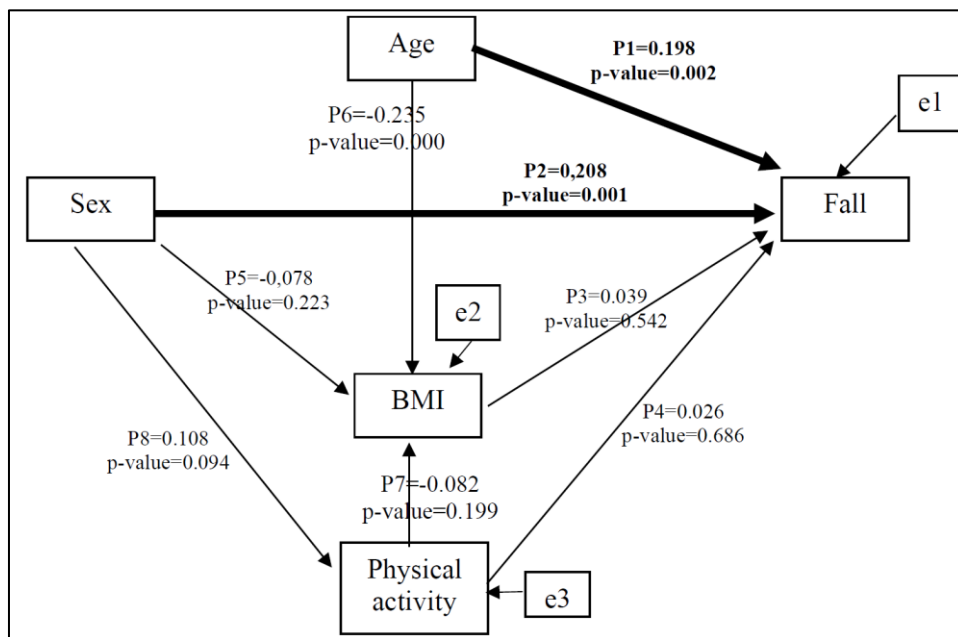


Figure 4 Path relationships in the model

The results of this path model indicate that older adults aged 55 years or above may still avoid experiencing falls. This is attributed to the presence of the BMI variable. BMI acts as an intervening variable, whereby the risk of falling is not only directly influenced by age but also indirectly influenced through BMI (although the p-value is not statistically significant; total coefficient= $0.198 + (-0.235 \times 0.039) = 0.2072$).

The variable of sex functions as a direct factor influencing falls and also as an indirect factor through the BMI variable (although the p-value indicates that the effect is not statistically significant). Similarly, the indirect effect of sex on falls through the intervening variable of physical exercise is observed (although the p-value also indicates that this effect is not statistically significant).

Old age is a stage of life that requires priority attention, both from individuals themselves and from families and communities, with the primary task of maintaining personal health. During this period, individuals experience physical, mental, and social decline, making it a less favorable phase of life.¹⁶ Among older age groups, characteristics often include incapacity, poverty, lack of skills, and dependency.¹⁷

Various aspects of aging in women include menopause, which affects bone fragility due to hormonal changes, particularly the decline in estrogen levels. As a result, postmenopausal women have a higher risk of bone fractures. Osteoporosis often develops without being recognized by older individuals; it is commonly only detected after a fall results in a fracture. In addition, in older age, height may decrease by several centimeters, and the spine may curve forward (kyphosis). This stooped posture or altered gait further complicates health conditions and increases the risk of falls among older adults.¹⁸

The results of this relational modeling support previous studies indicating that sex has a significant effect on the incidence of falls. Several considerations include factors related to physical aspects in women as well as the aging process itself.¹⁹

Indonesia is entering an era of an aging population structure. As individuals grow older, the number of those experiencing various problems (such as slowed movement and reduced body balance) increases. When these conditions affect older adults, the challenges they face become more complex. The impact may also extend to the family's economic condition, including increased costs of treatment and care, particularly among families with lower socioeconomic status.

4. Conclusion

The city of Surabaya is characterized by an older population group classified within the senescence stage. This group tends to show low motivation to engage in physical exercise, with no notable differences between male and female groups. The variables that have direct effects are age and sex, without mediation through BMI and physical exercise. Based on the analysis of the variables, efforts are needed to improve quality of life, particularly for women, through self-care practices.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in this study.

Statement of ethical approval

This study received approval from the Ethics Committee of the Faculty of Dental Medicine, Universitas Airlangga.

Statement of informed consent

Informed consent was obtained from all respondents, who voluntarily agreed to participate. The information presented ensures the confidentiality and anonymity of the respondents.

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