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The Leading Causes of Death among Adult Mortality: Data Analysis of Sleman Health and Demographic Surveillance System, Indonesia

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Abstract
Determining the cause of death (CoD) is crucial for effective health policy and decision-making, particularly in population health programs. The World Health Organization (WHO) developed the Verbal Autopsy (VA) tool to ascertain CoD through verbal information, particularly in countries lacking comprehensive vital registration systems. In Indonesia, the health landscape is shifting from communicable diseases to non-communicable diseases (NCDs), highlighting the need for updated mortality surveillance. This study aimed to determine the major causes of death among adult mortality in Sleman Health and Demographic Surveillance System (HDSS) Indonesia. A demographic surveillance system was employed to monitor vital events, including mortality, with verbal autopsy interviews conducted for each death. A total of 279 adult deaths (ages 15 years and older) from the first two cycles of surveillance were analyzed. Trained enumerators conducted verbal autopsy interviews with informants close to the deceased. The InterVA program was used to process the verbal autopsy data, identifying the CoD for 274 adult deaths. Descriptive analysis was performed to determine the proportion of each cause of death, and Chi-square tests were used to assess differences in proportions. The findings revealed that 68.2% (95% CI: 62.38–73.72) of deaths were due to NCDs, including stroke, heart disease, diabetes, asthma, and chronic liver disease. Infectious diseases accounted for 24.8% (95% CI: 19.82–30.37), while injuries (primarily accidents) contributed to 6.6% (95% CI: 3.94–10.18). Stroke was the leading cause of death, particularly in individuals aged 50–64 years (21.2%, 95% CI: 16.48–26.49), followed by acute respiratory infections, including pneumonia (10.6%, 95% CI: 7.2–14.85). The study concluded that NCDs, particularly stroke, are the leading causes of adult mortality in Sleman HDSS, with significant contributions from acute respiratory infections and injuries. It is recommended for future research to further develop Verbal Autopsy technology, such as AI-based applications that can improve the accuracy of determining the cause of death.

Keywords: Cause of Death, Verbal Autopsy, InterVA, NCD, HDSS.

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1. INTRODUCTION

The epidemiological transition of global disease burdens towards non-communicable diseases (NCDs) in recent years has positioned them as the leading causes of death (CoD) worldwide (Atiim & Elliott, 2016; Weisz, 2016; Bai et al., 2023; Aminorroaya et al., 2024; Goswami, 2024). As a developing country, Indonesia faces increasingly complex health challenges. Various efforts have been undertaken to achieve the Millennium Development Goals, including the implementation of the National Health Insurance policy. However, while infectious diseases remain unresolved, the prevalence of NCDs continues to rise. In 2014, 71% of deaths in Indonesia were attributed to NCDs, while 29% resulted from infectious diseases (WHO, 2014). This shift in disease patterns has significantly contributed to Indonesia's growing health burden.

The high prevalence of NCDs negatively impacts public health by increasing mortality among individuals under the age of 70. Moreover, NCDs impose a substantial socioeconomic burden, leading to reduced productivity and increased healthcare costs for affected individuals (Bloom et al., 2020; Murphy et al., 2020; Behera & Pradhan, 2021; Chai, Wan, & Kinfu, 2021; Verma, Kumar, & Dash, 2021; Thanh & Duong, 2022). Civil registration and vital statistics (CRVS) systems serve as primary sources of mortality data and are intended to operate continuously. However, in Indonesia, data on CoD have not been systematically collected through the national vital statistics system. When available, such data are often considered unreliable, as they are not based on medical records or autopsy reports collected using standardized methods (National Population and Family Planning Board et al., 2018). While community surveillance systems can be used to record vital demographic events, including deaths, they are costly and labor-intensive.

Verbal autopsy is a widely used systematic approach for determining CoD in populations lacking routine medical certification. This method is primarily employed in research settings and involves extensive interviews, making the process relatively time-consuming (Leitao et al., 2013). Traditionally, CoD analysis is conducted manually by physicians, which may lead to variations in results and further delays in the classification process. This study aimed to determine the major causes of death among adult mortality in Sleman Health and Demographic Surveillance System (HDSS) Indonesia.

2. RESEARCH METHOD

This study is a follow-up analysis of mortality data collected from the baseline survey conducted in the Sleman Health and Demographic Surveillance System (HDSS) in Yogyakarta, Indonesia. Sleman HDSS is a field research laboratory under the Faculty of Medicine, Public Health, and Nursing at Universitas Gadjah Mada. Established in 2014, it is located in the northern region of the Special Region of Yogyakarta. One of the key components of data collection in this surveillance system is the identification of demographic events, including vital registration for births and deaths.

The baseline sample consisted of 5,154 households distributed across 216 census blocks, comprising 184 urban and 32 rural areas. A two-stage sampling procedure with Population Proportionate to Size (PPS) was employed. In the first stage, census blocks were selected as clusters, and in the second stage, 25 households were randomly chosen from each cluster. The census blocks were obtained from the National Statistical Bureau. The total population under Sleman HDSS was 19,753 individuals, comprising 9,757 men and 9,996 women, with over 90% of the HDSS area classified as urban.

During the first two surveillance cycles (2015 and 2016), 288 deaths were identified, of which 274 were adult deaths (aged 15 years and above). This study focuses on analyzing these adult mortality cases. Cause of death (CoD) data were collected using the World Health Organization (WHO) verbal autopsy (VA) questionnaire, which was translated into Indonesian. The VA questionnaire included demographic variables and indicators related to the cause of death. The determination of CoD was performed using InterVA-4 software, which applies a

Bayesian-based probability model. Descriptive analysis was conducted by calculating proportions for each CoD.

This study employed a descriptive cross-sectional design, utilizing the standardized InterVA-4 instrument developed by the WHO (Byass et al., 2012; Leitao et al., 2013). Data were collected through interviews conducted by trained field officers with a health education background. Interviews were carried out during home visits at least one month after the individual's death. Information was obtained from the closest adult relative who was present at the time of death. Informed consent was obtained before the interviews. A total of 22 field officers were involved in data collection, with two supervisors assigned to ensure completeness and accuracy in the paper-based VA forms.

Data entry was performed using EpiData software by trained data operators. To ensure accuracy, a double data entry process was conducted on 10% of randomly selected questionnaires. Data cleaning for completeness and consistency was performed immediately after data entry. In cases of missing or inconsistent data, the original questionnaire was returned to the interviewer for correction. The cleaned dataset was then transferred into STATA database format, where variable names and coding were adjusted according to the InterVA-4 User Guide: APPENDIX 1 - Indicators.

The InterVA-4 program was used to determine and assign CoD based on its Bayesian probability model. This method has been widely applied in several developing countries conducting HDSS under the INDEPTH Network, including studies in Africa and Asia (Streatfield et al., 2014a; Streatfield et al., 2014b; Streatfield et al., 2014c). The validity of InterVA has been demonstrated in previous studies, including those conducted in KwaZulu-Natal, South Africa (Herbst et al., 2011). Descriptive analysis was performed to calculate the proportion of each cause of death, with 95% confidence intervals (95% CI) and Chi-square tests applied.

3. RESULTS AND DISCUSSION

The nonresponse rate in this study was 1.8%. The number is smaller compared to that reported by Alexander for a nonresponse rate during VA procedures in India and China, which were 10.9% and 6.5%, respectively (Alexander, et al., 2013). There were 3.4% of causes of death which were not able to assign, which is significantly less than that reported by Alexander where the VA could not assign a specific cause for 15% - 18% of deaths (Alexander et al., 2013). Using InterVA-4 output identified that there are 30 CoD categories among the Sleman HDSS adult population (15 years old and above).

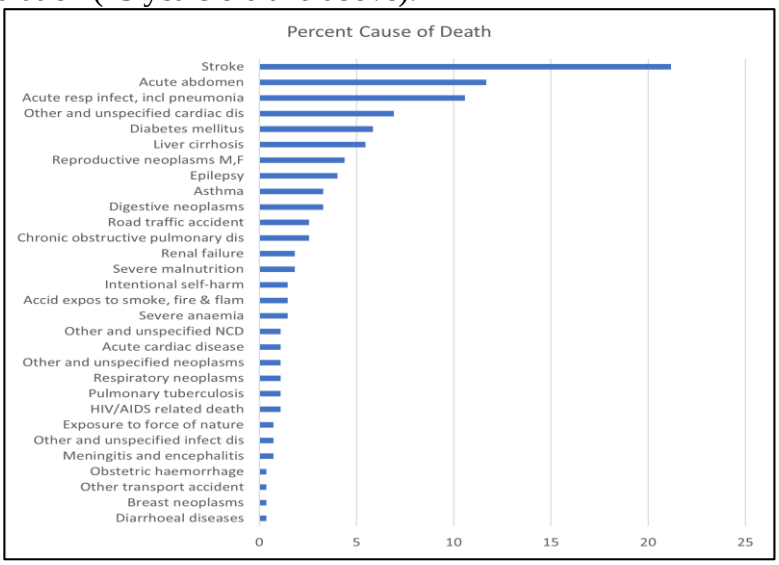

Figure 1. Percentage distribution of Cause of Death, ordered from the higher proportion

Figure 1 shows that the leading CoD is stroke with the highest proportion. The second most common CoD was acute abdomen, then followed by acute respiratory infection (or pneumonia), other cardiovascular diseases, and diabetes mellitus.

Table 1. The cause of death proportion with 95% confidence interval by gender

Cause of death	Total (n=274)	Male (n=134)	Female (n=140)	*p*-value
	Percent (95%CI)	Percent (95%CI)	Percent (95%CI)	
Eight Higher Cause of Death (70% data)				
Stroke	21.2 (16.48-26.49)	16.4 (11.1-23.5)	25.8 (19.3-33.6)	0.112
Acute abdomen	11.7 (8.13 - 16.09)	10.7 (6.4 - 17.4)	11.4 (7.1 - 17.9)	0.102
ARI, pneumonia	10.6 (7.2 - 14.85)	14.4 (9.4 - 21.4)	8.1 (4.6 - 13.7)	0.642
Other and unspecified CVD	6.9 (4.23 - 10.62)	7.0 (3.8 - 12.4)	5.6 (2.9 - 10.6)	0.416
Diabetes mellitus	5.8 (3.37 - 9.31)	4.3 (2 - 9.1)	6.5 (3.5 - 11.9)	0.347
Liver cirrhosis	5.5 (3.1 - 8.87)	6.2 (3.2 - 11.8)	4.7 (2.3 - 9.4)	0.724
Reproductive neoplasms	4.4 (2.28 - 7.53)	3.8 (1.6 - 8.9)	5.2 (2.5 - 10.5)	0.608
Epilepsy	4.0 (2.02 - 7.07)	0.9 (0.2 - 3.8)	7.1 (3.8 - 12.7)	0.007*
Grouping				
NCD	68.2 (62.38-73.72)	64.9 (56.21-72.96)	71.4 (63.19-78.74)	0.248
Infectious diseases	24.8 (19.82-30.37)	28.4 (20.91-36.79)	21.4 (14.95-29.16)	0.184
Injury	6.6 (3.94 - 10.18)	6.7 (3.12-12.37)	6.4 (2.98-11.85)	0.923

***Note**: CVD=Cardiovascular diseases; ARI= Acute respiratory infection; NCD=Non-communicable diseases; *Significant different*

Table 1 presents the distribution of causes of death (CoD) in the study population. Stroke was the leading cause, accounting for 21.2% of deaths (95% CI: 16.48–26.49), followed by acute abdomen (11.7%; 95% CI: 8.13–16.09), acute respiratory infection (ARI) (10.6%; 95% CI: 7.2–14.85), other cardiovascular diseases (6.9%; 95% CI: 4.23–10.62), diabetes mellitus (5.8%; 95% CI: 3.37–9.31), liver cirrhosis (5.5%; 95% CI: 3.1–8.87), reproductive neoplasms (4.4%; 95% CI: 2.28–7.53), and epilepsy (4.0%; 95% CI: 2.02–7.07).

According to the ICD-10 classification, the 30 identified causes of death were categorized into three major groups: non-communicable diseases (NCDs), infectious diseases, and accidents. Among these, NCDs accounted for the highest proportion at 68.2% (95% CI: 62.38–73.72), followed by infectious diseases at 24.8% (95% CI: 19.82–30.37), and accidents at 6.6% (95% CI: 3.94–10.18). Notably, deaths due to NCDs were nearly three times higher than those caused by infectious diseases.

Table 1 also compares the proportion of CoD by gender, covering the eight most common causes, which represent 70% of the total deaths recorded. The proportion of stroke and epilepsy-related deaths was higher among women than men. Stroke was more prevalent in women (25.8%) compared to men (16.4%), although the difference was not statistically significant. In contrast, epilepsy showed a significant gender difference, with 7.1% of female deaths attributed to epilepsy compared to only 0.9% in men.

Conversely, deaths due to ARI (pneumonia) were more common among men (14.4%) than women (8.1%), though the difference was not statistically significant. Overall, the data demonstrate that NCD-related deaths accounted for nearly two-thirds (68.2%) of total deaths, while infectious diseases contributed 24.8%. Further analysis using the Chi-square test revealed significant differences in the proportion of deaths across the three age groups for stroke, ARI, and reproductive neoplasms. Stroke-related mortality was higher in older age groups, indicating an increasing trend with age.

Table 2. The cause of death percentage with 95% confidence interval by age group

Cause of death	Adult (n=33)	Midage (n=60)	Elder (n=181)	*p*-value
	Percent (95%CI)	Percent (95%CI)	Percent (95%CI)	
Eight Higher Cause of Death (70% data)				
Stroke	3 (0.08 - 15.76)	18.3 (9.52 - 30.44)	25.4 (19.25-32.41)	0.013*
Acute abdomen	12.1 (3.4 - 28.2)	6.7 (1.85 - 16.2)	11.6 (7.33 - 17.19)	0.534
ARI, pneumonia	9.1 (1.92 - 24.33)	3.3 (0.41 - 11.53)	14.9 (10.07-20.96)	0.047*
Other and unspecified CVD	9.1 (1.92 - 24.33)	5.0 (1.04 - 13.92)	7.2 (3.88 - 11.97)	0.740
Diabetes mellitus	3.0 (0.08 - 15.76)	10.0 (3.76 - 20.51)	5.0 (2.30 - 9.23)	0.271
Liver cirrhosis	9.1 (1.92 - 24.33)	10.0 (3.76 - 20.51)	3.3 (1.23 - 7.08)	0.089
Reproductive neoplasms	6.1 (0.74 - 20.23)	11.7 (4.82 - 22.57)	1.7 (0.34 - 4.77)	0.004*
Epilepsy	6.1 (0.74 - 20.23)	1.7 (0.04 - 8.94)	4.4 (1.93 - 8.52)	0.524
Grouping				
NCD	48.5 (30.8 - 66.46)	65 (51.6 - 76.87)	72.9 (65.84-79.25)	0.248
Infectious diseases	36.4 (20.4 - 54.88)	30 (18.85 - 43.21)	21 (15.31 - 27.66)	0.184
Injury	12.1 (3.4 - 28.2)	5 (1.04 - 13.92)	6.1 (3.07 - 10.61)	0.923

***Note**:CVD=Cardiovascular diseases; ARI= Acute respiratory infection; NCD=Non-communicable diseases; *Significant difference.*

Table 2 shows that the proportion of deaths due to stroke was highest among the elderly group (65+ years) compared to the middle-aged group (50–64 years) and adults (15–49 years), with 25.0% (95% CI: 19.25–32.41) of deaths occurring in the elderly, compared to 18.0% (95% CI: 9.52–30.44) in the middle-aged group and 3.0% (95% CI: 0.1–15.76) in adults. Similarly, deaths due to acute respiratory infection (ARI/pneumonia) were more prevalent in the elderly group than in the adult and middle-aged groups, accounting for 14.9% (95% CI: 10.07–20.96) of deaths, compared to 9.1% (95% CI: 1.92–24.33) in adults and 3.3% (95% CI: 0.41–11.53) in the middle-aged group. In contrast, reproductive neoplasm-related deaths were most common in the middle-aged group, with a proportion of 11.7% (95% CI: 4.82–22.57), followed by 6.1% (95% CI: 0.74–20.23) in adults and 1.7% (95% CI: 0.34–4.77) in the elderly.

DISCUSSION

There are distinct age group patterns associated with non-communicable diseases (NCDs), communicable diseases, and injuries. The proportion of deaths due to NCDs was predominantly observed in individuals aged 50 years and above, while deaths caused by infectious diseases were more common among those under 50 years old. Meanwhile, injury-related deaths were more frequent in both individuals under 50 years old and those over 64 years old.

This study highlights that NCDs are the leading causes of death (CoD) in Sleman HDSS, with stroke being the most prevalent cause among NCD-related deaths. These findings are consistent with the Indonesian Mortality Registration System Strengthening Project, which reported stroke, ischemic heart disease, and chronic respiratory diseases as the leading causes of death in Central Java (Wahab et al., 2017). Similarly, previous studies have identified stroke as the most common cause of death (Ren et al., 2024). This aligns with the WHO Indonesia Country Profile (2012), which reported that over 70% of deaths were attributed to NCDs, with two-thirds of those deaths caused by cardiovascular diseases, including stroke (WHO, 2020).

These findings are further supported by research in rural India, which identified NCDs and chronic diseases as the leading causes of death (Rai et al., 2020; Jana, & Chattopadhyay, 2022). A similar trend has been observed in global disease patterns, as well as in several studies conducted in urban Asia (Alexander et al., 2013). The shift in disease patterns is consistent with

global trends, where approximately 16 million people die prematurely (before the age of 70) due to NCDs each year, with four out of five of these deaths occurring in developing countries.

The increasing prevalence of stroke and other NCDs can be attributed to socioeconomic changes and shifting lifestyle trends, including physical inactivity, low fruit and vegetable consumption, obesity, smoking, and alcohol use (Vardell, 2020). As chronic diseases, NCDs not only pose a serious threat to public health but also have a significant impact on economic development and growth (Mendis, 2014). The four main types of NCDs include cardiovascular diseases (such as heart attacks and stroke), cancer, chronic respiratory diseases (e.g., chronic obstructive pulmonary disease (COPD) and asthma), and diabetes mellitus. The risk of dying from NCDs is strongly linked to tobacco use, physical inactivity, substance abuse, alcohol consumption, and unhealthy diets (Mendis, 2014).

The rising incidence of NCDs in Sleman District is closely related to lifestyle changes, including reduced physical activity, unhealthy dietary habits (consuming fewer than five servings of fruits and vegetables per day), smoking, and obesity. A 2015 study on the Sleman HDSS population reported a high prevalence of NCD risk factors among adults, except for smoking among women and alcohol consumption (Rahayujati et al., 2015). Additionally, age distribution data indicate that Sleman is predominantly composed of adults and middle-aged individuals. As the elderly population continues to grow, the prevalence of NCDs is expected to increase (Cheng et al., 2013; Hambleton et al., 2023).

The limitations of this study are related to the use of verbal autopsy questionnaires to determine the cause of death. The possibility that occurs is recall bias. This is related to the information provided by the respondents may be inaccurate or incomplete. Not all events or conditions of the corpse before death are known to the respondents with certainty. It could be that the respondents have difficulty remembering because it happened several months before the interview.

4. CONCLUSION

The study concluded that NCDs, particularly stroke, are the leading causes of adult mortality in Sleman HDSS, with significant contributions from acute respiratory infections and injuries. It is recommended for future research to further develop Verbal Autopsy technology, such as AI-based applications that can improve the accuracy of determining the cause of death.

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