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Factors that prolong the 'postmortem interval until finding' (PMI-f) among community-dwelling elderly individuals in Japan: analysis of registration data

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ABSTRACT

Objectives: To clarify the factors affecting 'postmortem interval until finding' (PMI-f) among elderly unexpected death cases.

Design: Cross-sectional study.

Setting: All area of Yamagata prefecture in Japan.

Participants: Entering subjects were 5675 elderly cases with age of ≥ 65 years selected from all 9002 cases of unexpected death from 2002 to 2007 in Yamagata prefecture between 2002 and 2007. Our final study subjects consisted of 3387 cases sampled with several criteria to assess the factors to prolong PMI-f.

Primary outcome measures: The outcome was the postmortem interval until finding (PMI-f) as the time from death until finding the body which we defined in this study.

Results: 'Living alone' showed the highest adjusted HR (3.73, 95% CI 3.37 to 4.13), also 'unnatural death' (1.50, 1.28 to 1.75), 'found at own home' (1.37, 1.22 to 1.55) and 'younger subjects' (0.99, 0.98 to 0.99). In the model including interactions with the household situation, we found 'male subjects living alone' and 'female subjects living with family' tended to be found later.

Conclusions: PMI-f is an effective outcome for quantitative analyses of risk of bodies left. To prevent the elderly dead bodies left for long time, it is necessary to keep regular home-based contact with elderly individuals living alone.

INTRODUCTION

In Japan, the population has been ageing at the highest rate in the developed world, and the proportion of people 65 and older was 23% in 2010. It has been projected that about 30% of the total population will be older than 65 in 2050.¹ The low total fertility rate, 1.37 in 2009, is also adding to the rapid changes in the Japanese population structure. In

ARTICLE SUMMARY

Article focus

■ Elderly Solitary Death, the case of elderly dead body left for long time and having regrettable post-mortem body change, is the public health issue in ageing society. We tried to reveal the causal relation for the dead bodies left for long time.

Key messages

■ Our results showed who, how, and how long a time elderly individuals' bodies tend not to be found. This study should help policy makers to identify and counsel of citizens at risk and to assess priorities for their services given limited budgets.

Strengths and limitations of this study

■ Our data were based on only one region. However, no study has discussed the causal factors involved in the dead bodies left for long time using the huge data of forensic medicine through several years.

addition to this rapid ageing, dramatic changes in family situations have occurred, affecting several aspects of society and leading to the weakening of the caretaking function traditionally performed by families.

At the same time, solitary death among elderly individuals has appeared as a new social problem related to the ageing society. The phrase 'solitary death' came into use in the mass media's reporting of a case that occurred in Japan during the 1980s in which the skeletal remains of an elderly person living alone was found as a result of the prolonged length of time from death until the finding of the dead body.² The Japanese people were shocked by the individual's remarkable postmortem bodily changes.

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Cleaning solitary deaths up has been established as a business for stable incidents of elderly solitary deaths. That unusual job was noticed by foreigners and elderly solitary death was introduced as just a Japanese problem.³ However, this Japanese issue has been spread over the sea. In Korea, several solitary deaths were reported in 2011.⁴ Korean rapid ageing of society with similarity to Japan has also influenced the social function around family.

However, what is 'solitary death' has not been defined clearly yet. Most of articles, which had tried to reveal the 'solitary death,' mentioned that this lack of definition is the biggest problem. One letter article from Japan showed the 35 cases treated as solitary deaths in 8 years from 2000. They showed the association between incident of solitary death and person who found resident's status in the public housing complex.⁵ In this report, they defined whether a case is solitary death or not depending on subjective opinion of person who found the case. One study operationally defined solitary death as unexpected death among the people living alone,⁶ in the other study, they added the death occurred at their own house on that definition.⁷ As a broader definition, there were some articles said solitary death is occurred not only among people living alone.^{8,9} One study researched the municipal bodies' practices for solitary death.¹⁰ They revealed that the definition of solitary death was varied.

Under these confused background, many studies tried to explain solitary death with various view points, such as household,^{6-8,10-12} age of subject,^{6,7,10,11} cause of death,^{7,8,10,11} the place where the subject was found,^{8,10} or the person who found the subject.^{7,8,12} All of these articles dealt with the time spent after the death^{6-8,10-12} as main characteristic of solitary death. The death left for long time and making remarkable postmortem bodily change must be avoided and the time spent after the death can be an important view point on solitary death. Therefore, in this study, we focused solely on this time spent after the death and analysed the factors affected on it.

About the time spent after the death, the 'postmortem interval' (PMI) is the essential parameter in forensic medicine. PMI is defined as the time from death until examination. There is one study on this PMI and they showed that the average of PMI was longer among the elderly living alone.⁶ However, because our study focused on the *finding* of a dead body, we defined the 'PMI until finding' (PMI-f) as the period from the estimated time of death until the finding of the dead body.

To obtain information about PMI-f, we focused on forensic medical data. Forensic medical data, especially the post-mortem examination (inspection) records, are informative in understanding the circumstances of deaths, including those involving elderly cases with long PMI-f.

On this PMI-f from forensic data, one study has been published. This study treated PMI-f as a categorical variable and presented only descriptive findings.⁷ To our knowledge, no study has discussed the causal factors to prolong the finding of the dead body and has analysed

PMI-f as a continuous quantity with Cox regression model. In addition, the household situation has been considered to be the prior factor making the differences in the process of leaving and finding of the dead body according to the literatures reported previously.^{6,8,13} Thus, the aim of the present study was to clarify the factors affecting PMI-f among elderly unexpected death cases by elderly people, focusing on the affect by the household situation.

METHODS

Definition of PMI-f

We defined the PMI-f as the time from death until finding the body. Thus, PMI-f typically has a positive value. Occasionally, the body is found *earlier* than the estimated time of death such as when a person is found dying and is rushed to the emergency unit of a hospital. In these cases, the death was confirmed by a medical doctor after medical examination.

Study setting

The subjects, which were registered in Yamagata prefectural police headquarter in Japan, consisted of 9002 cases of unexpected death from 2002 to 2007; they were a subset of the total of 76 788 deaths in Yamagata prefecture between 2002 and 2007.

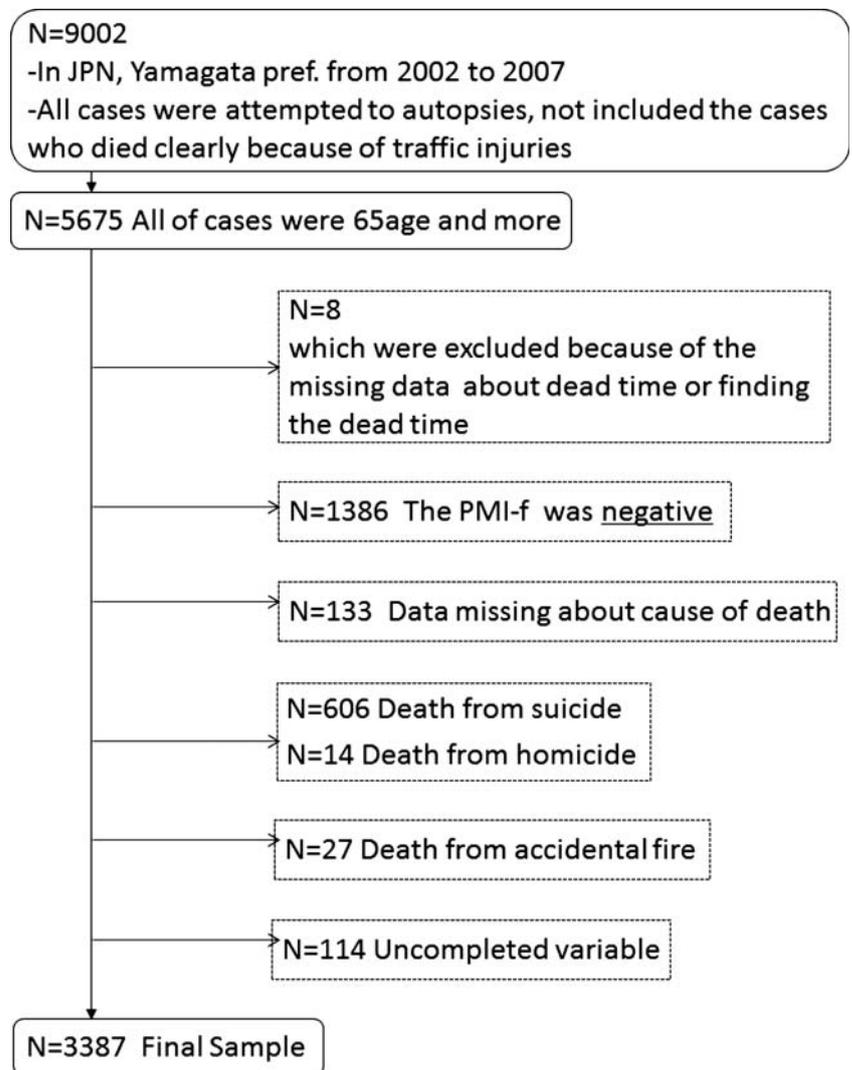
In Japan, police officers investigate all reported unexpected deaths to determine whether it is criminal case or not. Japanese law mandates that doctors report all unexpected deaths to the police. Even subjects whose death is witnessed (eg, when individuals are rushed to a hospital) are also subject to postmortem examination if the situations are not clear. If necessary, the autopsy is conducted as further examination by forensic pathologist.

Consent for use of the data was approved by Yamagata prefectural police headquarter after a formal application and explicit pledge to randomise all data and remove any individual identifiers to protect the privacy of the personal data supplied. Ethical considerations were examined in accordance with Japanese epidemiological guidelines for secondary data analysis. Our study was approved by the official ethical review board of University of Tsukuba and Yamagata University.

We used the following six criteria for selecting subjects in that order shown in [figure 1](#).

1. Age of ≥ 65 years ($n=5,675$) were included.
2. The subject whose PMI-f was zero or positive was included. Eight subjects were excluded because of missing data about the death or time of finding the body, and 1386 subjects were excluded because their PMI-f was less than zero.
3. Unclear cause of death ($n=133$) were excluded.
4. The cases involving suicide ($n=606$) and homicide ($n=14$) were excluded because the PMI-f was influenced by human intentions or actions and these cases could not meet the situation of solitary death.
5. Accidental fire ($n=27$) were excluded. Notification of the accident and PMI-f tended to be much shorter in

Figure 1 Sampling for final subjects.



cases of accidental fire than in other accidental deaths because of the resulting fire and smoke.⁸

6. Availability of complete data regarding the variables in our analytical model; 114 subjects were excluded because of incomplete data.

Variables

We used data about the following characteristics of the subjects; age at death, sex and household situation. In the autopsy, the police officers make the inquiry about subjects' living situation into subjects' relatives, neighbourhoods or any persons concerned, and make the official records of autopsy. The cause of death was classified as the natural death or the unnatural death from accident. We also analysed data about the relationship between the subjects and the person who found them and the place at which they were found.

Statistical analyses

First, we summarised the characteristics of the subjects in terms of exact numbers and proportions (table 1).

Second, we prepared Kaplan-Meier estimates with the generalised Wilcoxon test between the two categories of sex, household situation, cause of death, the place at which the subject was found, and the person who found the subject (results not shown). All the explanatory variables except for age were treated as dichotomous for purposes of simplicity. A Cox regression was conducted to establish the factors that prolonged the PMI-f with adjusting for the explanatory variables. We checked proportionality in the Cox model by the linearity of the log-log plot of the variables.

To assess the affect by the household situation, we created the product terms of the household situation to estimate the influence of interactions and analysed the models stratified by the household situation.

We used a significance level of 0.05 throughout this study. All analyses were conducted using the SAS software (V.9.1; SAS Institute Inc, Cary, North Carolina, USA).

RESULTS

Our final study sample consisted of 3387 cases. Characteristics of the study sample are presented in

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Table 1 Characteristics and situations in which study subject died and was found

Variables	n (%)
Age	
65≤, <75	957 (28.3)
75≤, <85	1565 (46.2)
85≤	865 (25.5)
Sex	
Male	1892 (55.9)
Female	1495 (54.1)
Household situation	
Living alone	659 (19.5)
Living with family	2728 (80.5)
Variables related to how study subject died	
Cause of death	
Natural death	3143 (92.8)
Cardiac problems	2390 (76.0)
Brain hemorrhage	441 (14.0)
Others	312 (9.9)
Unnatural death	244 (7.2)
Drowning	70 (28.7)
Falling from a height	61 (25.0)
Suffocation	57 (23.4)
Hypothermia	20 (8.2)
Poisoning	3 (1.2)
Others	33 (13.5)
Place at which the subject was found	
Indoors	3073 (90.7)
At own home site	2766 (90.0)
In hospital	224 (7.3)
At hotel	55 (1.8)
At relative's home	7 (0.2)
In vehicle at own home	2 (0.0)
In hut in mountain or forest	1 (0.0)
Others	18 (0.6)
Outdoors	314 (9.3)
In water*	100 (31.8)
On own property	63 (20.1)
In mountain or forest	44 (14.0)
On street	26 (8.3)
In vehicle on street	13 (4.1)
In hospital	2 (0.6)
At relative's home	3 (1.0)
Others	63 (20.1)
Person who found the subject	
Not family member	803 (23.7)
Neighbour	176 (21.9)
Passer-by	90 (11.2)
Others	537 (66.9)
Family member	2584 (76.3)
All	3387

*In a river, pond, lake, body of water used for industrial or agricultural purposes or a reservoir.

table 1. Over 70% of all cases were older than 75 years of age, and the maximum age was 101. In 659 cases (20%), the subject lived alone. Most dead bodies were found by family members (76%). The distribution of PMI-f is shown in table 2. The maximum PMI-f was 365 days. This was the one case which was older than 75,

female, natural death and found at own home by her family member. The PMI-f in 96 cases (3%) was zero. The distribution of PMI-f was concentrated around less than 1 day (87%). Among 49% of subjects living alone, their PMI-fs were more than 1 day.

Crude and adjusted HRs and 95% CIs for increasing of PMI-f were shown in table 2. In the crude models, the four variables with significant HRs were age, household situation, the place at which the dead body was found, and the person who found the dead body. The adjusted risk of living alone was the highest of all independent variables (HR 3.73, 95% CI 3.37 to 4.13). In the adjusted model, younger age (0.99, 0.98 to 0.99), unnatural death due to an accident (1.50, 1.28 to 1.75) and found at one's own home (1.37, 1.22 to 1.55) were also significant risk factors that delayed the finding of bodies.

The results of the model including interactions are also shown in table 2. Living alone showed the strongest influence (2.34, 1.64 to 3.33) also in the fully adjusted model including interactions. Other variables related to long PMI-f: age (0.99, 0.98 to 0.99), male (0.89, 0.82 to 0.96), unnatural death (1.45, 1.24 to 1.72) and finding at own home (1.32, 1.14 to 1.52). Significant interactions of the household situation (=living alone) were observed among male (1.31, 1.10 to 1.56) and finding at one's own home (1.47, 1.06 to 2.05).

The HRs of the multivariate model with interactions, 0.89 for sex, 2.34 for household situation and 1.34 for their interaction, mean that the males of living alone prolong the median PM-f 0.92 day, the males with family shrink it 0.01 day, and the females of living alone prolong it 0.29 day, with the reference of the females with family, which are obtained by transforming these HRs to median PM-f days in the model (not shown in table). The stratified analysis in table 3 showed the significant relations with longer PMI-f, among subjects living alone, finding at own home (1.99, 1.48 to 2.67), unnatural death (1.72, 1.02 to 2.91), male (1.23, 1.04 to 1.44), younger age (0.97, 0.96 to 0.98) in the adjusted model shown in table 3. Among subjects living with family, sex of male related shorter PMI-f (0.92, 0.85 to 0.99) as opposed to the case in living alone.

DISCUSSION

We assessed the factors affecting PMI-f using Cox regression models on forensic medical data. These results showed that living alone was the single most influential factor contributing to delays in finding elderly dead body. Other factors included death attributable to external causes, and younger age. We also considered interactions between household situation and other the independent variables, and found additional effects on delays in finding the dead body. These interactions may be interpreted in a multicausal model and our model referred to more empirical conclusion. To our knowledge, this is the first published study to conduct

Table 2 Distribution of postmortem interval until finding (PMI-f) and HRs

Variables	n	PMI-f (days)				Univariate models		Multivariate model		Multivariate model with interactions	
		Median	IQR	Q1	Q3	HR	95% CI	HR†	95% CI†	HR‡	95% CI‡
Age						0.98	0.97 to 0.98	0.99	0.98 to 0.99	0.99	0.98 to 0.99
65≤, <75	957	0.17	0.57	0.03	0.60						
75≤, <85	1565	0.13	0.40	0.02	0.42						
85≤	865	0.10	0.26	0.02	0.28						
Sex											
Male	1892	0.12	0.36	0.02	0.38	0.96	0.90 to 1.03	0.93	0.87 to 1.00*	0.89	0.82 to 0.96
Female	1495	0.15	0.41	0.03	0.44	1.00		1.00		1.00	
Household situation											
Living alone	659	1.00	2.54	0.46	3.00	3.92	3.58 to 4.31	3.73	3.37 to 4.13	2.34	1.64 to 3.33
Living with family	2728	0.08	0.23	0.01	0.24	0.24		1.00		1.00	
Cause of death											
Unnatural death	244	0.07	0.40	0.00	0.40	0.89	0.78 to 1.02	1.50	1.28 to 1.75	1.46	1.24 to 1.72
Natural death	3143	0.13	0.37	0.03	0.40	1.00		1.00		1.00	
Place at which the subject was found											
At own home	2766	0.16	0.40	0.04	0.44	1.53	1.40 to 1.67	1.37	1.22 to 1.55	1.32	1.14 to 1.52
Not at own home	621	0.03	0.23	0.00	0.23	1.00		1.00		1.00	
Person who found the subject											
Not family member	803	0.19	0.98	0.00	0.98	1.40	1.29 to 1.52	1.02	0.92 to 1.13	1.04	0.90 to 1.19
Family member	2584	0.13	0.29	0.03	0.32	1.00		1.00		1.00	
All			0.13	0.38	0.02	0.40					
(interaction terms§)											
Living alone and male										1.31	1.10 to 1.56
Living alone and unnatural death										1.12	0.64 to 1.96
Living alone and finding at own home										1.47	1.06 to 2.05
Living alone and not finding by family member										0.93	0.75 to 1.14

*p=0.0515.

†Age, sex, household situation, person who found the subject, cause of death and place at which the subject was found.

‡Age, sex, household situation, person who found the subject, cause of death, place at which the subject was found and interactions.

§Reference of interaction term is others.

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Table 3 Distribution of postmortem interval until finding (PMI-f) and HRs stratified by household situation

Variables	n	PMI-f (day)				Univariate models		Multivariate model	
		Median	IQR	Q1	Q3	HR	95% CI	HR†	95% CI†
Living alone (n=659)									
Age						0.97	0.96 to 0.98	0.97	0.96 to 0.98
65≤, <75	245	1.61	3.30	0.53	3.83				
75≤, <85	315	0.99	2.56	0.44	3.00				
85≤	99	0.61	1.44	0.36	1.80				
Sex									
Male	343	1.19	2.81	0.46	3.27	1.29	1.11 to 1.51	1.23	1.04 to 1.44
Female	316	0.87	1.56	0.46	2.02	1.00		1.00	
Cause of death									
Unnatural death	17	1.61	2.03	0.45	2.48	1.00	0.62 to 1.61	1.72	1.02 to 2.91
Natural death	642	1.00	2.54	0.46	3.00	1.00		1.00	
Place at which the subject was found									
At own home	600	1.08	2.50	0.50	3.00	1.74	1.33 to 2.28	1.99	1.48 to 2.67
Not at own home	59	0.27	1.94	0.00	1.94	1.00		1.00	
Person who found the subject									
Not family member	337	0.98	2.54	0.46	3.00	0.95	0.82 to 1.11	0.94	0.82 to 1.08
Family member	322	1.08	2.54	0.46	3.00	1.00		1.00	
Living with family (n=2728)									
Age						0.99	0.99 to 1.00*	0.99	0.99 to 1.00*
65≤, <75	712	0.08	0.24	0.01	0.25				
75≤, <85	1250	0.08	0.23	0.01	0.24				
85≤	766	0.08	0.19	0.02	0.21				
Sex									
Male	1549	0.08	0.22	0.01	0.23	0.93	0.86 to 1.00*	0.92	0.85 to 0.99
Female	1179	0.09	0.22	0.02	0.24	1.00		1.00	
Cause of death									
Unnatural death	227	0.06	0.33	0.00	0.33	1.17	1.02 to 1.35	1.35	1.02 to 2.91
Natural death	2501	0.08	0.21	0.02	0.23	1.00		1.00	
Place at which the subject was found									
At own home	2166	0.10	0.21	0.03	0.24	1.17	1.06 to 1.28	1.32	1.14 to 1.51
Not at own home	562	0.02	0.20	0.00	0.20	1.00		1.00	
Person who found the subject									
Not family member	466	0.01	0.19	0.00	0.19	0.87	0.79 to 0.97	0.94	0.82 to 1.08
Family member	2262	0.10	0.21	0.03	0.24	1.00		1.00	

*p<0.05.

†Age, sex, person who found the subject, cause of death and place at which the subject was found.

statistical analyses with estimated models to reveal factors related to PMI 'until finding.'

The analyses demonstrated that living alone was the strongest predictor of delays in finding elderly dead bodies; the risk was about four times higher in this group than in those living with family. This finding suggests that elderly subjects living alone were isolated and contactless. One study surveyed survival after falling among people living alone in San Francisco.¹³ Of 387 people, 90 were left un-rescued for an average of 18 h after becoming helpless in their own homes and died. Citizens living alone were difficult to find if they fell down. In Japan, the proportion of community-dwelling elderly individuals living alone is increasing with ageing. The proportion of elderly individuals living alone among whole elderly people was 13.8% in 2000 and 16.4% in 2010.¹⁴ This high risk to left the dead body for long time in living alone became an urgent public health issue.

We found the contrary results regarding sex between household situations (living alone or with family). 'Male subjects living alone' and 'female subjects living with family' tended to prolong their PMI-f. Male elderly people, in general, are said to have poor social relation. Thus, their dead bodies should be difficult to be found by their neighbourhoods or friends. However, among the subjects living with family, male subjects tend to be found their dead bodies than female subjects. In cases of male people, their family member will make more effort to seek. This might be due to the presence of spouse. In Japan, the life expectancy is longer in female people than in male¹⁵ and the age of a husband used to be older than his wife.^{15 16} It is suggested that the number of female widows were greater than male.

Interaction between living alone and dying at one's own home showed effect on PMI-f. This interaction showed the situation that elderly individual's home could be a risk factor to make them more isolated. This risk

indicates the need for automatic alarm-and-notification systems. Some municipalities provide such systems connected to local rescue services.¹⁷ If accidents occur, the systems can notify to rescue services. In addition to these systems, an important first step in preventing solitary death is to raise public awareness of the likelihood that elderly people living alone may become helpless and isolated in their homes within a community.

Regarding the causes of death included in our model, unnatural causes (eg, drowning, suffocation and falling) were associated with the fact that they are found later. It is natural that the people who were under medical care with some internal diseases can be found earlier. In contrast, external accidents happen suddenly, and therefore it is difficult for relatives to find the dead bodies. In reality, the biggest single cause of incapacitation that was left alone was reported to be a fall.¹³

In our adjusted model, younger individuals' deaths were found later. This suggests that accidents may have had a bigger impact on younger elderly than older individuals because the former may have been less concerned about death. The situation in which an individual dies and her/his dead body is found can be affected by her/his life and relationships while alive, especially in cases of unfortunate accidents. With a little of individual's concern and correspondence about her/his possibility of death, the people around her/him also can less take care of her/him death and find the dead body later.

We found differences between the crude and adjusted models with regard to significant variables. The identity of the person who found the dead body did not affect the PMI-f in the adjusted model. This indicates that who found the dead body depended on other factors and so that there was no directive this variable's association to PMI-f.

Our present study had several limitations. Variable settings were based on the official record written about the living and dying among the subjects by police officers. Variables including basic characteristics and other components were confirmed to be recorded. Those records were based on the inquiries by the police office; however, the accuracy of the information was not secured and it is difficult to assess the validation retrospectively. All of our study subjects were the cases that were reported as unexpected deaths and that were examined by police officers. This reporting system abides by law with compulsion for medical doctors. However, there should be unexpected deaths that are not reported and not performed autopsies. For example, if the doctors have known the family and attended the elderly before, they may not report the unexpected death. If such underreported cases were present, our PMI-f should be longer than actual one because PMI-f in such cases may not be so long. Other situations also may present. Our results should be captured under this limitation.

The PMI-f was analysed as an outcome in our multivariate model for the first time. Our results showed who,

how, and how long a time elderly individuals' bodies tend not to be found. These findings can provide the basis for more effective measures to prevent the phenomena of solitary death among elderly individuals; the delays in finding the bodies of elderly individuals that lead to regrettable postmortem changes. This study should help policy makers to identify and counsel of citizens at risk and to assess priorities for their services given limited budgets. Future studies should evaluate interventions designed to prevent solitary death among elderly individuals and this PMI-f could be a useful quantitative indicator.

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