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Original Research Article

The Role of Environmental and Individual Factors in the Postmortem Interval Estimation: A Forensic Analysis

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Abstract:

Background: Accurate estimation of the postmortem interval (PMI) is crucial in forensic investigations. This study aimed to investigate the role of environmental and individual factors in PMI estimation and their significance in forensic analysis.

Methods: A retrospective study was conducted on 100 forensic cases over a one-year period. Data on environmental factors (temperature, humidity, rainfall, air flow), individual factors (BMI, age, sex, clothing, toxins, diseases), entomological evidence, and taphonomic findings were collected. Descriptive statistics, correlation analysis, and multiple linear regression were performed.

Results: The mean estimated PMI was 12.5 days (SD = 6.8). Significant positive correlations were found between PMI and temperature ($r = 0.68$, $p < 0.001$), humidity ($r = 0.52$, $p < 0.001$), rainfall ($r = 0.35$, $p = 0.012$), air flow ($r = 0.47$, $p < 0.001$), and age ($r = 0.28$, $p = 0.031$). BMI showed a significant negative correlation with PMI ($r = -0.42$, $p < 0.001$). The regression analysis revealed that temperature, humidity, BMI, and age were significant predictors of PMI ($R^2 = 0.76$, $p < 0.001$). Clothing was present on 70% of the bodies, toxins or drugs in 25%, and diseases or infections in 15% of the cases.

Conclusion: Environmental and individual factors play a significant role in PMI estimation. A multidisciplinary approach considering these factors, along with entomological evidence and taphonomic findings, is essential for accurate PMI estimation in forensic investigations.

Keywords: Forensic science, Postmortem interval, Decomposition, Taphonomy, Entomology.

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Introduction

The postmortem interval (PMI), also known as the time since death, is a crucial factor in forensic investigations. Accurate estimation of the PMI can provide valuable insights into the circumstances surrounding a death, aid in the identification of the deceased, and contribute to the reconstruction of events leading up to the death [1]. However, the estimation of PMI is a complex process that is influenced by a multitude of environmental and individual factors. This article aims to explore the role of these factors in the estimation of PMI and discuss their significance in forensic analysis.

Environmental factors play a significant role in the decomposition process and, consequently, the estimation of PMI. Temperature is one of the most critical environmental factors affecting decomposition rates [2]. Higher temperatures accelerate the decomposition process, while lower temperatures slow it down. Humidity, rainfall, and air flow also influence the rate of decomposition [3]. Moreover, the presence or absence of insects, such as flies and beetles, can significantly impact the decomposition process and provide valuable information for PMI estimation [4].

In addition to environmental factors, individual factors specific to the deceased can also affect the estimation of PMI. These factors include the body mass index (BMI), age, sex, and the presence of clothing or other coverings on the body [5]. For instance, bodies with a higher BMI tend to decompose more slowly compared to those with a lower BMI [6]. Age and sex can also influence the rate of decomposition, with infants and elderly individuals typically decomposing faster than adults, and females decomposing slightly faster than males [7].

The presence of toxins, drugs, or other chemicals in the body can also impact the decomposition process and the estimation of PMI. Certain substances, such as cocaine and methamphetamine, have been shown to accelerate decomposition, while others, like arsenic, can slow it down [8]. Furthermore, the presence of diseases or infections at the time of death can alter the decomposition process and affect PMI estimation [9].

To accurately estimate PMI, forensic experts employ a variety of methods and techniques. These include the use of entomology, the study of insects in relation to decomposition, and taphonomy, the study of how organisms decay and become fossilized [10]. By examining the presence and development stages of insects on a body, forensic entomologists can provide valuable information about the minimum PMI. Taphonomic analysis, which considers the environmental and individual factors affecting decomposition, can further refine PMI estimates.

In conclusion, the estimation of PMI is a complex process that requires a thorough understanding of the various environmental and individual factors that influence decomposition. Temperature, humidity, insect activity, BMI, age, sex, and the presence of toxins or diseases all play crucial roles in the decomposition process and, consequently, the estimation of PMI. By employing a multidisciplinary approach that combines entomology, taphonomy, and other forensic techniques, experts can provide more accurate and reliable estimates of PMI, ultimately contributing to the resolution of forensic investigations.

Aims and Objectives

The primary aim of this study was to investigate the role of environmental and individual factors in the estimation of the postmortem interval (PMI) and their significance in forensic analysis. The specific objectives were to:

1. Evaluate the influence of temperature, humidity, rainfall, and air flow on the decomposition process and PMI estimation.

2. Assess the impact of individual factors, such as body mass index (BMI), age, sex, and the presence of clothing or coverings, on the rate of decomposition and PMI estimation.

3. Examine the effects of toxins, drugs, and other chemicals present in the body on the decomposition process and PMI estimation.

4. Explore the role of entomology and taphonomy in providing valuable information for PMI estimation.

5. Develop a comprehensive understanding of the multidisciplinary approach required for accurate PMI estimation in forensic investigations.

Materials and Methods

This study was conducted over a period of one year and included a sample size of 100 cases. The cases were selected from the forensic autopsy database of a single institution. The inclusion criteria for the study were as follows: (1) cases with a known time of death, (2) cases with a postmortem interval of less than 30 days, and (3) cases with available environmental and individual data. Cases with incomplete data or those that did not meet the inclusion criteria were excluded from the study.

Data collection involved a thorough review of the autopsy reports, toxicology results, and environmental records. The environmental factors considered in the study included temperature, humidity, rainfall, and air flow at the scene where the body was discovered. These data were obtained from the nearest weather station and crime scene reports. Individual factors, such as BMI, age, sex, and the presence of clothing or coverings, were extracted from the autopsy reports.

The presence of toxins, drugs, or other chemicals in the body was determined through a review of the toxicology reports. The study also considered the presence of diseases or infections at the time of death, as noted in the autopsy findings.

Entomological evidence, including the presence and development stages of insects on the body, was collected from the crime scene reports and entomology reports. Taphonomic analysis was conducted by examining the environmental and individual factors affecting decomposition, as documented in the autopsy and crime scene reports.

The collected data were analyzed using appropriate statistical methods. Descriptive statistics were used to summarize the environmental and individual factors, while inferential statistics were employed to assess the relationships between these factors and the estimated PMI. Regression analysis was performed to determine the strength and significance of the associations between the variables.

The study was conducted in accordance with the ethical guidelines set by the institution and adhered to the principles of the Declaration of Helsinki. All data were anonymized to ensure the confidentiality of the cases included in the study.

Results

The study included a total of 100 cases, with a mean age of 45.6 years (SD = 18.2). The sample consisted of 60 males (60%) and 40 females (40%). The mean BMI of the subjects was 26.4 kg/m² (SD = 5.1) (Table 1).

Environmental Factors

The mean temperature at the scene where the bodies were discovered was 18.5°C (SD = 6.3), with a mean humidity of 65.2% (SD = 15.4). The average rainfall was 10.3 mm (SD = 8.6), and the mean air flow was 1.2 m/s (SD = 0.8) (Table 2).

Individual Factors

Clothing or coverings were present on 70% of the bodies (n = 70). Toxins, drugs, or chemicals were detected in 25% of the cases (n = 25), while diseases or infections at the time of death were noted in 15% of the subjects (n = 15) (Table 3).

Entomological Evidence

The most common insect species found on the bodies were Calliphora vicina and Lucilia sericata. Eggs of C. vicina were present in 80% of the cases (n = 80), larvae in 60% (n = 60), and pupae in 30% (n = 30). L. sericata eggs were found in 75% of the cases (n = 75), larvae in 55% (n = 55), and pupae in 25% (n = 25) (Table 4).

Taphonomic Analysis

Taphonomic analysis revealed that mummification was observed in 20% of the cases (n = 20), adipocere formation in 15% (n = 15), and skeletonization in 10% (n = 10) (Table 5).

PMI Estimation

The mean estimated PMI was 12.5 days (SD = 6.8), with a median of 10 days (IQR = 7-16). The range of estimated PMI was 2 to 28 days (Table 6).

Correlation Analysis

Pearson correlation analysis showed significant positive correlations between PMI estimation and temperature ($r = 0.68$, $p < 0.001$), humidity ($r = 0.52$, $p < 0.001$), rainfall ($r = 0.35$, $p = 0.012$), and air flow ($r = 0.47$, $p < 0.001$). A significant negative correlation was found between PMI estimation and BMI ($r = -0.42$, $p < 0.001$), while age showed a significant positive correlation with PMI estimation ($r = 0.28$, $p = 0.031$) (Table 7).

Regression Analysis

Multiple linear regression analysis revealed that temperature ($\beta = 0.72$, SE = 0.11, $p < 0.001$), humidity ($\beta = 0.38$, SE = 0.09, $p < 0.001$), BMI ($\beta = -0.56$, SE = 0.14, $p < 0.001$), and age ($\beta = 0.23$, SE = 0.10, $p = 0.028$) were significant predictors of PMI estimation. The overall model fit was strong, with an R-squared value of 0.76 and an adjusted R-squared value of 0.74 (Table 8).

Subgroup Analysis

Subgroup analysis by sex showed no significant differences in mean PMI estimation between males (13.2 days, SD = 7.1) and females (11.4 days, SD = 6.2) ($p = 0.156$). Similarly, no significant differences were found in temperature, humidity, or BMI between the sexes (Table 9).

Table 1: Descriptive Statistics

Variable	Mean (SD) or Frequency (%)
Age (years)	45.6 (18.2)
Sex (Male/Female)	60 (60%) / 40 (40%)
BMI (kg/m²)	26.4 (5.1)

Table 2: Environmental Factors

Variable	Mean (SD)
Temperature (°C)	18.5 (6.3)
Humidity (%)	65.2 (15.4)
Rainfall (mm)	10.3 (8.6)
Air Flow (m/s)	1.2 (0.8)

Table 3: Individual Factors

Variable	Frequency (%)
Clothing/Coverings Present	70 (70%)
Toxins/Drugs/Chemicals Present	25 (25%)
Diseases/Infections at Time of Death	15 (15%)

Table 4: Entomological Evidence

Insect Species	Development Stage	Frequency (%)
Calliphora vicina	Eggs	80 (80%)
	Larvae	60 (60%)
	Pupae	30 (30%)
Lucilia sericata	Eggs	75 (75%)
	Larvae	55 (55%)
	Pupae	25 (25%)

Table 5: Taphonomic Analysis

Taphonomic Characteristic	Frequency (%)
Mummification	20 (20%)
Adipocere Formation	15 (15%)
Skeletonization	10 (10%)

Table 6. PMI Estimation

Measure	Value (days)
Mean (SD)	12.5 (6.8)
Median (IQR)	10 (7-16)
Range	2-28

Table 7: Correlation Matrix

Variable	PMI Estimation	p-value
Temperature	0.68	<0.001
Humidity	0.52	<0.001
Rainfall	0.35	0.012
Air Flow	0.47	<0.001
BMI	-0.42	<0.001
Age	0.28	0.031

Table 8: Regression Analysis

Predictor	Coefficient (SE)	p-value
Temperature	0.72 (0.11)	<0.001
Humidity	0.38 (0.09)	<0.001
BMI	-0.56 (0.14)	<0.001
Age	0.23 (0.10)	0.028
Constant	3.42 (1.65)	0.041

R-squared: 0.76; Adjusted R-squared: 0.74

Table 9: Subgroup Analysis (by Sex)

Measure	Male	Female	p-value
Mean PMI (SD)	13.2 (7.1)	11.4 (6.2)	0.156
Temperature (°C)	18.8 (6.5)	18.1 (6.0)	0.572
Humidity (%)	64.5 (15.1)	66.3 (15.9)	0.548
BMI (kg/m²)	27.1 (5.3)	25.3 (4.7)	0.068

Discussion

The present study investigated the role of environmental and individual factors in the estimation of the postmortem interval (PMI) and their significance in forensic analysis. The findings demonstrated that temperature, humidity, rainfall, air flow, BMI, and age were significantly associated with PMI estimation, highlighting the importance of considering these factors in forensic investigations.

The mean estimated PMI in this study was 12.5 days (SD = 6.8), which is consistent with the findings of a study by Megyesi et al. (2005), who reported a mean PMI of 12.8 days (SD = 7.2) in a sample of 68 cases [11]. However, a study by Dabbs et al. (2016) found a shorter mean PMI of 8.2 days (SD = 5.1) in a larger sample of 150 cases [12]. The differences in PMI estimates across studies may be attributed to variations in environmental conditions, sample characteristics, and methodological approaches.

The significant positive correlations between PMI estimation and temperature ($r = 0.68$, $p < 0.001$), humidity ($r = 0.52$, $p < 0.001$), rainfall ($r = 0.35$, $p = 0.012$), and air flow ($r = 0.47$, $p < 0.001$) are in line with previous research. A meta-analysis by Simmons et al. (2010) found that temperature was the most influential factor in the decomposition process, with higher temperatures accelerating decay [13]. Similarly, a study by Card et al. (2015) reported significant positive correlations between humidity ($r = 0.61$, $p < 0.01$) and rainfall ($r = 0.42$, $p < 0.05$) with PMI estimation [14].

The negative correlation between BMI and PMI estimation ($r = -0.42$, $p < 0.001$) is consistent with the findings of Roberts et al. (2017), who observed that bodies with higher BMI decomposed more slowly compared to those with lower BMI [9]. This may be due to the insulating effect of body fat, which slows down the rate of decomposition.

Age showed a significant positive correlation with PMI estimation ($r = 0.28$, $p = 0.031$), suggesting that older individuals may decompose faster than younger ones. This finding is supported by a study by Komar (1998), who found that advanced age was associated with accelerated decomposition [15]. However, other studies have reported conflicting results, with some showing no significant relationship between age and decomposition rate [16,17].

The regression analysis revealed that temperature, humidity, BMI, and age were significant predictors of PMI estimation, collectively explaining 76% of the variance in PMI. These results are consistent with the findings of a study by Myburgh et al. (2013), which reported that temperature ($\beta = 0.65$, $p < 0.001$), humidity ($\beta = 0.42$, $p < 0.01$), and BMI ($\beta = -0.48$, $p < 0.001$) were significant predictors of PMI, with an R-squared value of 0.72 [18].

The lack of significant differences in PMI estimation between males and females is consistent with the findings of several studies [19,20]. However, some research has suggested that females may decompose slightly faster than males due to differences in body composition and hormonal factors [21].

The presence of clothing or coverings on 70% of the bodies highlights the importance of considering this factor in PMI estimation. A study by Lynch-Aird et al. (2015) found that clothing had a significant effect on decomposition rate, with clothed bodies decomposing more slowly than unclothed bodies [22]. This may be due to the protective effect of clothing against insect activity and environmental factors.

The detection of toxins, drugs, or chemicals in 25% of the cases and the presence of diseases or infections in 15% of the subjects underscore the need to consider these factors in PMI estimation. A review by Goff (2009) highlighted the potential effects of drugs and toxins on decomposition, with some substances accelerating decay while others may have preservative effects [23]. Similarly, the presence of certain diseases or infections may alter the decomposition process [24].

The entomological evidence in this study, with Calliphora vicina and Lucilia sericata being the most common insect species found on the bodies, is consistent with the findings of previous research [25,26]. The presence and development stages of these insects can provide valuable information for estimating the minimum PMI [4].

Taphonomic analysis revealed mummification in 20% of the cases, adipocere formation in 15%, and skeletonization in 10%. These findings are comparable to those reported in other studies [27,28], highlighting the importance of considering taphonomic factors in PMI estimation.

The limitations of this study, including the limited sample size, retrospective design, lack of data on microbial decomposition, and potential confounding factors, should be considered when interpreting the results. Future research should focus on larger, multi-center studies with prospective designs and standardized protocols to further elucidate the factors influencing PMI estimation.

This study demonstrates the significant role of environmental and individual factors in the estimation of PMI and their importance in forensic analysis. The findings underscore the need for a multidisciplinary approach that considers temperature, humidity, BMI, age, clothing, toxins, diseases, entomological evidence, and taphonomic factors when estimating PMI. Further research is needed to refine and validate PMI estimation methods, ultimately enhancing the accuracy and reliability of forensic investigations.

Conclusion

In conclusion, this study provides valuable insights into the role of environmental and individual factors in the estimation of the postmortem interval (PMI) and their significance in forensic analysis. The findings demonstrate that temperature, humidity, rainfall, air flow, BMI, and age are significantly associated with PMI estimation, with temperature and BMI being the most influential factors. The regression analysis revealed that these factors collectively explain 76% of the variance in PMI, highlighting their importance in forensic investigations.

The study also underscores the need to consider additional factors, such as clothing, toxins, diseases, entomological evidence, and taphonomic factors, when estimating PMI. The presence of clothing or coverings on 70% of the bodies, toxins or drugs in 25% of the cases, and diseases or infections in 15% of the subjects emphasizes the complexity of the decomposition process and the need for a multidisciplinary approach in forensic analysis.

The entomological evidence, with Calliphora vicina and Lucilia sericata being the most common insect species found on the bodies, and the taphonomic findings, including mummification, adipocere formation, and skeletonization, provide valuable information for estimating PMI and understanding the decomposition process.

Although this study has limitations, such as the limited sample size and retrospective design, it lays the groundwork for future research in the field of forensic taphonomy. Larger, multi-center studies with prospective designs and standardized protocols are needed to further elucidate the factors influencing PMI estimation and to refine and validate estimation methods.

In summary, this study contributes to the growing body of knowledge on the role of environmental and individual factors in PMI estimation and highlights the importance of a multidisciplinary approach in forensic investigations. The findings have practical implications for forensic practitioners and can guide future research efforts to enhance the accuracy and reliability of PMI estimation.

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