

A retrospective study on solitary deaths (kodoku-shi) from the aspects of forensic and social medicine

Yumiko Hashizume

Wakayama Medical University

Akiko Ishigami

Wakayama Medical University

Yuko Ishida

Wakayama Medical University

Mizuho Nosaka

Wakayama Medical University

Yumi Kuninaka

Wakayama Medical University

Hiroki Yamamoto

Wakayama Medical University

Satoshi Hata

Wakayama Medical University

Jumpei Matsuki

Wakayama Medical University

Haruki Yasuda

Wakayama Medical University

Tatsunori Takayasu

Wakayama Medical University

Fukumi Furukawa

Wakayama Medical University

Akihiko Kimura

Wakayama Medical University

Toshikazu Kondo

`kondot@wakayama-med.ac.jp`

Wakayama Medical University

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Abstract

Background: Solitary death is a major social and medical problem. However, the situation of solitary death has not been investigated fully. Our purpose was to clarify the present situation of solitary death from the viewpoint of forensic medicine.

Methods: A total of 3,000 forensic autopsies were performed at the Department of Forensic Medicine, Wakayama Medical University, from April 2003 to December 2018. We retrospectively reviewed the autopsy reports of all cases and selected cases of solitary death or presumed solitary death. Solitary death was defined as death in people living alone that occurred at home or on the premises of home. A total of 637 cases were selected as solitary death cases or presumed solitary death cases in accordance with the abovementioned definition. We investigated the tendency of solitary death in forensic autopsies, sex, age distribution, manner or cause of death, dementia cases, postmortem interval until finding (PMI-f), first finder, past medical histories, and economic conditions. Moreover, the regional characteristics in Wakayama Prefecture were also examined.

Results: Solitary death predominantly occurred in men (471 males, 166 females). This tendency increased from the age of 40 years in men and 60 years in women. Among the cases, 349 and 199 were natural death and external death, respectively. Ischemic heart disease- and fire-related fatalities were most common in natural death and external death cases, respectively. Suicidal death was more frequent in women than in men. The PMI-f in female cases was significantly shorter than that in male cases ($p < 0.001$). Kushimoto and Shingu, located in the southern part (Kinan region), had a high solitary death rate in forensic autopsy cases. However, focusing on the economic state, few cases were welfare recipients in solitary death cases in Kinan region (non-urban area), and 23 of 36 welfare recipients lived in Wakayama City, indicating that the economic state would contribute more to the occurrence of solitary death in Wakayama City (urban area).

Conclusions: We identified several risk factors and regional characteristics for solitary death cases, and our observations could contribute to administrative welfare measures for the prevention of solitary deaths.

Introduction

Remarkable improvements in elderly survival rates have been accelerated the growth of the elderly population^{1,2}. Japan has reached aging at a rate unprecedented in the world due to high life expectancy and a low birth rate among developed countries. According to the WHO³, especially in developing countries, population aging is expected to accelerate in the coming decades. Furthermore, with the aging, the number of elderly single-person households is expected to increase in various countries, including Japan⁴⁻⁶. These changes have created concerns around the world about serious problems in the elderly population⁷⁻¹⁰. In Japan, the number of individuals in single-person households aged ≥ 65 years was 881,000 in 1980, and 6,717,000 in 2020. In contrast, during the same period the number of traditional extended family households declined sharply⁶. At the same time, these changes have led to a weakening of the caregiving functions traditionally carried out by families. And Japanese society has been facing the problem of solitary death for decades.

In the 1970s, when solitary death (kodoku-shi in Japanese) was first noted, but it became widely known to the public after the Great Hanshin-Awaji Earthquake that occurred in 1995. This is because the media reported as solitary deaths that instances where single residents of temporary housing, which is where victims were living, die without anyone noticing¹¹. After that, it became clear that solitary deaths were occurring outside the disaster-affected areas.¹² Since the 1990s, the relationship with poverty has become a problem, and in the latter half of the 2000s,

solitary death became a social problem as a result of social exclusion¹³. In addition, solitary deaths associated with social isolation have a negative impact on public health and increase the economic burden¹⁴. And social isolation and loneliness have been reported to increase the risk of coronary heart disease (CHD)¹⁵, dementia¹⁶, etc. Thus, solitary death is a major social and medical problem.

Currently, solitary death has attracted public concern as it is a familiar phenomenon that is the result of disease, poverty, and isolation from families and communities, not a special phenomenon¹³. In fact, half of individuals single-person households aged 60 and over in Japan are concerned about solitary deaths¹⁷. In addition, Similar concerns have been reported among elderly people living alone in South Korea¹⁰. Therefore, solitary death is not a phenomenon unique to Japan. To our knowledge, there have also been reports of it from South Korea⁵, the Netherlands^{18,19}, and Spain²⁰.

Recently, the Japanese government has presented a new term for isolated deaths. However, solitary death or isolated death has not yet been clearly defined. Regarding the definition of solitary death, the Tokyo Medical Examiner's Office operationally defined solitary death "as an unnatural death at the home of a person living alone in a private household"^{21, 22}, limited to people living alone. In other studies, solitary death occurred not only among people living alone but also among people living with the family^{23–27}. There are various interpretations of this definition. Conversely, the Ministry of Health, Labor and Welfare in Japan defines isolated death as "miserable death that damages the dignity of a person, i.e., a death that was not found for a long period as a result of being isolated from society"²⁸.

It is well known that there are regional differences in suicide mortality²⁹, but it is also considered that there are regional differences in the situation of solitary deaths. Thus, available welfare measures are required to prevent solitary deaths, giving greater consideration to regional differences. However, there are not many previous studies^{18,19,26,30–33} that have investigated regional differences in the situation of solitary deaths. There are two main reasons for this: the first is that the definition of solitary death is not clear, and the second is that it is not easy to obtain information before death due to social isolation.

Forensic medicine, a type of social medicine, is indispensable for maintaining social order and has a mission to reflect the social situation of that era. Investigation of the cause of death is a major issue in forensic medicine. Moreover, information obtained from forensic practice can provide a basic academic reference for formulating effective policies to prevent solitary deaths. Thus, we performed a retrospective study of forensic cases of solitary death and clarified the present situation of solitary death from the viewpoint of forensic medicine.

Methods

Study design

This is a retrospective study.

Autopsy cases

A total of 3,000 forensic autopsies were performed at the Department of Forensic Medicine, Wakayama Medical University, from April 2003 to December 2018. We retrospectively reviewed the autopsy reports of all cases and selected cases of solitary death or presumed solitary death. In this study, "solitary death" was defined as death in people living alone that occurred at home or on the premises of home. We excluded homicide cases and those in

which the deceased were discovered outside of their home premises and nursing homes or in homeless individuals. Among 3,000 autopsy cases performed at our department, 637 cases were selected as solitary death cases or presumed solitary death cases in accordance with the abovementioned definition. Based on the autopsy records and police reports, the tendency of solitary death in forensic autopsies, sex, age distribution, manner or cause of death, dementia cases, Postmortem interval until finding (PMI-f), first finder, past medical histories, and economic conditions were investigated. Moreover, the regional characteristics in Wakayama Prefecture were also examined.

Statistical analyses

A chi-square test was used only for PMI, compared the differences between < 7 days and ≥ 7 days with regard to sex and cause of death. P-values < 0.05 were considered significant. Statistical analysis was performed using Microsoft Excel Office version 16.

Results

Tendency of solitary death cases in forensic autopsy

In the past 16 years, the number of forensic autopsies performed has progressively increased. In accordance with this tendency, the number of solitary deaths increased simultaneously. In 2003, the number of solitary deaths was only seven (10.3%, percentage of annual autopsy cases), and there were 64 cases of solitary death (29.4%) in 2018. Moreover, the rate of home deaths among forensic autopsy cases has increased from 26.5% in 2003 to 50% in 2018. The rate of solitary deaths among home death cases has increased from nearly 40% in 2003 to nearly 60% in 2018 (Fig. 1a).

Sex and age distribution

Of 637 cases who had solitary death, 471 (73.9%) were male, and 166 (26.1%) were female, indicating that solitary death predominantly occurred in men (Fig. 1b). As for age distribution, cases in their 70s were the most common, followed by those in their 60s. According to sex, men in their 60s and women in their 80s were the most common. Solitary death cases in men and women tended to increase from the age of 40 years and 60 years, respectively (Fig. 1c).

Manner or cause of death

Among 637 autopsy cases of solitary death, 349 (54.8%) and 199 (31.2%) were natural death and external death cases, respectively. The remaining 89 cases (14.0%) were unknown because of advanced postmortem changes. Among 471 male cases, natural death and external death occurred in 273 (58.0%) and 130 (27.6%), respectively. In contrast, in female cases, the number of natural deaths (76 cases, 45.8%) was similar to that of external deaths (69 cases, 41.6%) (Fig. 2a).

Cause of death in natural death cases

The causes of death in the natural death cases are presented in Table 1. Cardiovascular disease was the leading cause of death in both sexes, followed by gastrointestinal and cerebrovascular diseases. Particularly, ischemic heart disease (IHD) was the most prevalent cardiovascular disease. The age distribution of natural death cases is shown in Fig. 2b. Especially, solitary deaths due to natural causes increased in men in their 40s.

Table 1
Cause of death in natural death.

Disease	Male (%)	Female (%)	Total (%)	Most common disease
Cardiovascular	149 (54.6)	51 (67.1)	200 (57.3)	Ischemic heart disease (155)
Cerebrovascular	27 (9.9)	5 (6.6)	32 (9.2)	Cerebral hemorrhage (30)
Respiratory	11 (4.0)	0 (0.0)	11 (3.2)	Pneumonia (9)
Gastrointestinal	54 (19.8)	9 (11.8)	63 (18.1)	Gastrointestinal bleeding (34)
Malignant	13 (4.8)	3 (3.9)	16 (4.6)	Liver, Lung cancer (4 each)
Malnutrition	6 (2.2)	4 (5.3)	10 (2.9)	Malnutrition (10)
Other	13 (4.8)	4 (5.3)	17 (4.9)	
Total	273 (100.0)	76 (100.0)	349 (100.0)	
Other diseases were classified as urinary organs, metabolic diseases, dehydration, infectious diseases, etc.				

Cause of death in external death cases

Among 199 (31.2%) external deaths, 154 (24.2%) were accidental, and 45 (7.1%) were suicidal. As shown in Fig. 2c, the suicide rate was more than twice as high in women (20 cases, 12.0%) than in men (25 cases, 5.3%). In accidental death 154 cases, fire-related death (80 cases, 51.9%) was the most common, followed by asphyxia (23 cases, 14.9%) and traumatic death (22 cases, 14.3%). Among the fire-related deaths, 77 were caused by home fire. Among the asphyxia cases, drowning was the most common (11 cases). Most traumatic death cases were due to falls and include intracranial injury, hemorrhagic shock due to injury or fracture, and cervical dislocation (Table 2). The age distribution of accidental deaths is shown in Fig. 2d. Accidental deaths were common in the 70s and 80s age group. In suicide 45 cases, asphyxia was the most common, followed by intoxication. hanging was the most common method of asphyxia. There were 17 cases of intoxication among the suicidal cases. Among the 17 cases, psychiatric drugs were most frequently used. According to the sex, hanging was the most common method of suicide for men, while drug overdose was the most common method of suicide for women (Table 3). The age distribution of suicidal cases is shown in Fig. 2e, and most of them were in their 30s to 60s. And 18 cases (40.0%) had psychiatric disease. The prevalence of psychiatric disease was much higher in female than in men, with 5 (20.0%) out of 25 cases occurring in men and 13 (65%) out of 20 in female. The psychiatric disease of suicide cases is shown in Fig. 2f. Depression was the most common, especially among women.

Table 2
Cause of death in accidental death.

	Male (%)	Female (%)	Total (%)
Fire-related	59 (56.2)	21 (42.9)	80 (51.9)
Heat stroke	6 (5.7)	2 (4.1)	8 (5.2)
Hypothermia	6 (5.7)	5 (10.2)	11 (7.1)
Asphyxia	13 (12.4)	10 (20.4)	23 (14.9)
Drug	6 (5.7)	2 (4.1)	8 (5.2)
Alcohol	2 (1.9)	0 (0.0)	2 (1.3)
Trauma	13 (12.4)	9 (18.4)	22 (14.3)
Total	105 (100.0)	49 (100.0)	154 (100.0)

Table 3
Cause of death in suicidal death.

	Male (%)	Female (%)	Total (%)	Most common cause of death
Asphyxia	16 (64.0)	7 (35.0)	23 (51.1)	Hanging (15)
Hyperthermia	1 (4.0)	1 (5.0)	2 (4.4)	Fire (2)
Intoxication	5 (20.0)	12 (60.0)	17 (37.8)	Drug (12)
Trauma	3 (12.0)	0 (0.0)	3 (6.7)	Sharp weapons (3)
Total	25 (100.0)	20 (100.0)	45 (100.0)	

Dementia cases

We also investigated dementia in solitary death cases. Of the 637 solitary death cases, 13 were dementia cases (2.0%; proportion of all solitary deaths), 7 were male (1.5%) and 6 were female (3.6%). As for age distribution, cases in their 80s were the most common (Fig. 3a). Manner of death is shown in Fig. 3b. The most common was external death (10 cases, 76.9%), followed by natural death (2 cases, 15.4%). Of the 10 external deaths, 9 were accidental deaths and 1 was suicidal. In accidental death cases, half cases were fire-related death by home fire, followed by traumatic death or hypothermia cases were due to falls.

Postmortem interval until finding (PMI-f)

In each case, we evaluated the PMI-f of the body. Figure 4a shows that there are two peaks of the PMI-f: < 1 d (182 cases, 28.6%) and 7 days to < 1 month (164 cases, 25.7%). Comparing PMI-f by sex, in men, PMI-f of 7 days to < 1 month was the most common (135 cases, 28.7%), followed by PMI-f of < 1 d (124 cases, 26.3%). Conversely, in women, PMI-f of < 1 d was observed in 58 cases (34.9%), and that of 7 days to < 1 month in 29 cases (17.5%). Moreover, comparing PMI-f with the cause of death, the PMI-f of natural death cases tended to be longer than that of external death cases (Fig. 4b). Moreover, we divided the cases in accordance with PMI-f of < 7 days and that $\geq$ 7 days. Comparing PMI-f by sex, PMI-f in women was significantly shorter than that in men ($p < 0.001$) (Table 4). Comparing PMI-f between natural death and external death cases, PMI-f of < 1 week was observed in 152 natural death cases (43.6%) and 167 external death cases (83.9%). In contrast, PMI-f of $\geq$ 1 week was observed in 197

natural death cases (56.4%) and 32 external death cases (16.1%). PMI-f of external death cases was significantly shorter than that of natural death cases ($p < 0.001$) (Table 5).

Table 4
Comparison of < 7 days PMI-f and ≥ 1 week PMI-f by gender.

PMI-f	Male (%)	Female (%)	
< 7days	222 (47.1)	106 (63.9)	p<0.001
≥ 7 days	249 (52.9)	60 (36.1)	
PMI-f: postmortem interval until finding.			

Table 5
Comparison of < 7 days PMI-f and ≥ 1 week PMI-f in natural death and external death.

PMI-f	Natural death (%)	External death (%)	
< 7days	152 (43.6)	167 (83.9)	p<0.001
≥ 7 days	197 (56.4)	32 (16.1)	
PMI-f: postmortem interval until finding.			

First finder

The first finder was defined as the first person to find the victim. The first finders were classified as family members/relatives, friends, owner of their house, neighbors, colleagues, nursing or welfare staff, delivery staff, police officer, passers-by, and unknown. In this study, we investigated 556 cases, excluding 81 cases that were discovered by police officers or firefighters due to a home fire (The breakdown of the 81 cases is as follows: there were 77 fire-related deaths due to house fires. However, one case was excluded due to family discovery, resulting in 76 cases. The remaining five cases suffered a house fire after they died of natural death). As shown in Fig. 4c, of the 556 cases who had solitary death, police officers were the most common (195 cases, 35.1%), followed by family members/relatives (166 cases, 29.9%). In men, Police officers were the most common (156 cases, 38.0%), followed by family members/relatives (112 cases, 27.3%). Conversely, in women, family members/relatives (54 cases, 37.2%), followed by police officers (39 cases, 26.9%).

Past medical histories

The medical history of cases is shown in Table 6. Cardiovascular disease (153 cases, 24.0%) was the most common in both sexes, followed by psychiatric disease (114 cases, 17.9%), excluding other diseases. Hypertension (HT) was the most prevalent cardiovascular disease worldwide. Depression was the most prevalent psychiatric disorder. Among other diseases, diabetes mellitus (DM) was the most prevalent disease. According to sex, men exhibited a twofold higher incidence of respiratory and gastrointestinal diseases and an approximately sevenfold higher incidence of malignancy than female cases. Alcoholic liver disease, alcoholism, and schizophrenia were more common in men than in women.

Table 6
Past medical histories.

Disease	Male (%)	Female (%)	Total (%)	Most common disease
Cardiovascular	107 (22.7)	46 (27.7)	153 (24.0)	Hypertension (106)
Cerebrovascular	24 (5.1)	8 (4.8)	32 (5.0)	Cerebral infarction (16)
Respiratory	20 (4.2)	3 (1.8)	23 (3.6)	Pulmonary emphysema (7)
Gastrointestinal	79 (16.8)	12 (7.2)	91 (14.3)	Alcoholic liver disease (21)
Malignant	33 (7.0)	0 (0.0)	33 (5.2)	Liver cancer (9)
Ophthalmic disorders	6 (1.3)	1 (0.6)	7 (1.1)	Glaucoma (4)
Orthopedic	13 (2.8)	11 (6.6)	24 (3.8)	Fracture (8)
Psychiatric	80 (17.0)	34 (20.5)	114 (17.9)	Depression (35)
Other	90 (19.1)	34 (20.5)	124 (19.5)	Diabetes (56)
Total	452	149	794	
Other diseases were classified as urinary organs, metabolic diseases, infectious diseases, etc.				

Regional characteristics in Wakayama prefecture

We aimed to clarify the regional characteristics of solitary deaths in Wakayama prefecture and divided the regions where solitary deaths occurred according to the jurisdiction of the Wakayama prefectural police. The jurisdiction of Wakayama prefectural police is shown in Fig. 5a. There are 14 police stations, and Wakayama City, the prefectural office of Wakayama Prefecture, is under the jurisdiction of three police stations: Wakayama north, east, and west police stations. The number of solitary death cases by police station and average annual number of autopsies for solitary death cases per 100,000 population are shown in Fig. 5b. The highest number of solitary deaths occurred at the Wakayama police stations (north, east, and west police stations). However, in terms of the average annual number of autopsies for solitary death cases per 100,000 people, the top was the Shingu police station, followed by the Kushimoto police station. The average annual number of autopsies for solitary death cases per 100,000 people in Wakayama Prefecture was 4.3, and Wakayama, Katsuragi, Gobo, Kushimoto, and Shingu police stations exceeded the prefecture average. The rate of solitary deaths among home death cases by police station is shown in Fig. 5c. The highest solitary death rate was noted at the Kushimoto police station (85.2%), followed by the Shingu police station (68.0%). The average rate of solitary deaths among home death cases in Wakayama Prefecture was 52.7%, and Wakayama, Kushimoto, and Shingu police stations exceeded the prefecture average.

Economical condition

We examined the economic conditions of solitary death cases and selected individuals who had received welfare aid during their lifetime. Among the 637 cases of solitary death, 36 were welfare recipients, accounting for 5.7% of all solitary death cases. Among the 36 welfare recipients, 29 were male, and 7 were female. The rates by sex were 6.2% and 4.2% for men and women, respectively. As for age distribution, those in their 50s were the most common, followed by those in their 60s. Particularly, in men, most cases were in their 50s and those in their 60s (Fig. 5d). Moreover, we divided the regions where 36 welfare recipients were found as solitary death cases, according to the jurisdiction of Wakayama prefectural police stations. The number of welfare recipients by police stations and the average annual number of welfare recipients per 100,000 population are shown in Table 7. Wakayama police stations

(north, east, and west) showed the greatest number of cases (23 cases, 63.9%, and per 100,000 population; 0.4). However, in Kushimoto and Shingu police stations, where the average annual number of autopsies for solitary death cases per 100,000 population and the solitary death rate among home death cases were extremely high, almost no welfare recipients could be confirmed.

Table 7
The number of welfare recipients among solitary death cases by police station and the average annual number of welfare recipients per 100,000 population.

Police stations	Number	Population	Average annual number welfare recipients
Wakayama	23	357,868	0.4
Iwade	3	113,442	0.2
Katsuragi	0	16,249	0.0
Hashimoto	1	68,833	0.1
Kainan	1	58,171	0.1
Arida	0	26,937	0.0
Yuasa	2	44,167	0.3
Gobo	1	61,119	0.1
Tanabe	3	98,757	0.2
Shirahama	1	20,787	0.3
Kushimoto	0	21,967	0.0
Shingu	1	45,754	0.1
Total	36	934,051	0.2

Discussion

With regard to interaction with neighbors among elderly people aged ≥ 60 , the Annual Report on the Ageing Society in Japan³⁴ revealed that "We just have stand-up chats outside" is the most common at 64.7%. On the other hand, the proportion of the elderly consulting with each other or helping each other out during illness is extremely low compared to the United States or Germany, and it has been reported that social isolation among elderly people in Japan is more severe than in other countries. These social situations prompted us to investigate the actual condition of solitary death cases from the viewpoint of forensic medicine.

In the past 16 years, the number of forensic autopsies has doubled from 123 in 2004 to 240–250 since 2012. In accordance with this tendency, the rates of home death and solitary death increased approximately 1.7-fold and 2.3-fold, respectively. This tendency seems to result from an increase in single-person households with the progress of aging in Japan. Particularly, in Wakayama Prefecture, the rate of individuals in single-person households aged ≥ 65 years increased from 20.7% in 2012 to 22.4% in 2020³⁵. Moreover, while the aging rate in Japan was 28.6% in 2020, the aging rate in Wakayama Prefecture was extremely high, at 33.4 rate in 2020³⁶, and is expected to reach 38.9% in 2040³⁵. Thus, it is expected that the number of solitary deaths in Wakayama Prefecture will continue to increase.

In this study, solitary deaths were more common among men. The peak age of solitary deaths was in their 70s, followed by their 60s, but there was a gender difference, with men in their 60s and women in their 80s. It was characteristic that men showed an increasing trend from their 40s and women from their 60s. It considers that these results reflect the fact that in Japan, the rate of single-person households for women is high among the elderly, while the rate of single-person households for men tends to be high even among middle-aged and elderly people³⁶. This high risk of gender and age in solitary death has also been observed in previous studies^{18–20,22,26,30,31,37–40}, consistent with our findings.

As for the manner of death, natural death accounted for half of all cases, and IHD was the leading cause of death in both sexes, as previously reported^{18–20,26,30,31,33,37,39,41}. In cases of solitary death, a large number of natural deaths are considered to reflect a large number of elderly people. Interestingly, the finding that the peak age of natural death is in the 60s and 70s, and increases from the 40s for men and the 60s for women, is consistent with the finding of the age of solitary death. Kanawaku et al.³⁸ have reported that solitary death is a serious problem even among middle-aged men in their 40s, and that measures to prevent solitary death that target only the elderly are insufficient. Thus, we consider that it is important to take measures to prevent natural death in men from middle-aged onwards.

On the other hand, in the dementia cases, accidental death was overwhelmingly common, which was different from the overall trend of solitary deaths. It is reported that among people with cognitive impairment, the risk of accidental death and fall increased^{42,43}. Our results may suggest that cases with dementia require higher levels of unexpected accident prevention measures compared to cases without dementia. However, future data accumulation is necessary.

There was a difference in age distribution between accidental and suicidal death cases: accidental cases and suicidal cases were common in the 70s and 80s aged group and 30s to 60s age group, respectively. In line with a previous study²⁵, fire-related death was the most common cause of accidental cases of solitary deaths because most fire-related deaths were usually victims for forensic autopsy. And followed by traumatic death due to falls. According to a report by the Fire and Disaster Management Agency⁴⁴, more than 70% of the deaths from fires at home were from elderly persons aged ≥ 65 years, indicating that single-person households of the elderly population have a high risk of accidental death due to fire at home. Moreover, we recognize that deaths due to injuries caused by falls are important in that it is likely that the victim could have been saved had they been detected early. Because many traumatic deaths due to a fall takes a relatively long time from injury to death compared to sudden unexpected natural death or drowning etc. Most injuries from falls are not fatal⁴⁵. Therefore, early detection is most important, although it is not limited to falls. Our results in unexpected accidental deaths suggest that preventive measures tailored to the characteristics of the elderly are important.

The rate of suicide in Japan is higher among men, as in other countries. However, in line with previous study³⁷, the rate of suicide was higher in women than in men in our survey. One of the reasons for this may be that the suicide location is the home. According to the Japanese government⁴⁶, the domestic suicide rate is higher for women than for men. Similar trends have been observed in previous study⁴⁷. As for the suicide methods, hanging and intoxication were common methods, as previously reported^{20,37}. Suicide cases were more common in the younger generation than accidental death cases. This is expected to reflect the fact that suicides in Japan peak between the ages of 40 and 60⁴⁶. And in this study, the prevalence of psychiatric disease was higher in female than in men. This could be attributed to the fact that the most common method of suicide among women was drug overdose. Irii, et al.⁴⁸ and Hatake, et al.³⁷ reported that the prevalence of psychiatric disease was higher among cases of suicide by drug overdose. Therefore, it is important to provide psychological support to people with psychiatric disease.

We found two peaks in PMI-f: < 1 d and 7 days to < 1 month. The PMI in male cases was significantly longer than that in female cases. Several lines of accumulating evidence imply that a PMI of $\leq$ three days is the most common^{30,31,38,49}. In contrast, approximately half of the cases in this study were found more than seven days after death, suggesting that the victims were likely isolated from their families and communities. This tendency was greater in men than in women. In line with our observations, PMI of solitary death cases tended to be longer in men than in women^{18,19,22,24,32,37–39}. It is important that social exclusion is closely related to solitary and isolated deaths. The evaluation of PMI might be useful as an indicator of the isolated state^{24,27}. On the other hand, the PMI of external death cases was significantly shorter than that of natural death cases. There are two main reasons for this. First, there were many cases of home fires. Home fires are easily visible from the outside and are likely to be discovered early. Secondly, elderly individuals of external death cases may have been monitored more by family members or neighbors than that of natural death cases, because cases of external death were older than cases of natural death. The peak age of natural death was in the 60s and 70s, while that of external death was in the 70s and 80s. Regarding the relationship between age and PMI, several previous studies^{18,19,24} have reported that PMI tends to be shorter in older age groups among the elderly. And this same trend is true for between men and women.

According to several previous studies^{30,31,49}, the rate of discovery by family members/relatives was the highest (40–90%). In contrast, in this study, police officers were the most frequent finders, followed by family members/relatives. However, according to the sex of the victims, the rate of discovery by family members/relatives was higher in women than in men. It may be natural that the police were the most common of the first finder, because half of solitary death were more than seven days after death, and it was especially common among men. Regarding the relationship between PMI-f and the first finders, it has been pointed out that the rate of discovery by family members/relatives became lower in cases with long PMI-f^{31,33}. Thus, these observations imply that the type of first finder might be another indicator for the evaluation of the isolated state.

Hypertension was the most common, followed by DM and depression in both sexes, according to past medical history. Alcoholic liver disease, alcoholism, and schizophrenia were more frequent in men than in women. Previous studies^{24–26,39,41,50} have reported a higher prevalence of hypertension and alcohol-related disease in solitary death cases. Our results are consistent with this finding. Interestingly, as if to confirm that living alone is associated with deterioration in mental health^{10,51,52}, psychiatric disease such as depression were frequently observed in this study as well.

Accumulating evidence has shown that solitariness or isolation from the social community increases the risk of alcohol abuse, frailty, and sarcopenia^{53,54}. Moreover, welfare recipients often develop alcohol-related diseases⁵⁵. These observations imply that alcohol abuse, mental health, and physical health should be considered as risk factors of solitary death.

Several lines of accumulating evidence implied that there are regional characteristics and differences in the background of solitary deaths^{18,19,26,30–33}. Wakayama Prefecture has a long north–south terrain and consists of three areas: Kihoku, Kichu, and Kinan (Supplementary Fig. 1a). Population concentration in urban areas and local depopulation are serious issues. The aging rate and the rate of individuals in single-person households aged ≥ 65 years tended to be high, particularly in depopulated areas (Supplementary Fig. 1b,1c). In the present study, we found regional characteristics in the background of solitary deaths in the Wakayama Prefecture. The average annual number of solitary deaths per 100,000 population was 4.3 in Wakayama Prefecture. However, Kushimoto and Shingu, located in the southern part (Kinan region), had an extremely high solitary death rate in forensic autopsy cases. We suggest that this is because this area has the highest aging rates and the rate of individuals in single-person

households aged ≥ 65 years in Wakayama Prefecture. Several lines of accumulating evidence suggest that low income, unemployment, and welfare are risk factors for solitary death^{21,22}. With focus on economic conditions, 36 cases were welfare recipients. However, few cases were welfare recipients in solitary deaths in the Kinan region (Kushimoto and Shingu). In contrast, 23 of 36 welfare recipients, who had solitary death, lived in Wakayama city, indicating that the economic state would contribute more to the occurrence of solitary death in Wakayama city. These observations indicate a difference in the background of solitary deaths between urban and non-urban areas.

Finally, the present study demonstrated several risk factors and regional characteristics of solitary death cases. However, this study has a limitation in that all data were obtained from forensic autopsy cases. Therefore, it should be noted that it does not reflect all solitary deaths in Wakayama Prefecture. Previous studies have reported that some cases had long PMI-f despite living with family^{23–27}. Therefore, in future studies, it will be necessary to conduct a survey that is not limited to living alone. However, these observations could contribute to administrative welfare measures for the prevention of solitary deaths.

Conclusions

The findings of this study identified several risk factors and regional characteristics for solitary death cases. These observations based on forensic practice could contribute to administrative welfare measures for the prevention of solitary deaths.

Declarations

Conflict of interest statement

The authors have declared that no conflict of interest exists.

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Author contributions

Conceptualization: Y.H., T.K.; Formal Analysis: Y.K., A.I., Y.I., M.N., H.Y., J.M., H.Y., and S.H.; Funding Acquisition: Y.K., Y.I. and T.K.; Investigation: Y.H., A.I. and Y.I.; Project Administration: T.K.; Validation: M.N. and A.K.; Writing—Original Draft Preparation: Y.H.; Writing—Review and Editing: F.F., A.K. and T.K.

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Availability of data and materials

The authors declare that all data are available in the article file, or available from the authors upon reasonable request.

Ethical approval and consent to participate

Our study was approved by the Research Ethics Committee of Wakayama Medical University (No. 3228). All procedures were carried out in accordance with the Declaration of Helsinki Principles. Moreover, this study was conducted using autopsy records from the past, and we could not obtain informed consent from the bereaved family for the use of the records. Therefore, in accordance with the “Ethical Guidelines for Medical Research Involving Human Subjects (enacted by the Ministry of Health, Labor and Welfare in Japan),” Sect. 12–1 (2) (a) (c). Thus, the review board of Research Ethics Committee of Wakayama Medical University waived the need for written informed consent from relatives of individuals studied since this was a de-identified retrospective study of archived autopsy records.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Figures

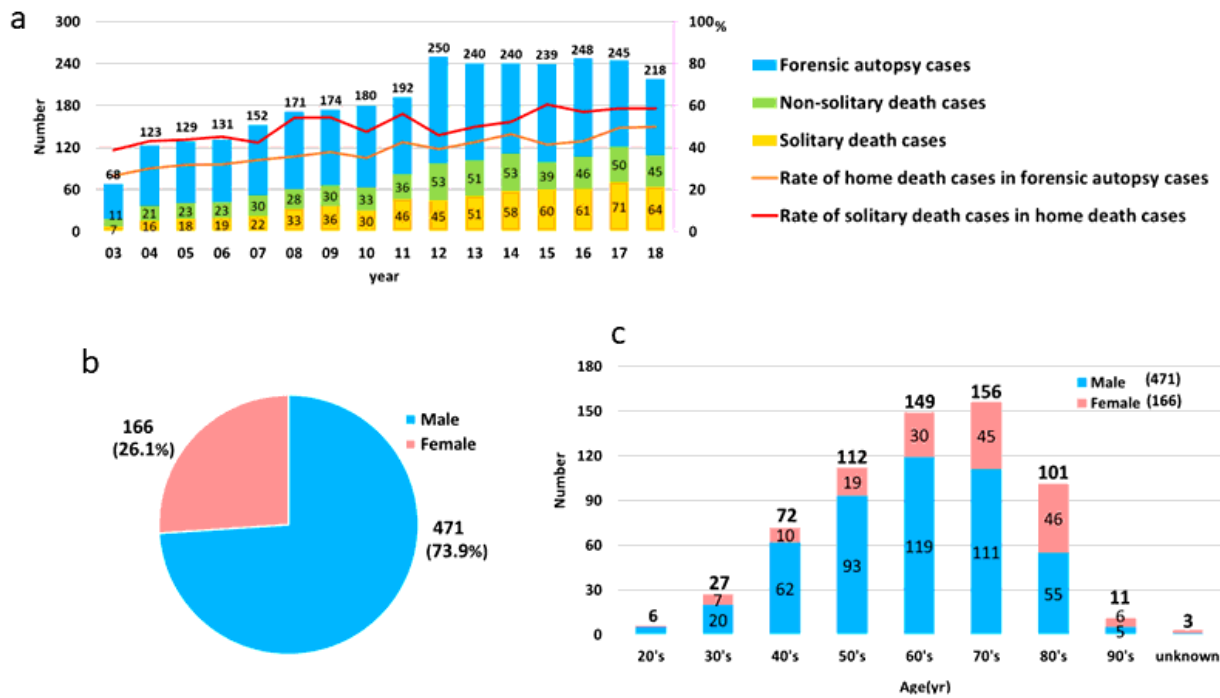


Figure 1

Figure 1

(a) Change in cases of home death and solitary death.

Home death cases: Combined solitary and non-solitary death cases.

(b) Sex distribution.

(c) Age distribution.

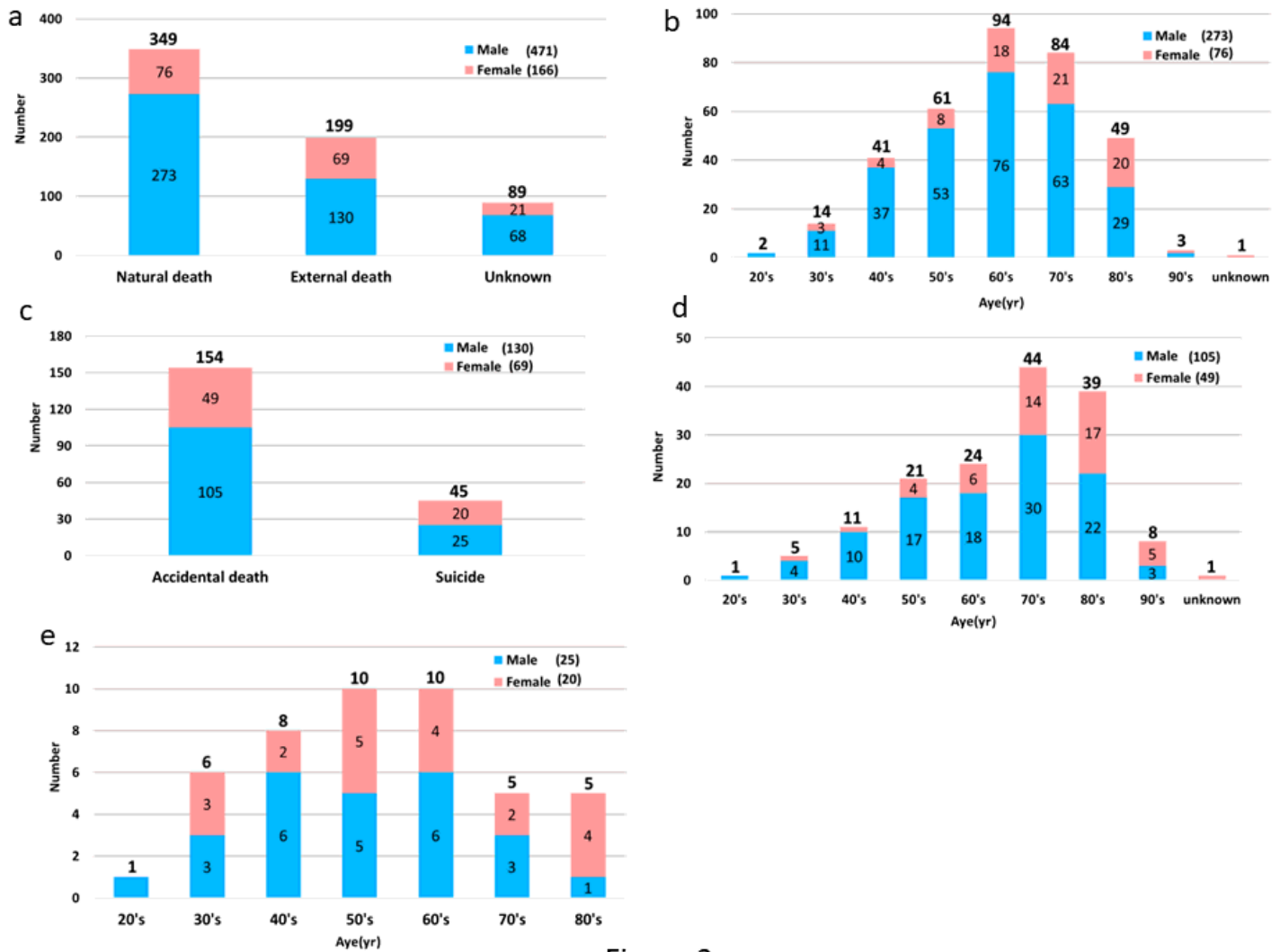


Figure 2

Figure 2

- (a) Manner of death.
- (b) Age distribution of natural death.
- (c) Manner of external death.
- (d) Age distribution of accidental death.
- (e) Age distribution of suicidal death.

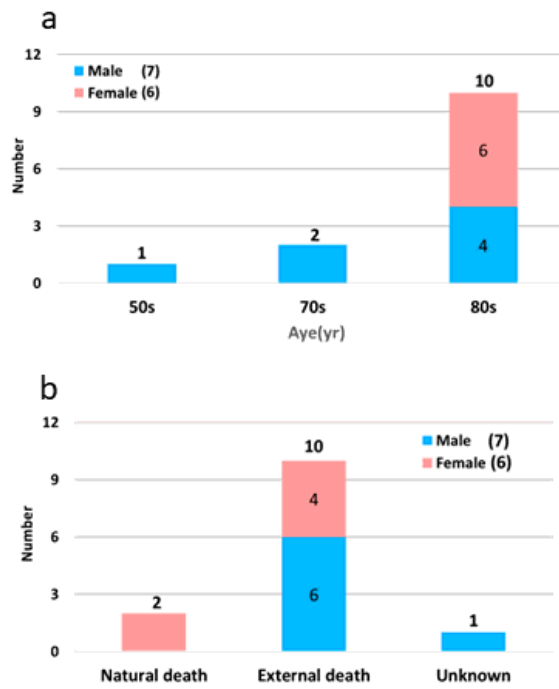


Figure 3

Figure 3

(a) Age distribution of dementia cases.

(b) Manner of death in dementia cases.

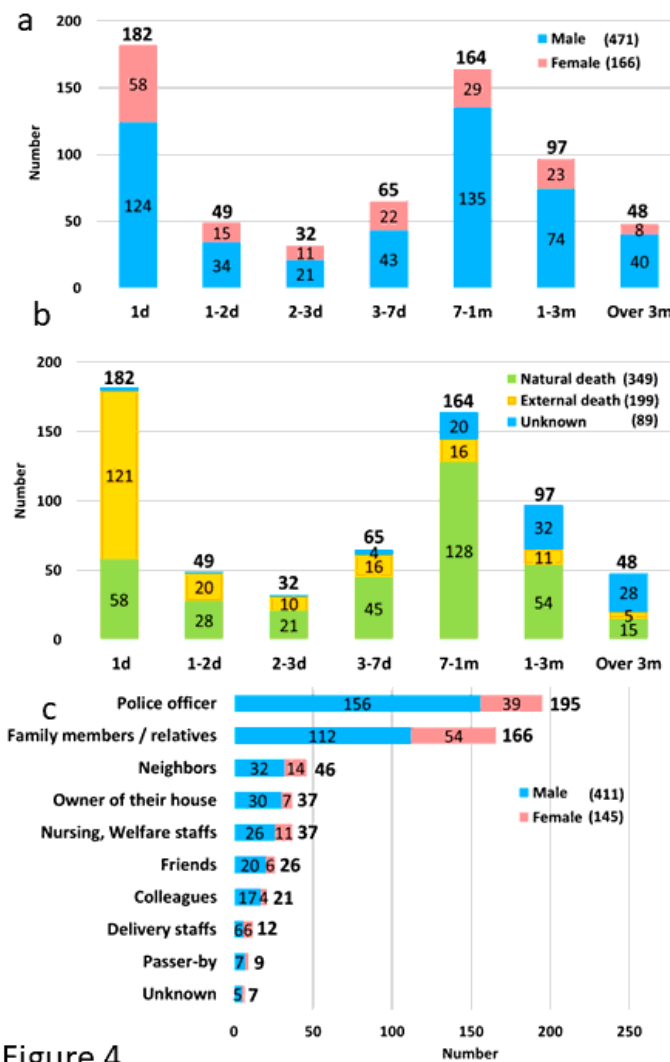


Figure 4

Figure 4

(a) Postmortem interval until finding.

(d: day, m: month)

(b) Postmortem interval until finding in accordance with the manner of death.

(d: day, m: month)

(c) First finder.

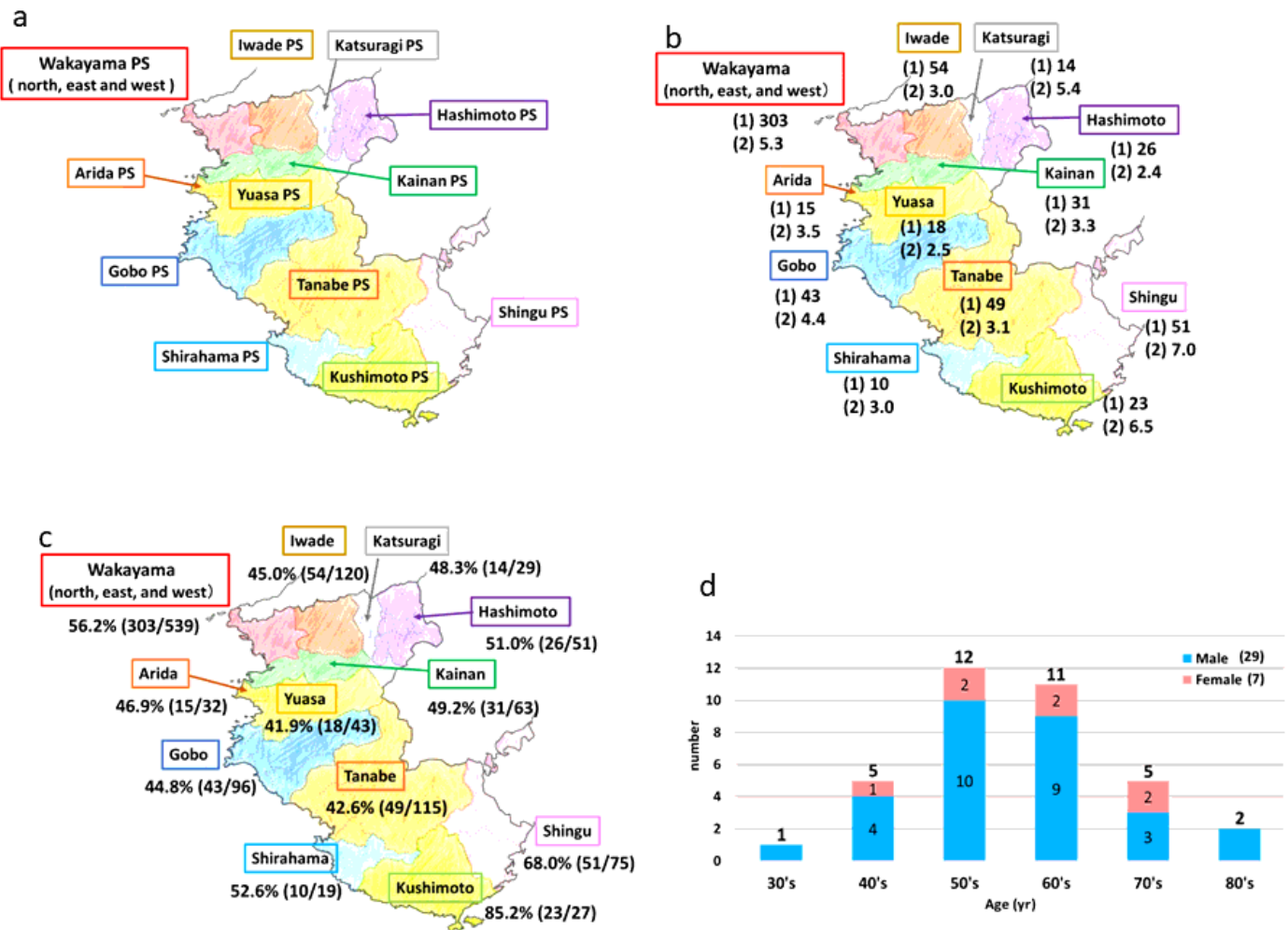


Figure 5

Figure 5

(a) Wakayama Police Station in Wakayama Prefecture.

PS: Police Station.

(b) The number of solitary death cases by police station and average annual

number of autopsies for solitary death cases per 100,000 population.

(1) The number of solitary death cases by police station.

(2) Average annual number of autopsies for solitary death cases per 100,000 population (average: 4.3).

(c) The rate of solitary death among home death cases by police station.

%: rate of solitary death among home death cases by police station (average: 52.7%).

() : number of solitary death cases/ home death cases.

(d) Age distribution of welfare recipients.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryDatasetfilelessolitarydeath.pdf](#)