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ESTIMATION OF POST-MORTEM INTERVAL OF DISMEMBERED BODIES: A SCOPING-NARRATIVE REVIEW

Darlington Nnamdi Onyejike[1, 2*], Okikioluwa Stephen Aladeyelu[3], Sipho Mfolozi[2]

[1]Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria.
[2]Discipline of Forensic Medicine, School of Medicine, College of Health Sciences, University of KwaZulu-Natal, South Africa.
[3]Discipline of Anatomy, School of Medicine, College of Health Sciences, University of KwaZulu-Natal, South Africa.

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ABSTRACT

Background: Estimation of the post-mortem interval (PMI) in dismembered bodies presents forensic challenges because dismemberment disrupts decomposition, exposes internal tissues, and causes body segments to experience varying environmental conditions. This review assessed approaches to PMI estimation in dismembered remains and identified gaps. **Methods:** A literature search was conducted in May 2024 using Google Scholar, PubMed, Medline, and the Cochrane Library. Searches used combinations of post-mortem interval, dismemberment, decapitation, total body score, accumulated degree days, and bodies. Eligible studies addressing PMI estimation in dismembered or decapitated remains were screened by authors. Data were extracted and synthesized narratively because of heterogeneity among the included studies. **Results:** Twenty-three articles were identified; seven duplicates were removed, and six studies met the eligibility criteria. The included studies, published between 1995 and 2024, employed biochemical markers, protein degradation analysis, entomological evidence, radiological imaging, accumulated degree days (ADD), and decomposition scoring systems. Findings showed that wrapping and encasement altered decomposition and delayed insect activity, while protein degradation and biochemical markers demonstrated potential for estimating PMI. ADD and decomposition scoring provided approaches for assessing decomposition. However, most studies relied on animal proxies, small sample sizes, or controlled environmental conditions, limiting generalizability to human forensic cases. **Conclusions:** PMI estimation in dismembered remains is supported by multidisciplinary approaches combining biochemical, entomological, radiological, and decomposition-based methods. Nevertheless, variable exposure, containment, environmental conditions, interspecies differences, and limited validation remain challenges. Larger studies under diverse environmental conditions and validation using human remains are needed to improve accuracy and forensic applicability of PMI estimation.

Keywords: Accumulated degree days, Decomposition, Dismemberment, Entomology, Total body score.

[*]**Corresponding Author.** E-mail: dn.onyejike@unizik.edu.ng

INTRODUCTION

The estimation of post-mortem interval (PMI) remains a cornerstone of forensic investigations, particularly when human remains are subjected to dismemberment or decapitation. Determining the PMI in these cases is uniquely challenging due to the disruption of natural decomposition processes, including autolysis and putrefaction, as well as external factors that affect dismembered body parts differently than intact remains. Following death, the human body undergoes a series of complex degradation processes, primarily categorized into autolysis and putrefaction. During putrefaction, microbial activity primarily from the gastrointestinal tract microbiome becomes the dominant driver of decomposition, with its rate significantly influenced by both intrinsic and extrinsic factors [**1**]. Among the extrinsic factors, environmental and climatic conditions play a pivotal role in modulating the activity of microorganisms and necrophagous insects, which are essential

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external agents in the decomposition process [**2, 3**]. The decomposition process is typically classified into five distinct but continuous stages: fresh, bloat, active decay, advanced decay, and finally, skeletonization [**4**]. However, it is essential to note that each researcher may define and divide these stages differently. Understanding these stages and the factors that influence them provides forensic scientists with essential tools for reconstructing timelines and circumstances surrounding death, thereby contributing to the resolution of criminal cases.

Dismemberment is a documented phenomenon in homicide investigations, often employed to facilitate the concealment or transportation of human remains -- and to prevent identification of the victim. In such cases, perpetrators may aim to reduce the bulk of the body for easier movement from the primary crime scene to a secondary disposal site. Common concealment methods include encasing remains in plastic bags or depositing them in remote locations, such as dense vegetation or secluded pathways, thereby delaying discovery and complicating forensic identification. Disposal in bodies of water is also common [**5**]. This practice is not limited to homicides; dismemberment and decapitation also occur in various contexts, including ritual killings, organized gang violence, and high-impact events such as vehicular accidents, natural disasters, and armed conflict [**5, 6**]. Each scenario poses unique forensic challenges, from reconstructing post-mortem trauma patterns to identifying victims and estimating the time since death. These complexities underscore the need for innovative investigative methodologies, including advanced imaging techniques, DNA profiling, and interdisciplinary collaboration, to effectively address concealed homicides and other dismemberment-related cases [**7, 8**].

Dismemberment can alter the exposure of tissues to environmental variables such as temperature, moisture, and microbial colonization, complicating the applicability of traditional PMI estimation techniques [**9, 5**]. Exposure of the gastrointestinal (GI) tract to the external environment significantly alters decomposition. Normally, gut microbes play a crucial role in decay; however, when the GI tract is exposed, both gut and external microbes can spread more freely, thereby accelerating decomposition [**5**]. Environmental conditions such as temperature and moisture influence decomposition after exposure. Dry conditions can slow microbial activity through dehydration, while moist conditions promote microbial growth and faster decay [**10**]. Furthermore, the leakage of digestive fluids into surrounding tissues enhances liquefaction and accelerates decay [**11**].

Forensic taphonomy has emerged as an area of focus within criminal investigations, offering novel insights into estimating the post-mortem interval (PMI) in cases of clandestine homicides [**12**]. Recent advancements in forensic taphonomy emphasize the importance of multidisciplinary approaches to improve PMI estimation in dismemberment cases. Microbial activity, which plays a critical role in decomposition, has been explored as a potential biomarker for PMI determination, showing promise in both experimental and real-world scenarios [**13**]. Similarly, entomological evidence, particularly the activity of necrophagous insects, offers valuable insights, although it may be affected by dismemberment and the selective exposure of body parts [**14**]. Therefore, this review seeks to explore studies on PMI estimation in dismembered bodies, critically evaluating experimental methodologies and outcomes.

The primary research question addressed in this review was: What are the most effective and reliable methods for estimating the PMI of dismembered bodies, and how do these methods compare to those used for intact bodies? Secondary questions that are explored include the forensic techniques currently employed to estimate PMI in dismembered bodies, the influence of environmental factors such as temperature, humidity, and location on such PMI estimation, and the challenges associated with PMI estimation in dismembered remains compared to intact bodies. Additionally, this review examined variations in methods across different regions or legal systems, recent technological innovations that have improved accuracy in PMI estimation for dismembered remains, limitations and gaps in the current literature, and the potential of a multidisciplinary approach—combining fields such as anthropology, toxicology, and entomology—to enhance accuracy and reliability.

METHODS

A literature search was conducted in May 2024 to identify studies that reported PMI estimation in dismembered bodies. Studies were identified through searches of the following databases: Google Scholar, PubMed, Medline, and the Cochrane Library electronic databases. The search utilized the following keywords: post-mortem interval (PMI), dismemberment, decapitation, total body score (TBS), accumulated degree days (ADD), and bodies. These keywords were used independently and combined using the Boolean operators 'OR' and 'AND'. Further search was conducted by scanning through relevant studies. To maximize our chances of retrieving all relevant and available studies, limitations on the year of study were not imposed.

Inclusion Criteria

Studies were included if they met the following criteria: original articles, review articles, and reports with a primary focus on PMI estimation in cases of body dismemberment or decapitation; original articles, review articles, and reports published in the English language.

Exclusion Criteria

Books and book chapters were excluded, as were studies unrelated to PMI estimation and review articles that did not primarily address PMI estimation for dismembered or decapitated bodies.

Study Selection

The selection process was guided by the inclusion and exclusion criteria. Two authors, DNO and OSA, screened the titles and abstracts of all retrieved studies to determine their eligibility. Full articles were further screened in cases where eligibility could not be determined from the title and abstract. Due to the limited number of studies identified in line with the review objective, the authors decided to include both qualitative and quantitative studies.

Data Extraction and Analysis

A data extraction form was developed by DO and OA, which was reviewed by SM. DO and OA then used this form to extract key information, such as the names of the first author and year of publication, sample size, modality of the study, and key information on methodology and outcome, from all eligible studies. Due to the heterogeneity of the included studies in terms of sample size, design, methods, and data presentation and analysis, a narrative synthesis was employed to synthesize and summarize the extracted data from the included studies [15,16]. All data were compiled on a spreadsheet and imported into Microsoft Excel 2010.

RESULTS

Data Overview

The systematic search revealed a total of 23 articles, of which seven were duplicates and subsequently excluded. After screening the remaining 16 articles against the eligibility criteria, six studies were included in the review. The other ten articles were excluded for not meeting the inclusion criteria (Figure 1). Notably, no case reports or research articles specifically addressing PMI estimation in cases of body dismemberment or decapitation were identified during the third and fourth search steps.

Description of Included Studies

The dataset included studies conducted between 1995 and 2024, reflecting a broad exploration of methodologies for estimating the PMI of dismembered or decapitated bodies. These studies employed laboratory experiments, fieldwork, case reports, and empirical analyses, covering both human remains and animal proxies. The literature included for this review encompassed a variety of forensic techniques, focusing on variables such as protein degradation, decomposition rates, environmental influences, wrapping methods, radiological imaging, and biochemical markers (Table 1). These studies demonstrated a diverse and multidisciplinary approach to PMI estimation. The researchers have employed methods such as protein analysis, biochemical assays, radiological imaging, entomological studies, and observational experiments (quantitative approach using ADD and TBS). Some studies focused on exploring new forensic markers, while others addressed practical challenges, including decomposition under concealed or remote conditions. Most studies exhibited strong experimental rigor, although they were often limited using animal models or controlled environments (Table 1). Delabarde and Ludes [**17**] examined three sets of disarticulated and incomplete human remains from the Ecuadorian jungle. The aim was to determine biological profiles, analyze cut marks for information on the tools utilized and the sequence of events, and reconstruct events leading to dismemberment and disposal. Two male individuals were identified by DNA, and the tools were identified as a machete and a chainsaw. A subsequent study was conducted on pig bones.

Sener and colleagues [**18**] investigated the differences in endogenous oxidant and antioxidant parameter levels in liver tissue to estimate early post-mortem interval utilizing 60 rats. The rats were divided into six groups of 10 and kept at room temperature with samples extracted at one-hour intervals post-mortem. The samples were tested for Superoxide dismutase (SOD), Malondialdehyde (MDA), Glutathione peroxidase (GPx), Glutathione S-transferases (GST), Total glutathione (tGSH), Catalase (CAT), and Nitric oxide (NO). SOD, GST, and NO were identified as significant factors independently affecting the prediction of the time of death. The model used for prediction had a high predictive value. Scholl and Moffatt [**19**] investigated sealing dismembered pig parts in plastic to see the effect of this barrier on decomposition rates, insect activity, and overall PMI estimation. Thirty-four pigs were used, 24 of which were divided into torsos, heads, and limbs. Ten intact pigs served as controls. Visual inspection occurred over 743 accumulated degree days, at which time decomposition was scored, insect activity noted, and specimens collected.

Matzen and colleagues [**20**] included a case report along with an empirical study. The aim of the study was to evaluate the effectiveness of radiological imaging techniques (post-mortem CT and X-rays) in visualizing post-mortem changes in encased body parts. In the case under investigation, a human body had been dismembered and encased in concrete. Radiology assisted in locating the remains and allowing safe extraction of the body parts. A pig head and a trotter encased in concrete were used in a subsequent experiment, again focusing on the imaging aids to locating body parts. Brownlow and associates [**21**] investigated the effect of wrapping methods on insect activity and PMI estimation using pig hock sections. Four treatments (unwrapped, plastic wrapping, zipped wash bag, and combined wash bag and plastic wrapping) were utilized. Observations were made on insect attraction,

oviposition timing, and resulting maggot numbers. Geissenberger and colleagues [**22**] utilized six pigs, three of which had both hind limbs removed after slaughter. The pigs were examined over a 10-day period under controlled environmental conditions. Muscle samples were taken at predefined time intervals (0 to 240 hours post-mortem) and processed for protein analysis. Western blotting and SDS-PAGE were used to monitor the degradation patterns of specific proteins, including vinculin, GAPDH, alpha-actinin, alpha-tubulin, and tropomyosin.

Trends in PMI Estimation Studies for Body Dismemberment Over Time

The study of PMI estimation in body dismemberment has evolved significantly over time. Early research in the 1990s had narrow scopes and limited methodologies, focusing on basic decomposition patterns. By the 2000s and 2010s, studies adopted more complex designs, integrating biochemical and entomological analyses and simulating real-world scenarios with animal proxies (Figures 2 and 3). In the 2020s, there has been a marked increase in multidisciplinary approaches, employing advanced tools such as radiological imaging, protein degradation analysis, and sophisticated statistical models. Recent studies also emphasize diverse environmental conditions and practical forensic challenges, reflecting advancements in forensic science and the growing need for accurate PMI estimation in complex cases. Over the years, the frequency of publications and their scientific rigor have steadily increased, underscoring heightened interest and innovation in this field (Figures 2 and 3).

Regional Distribution of Studies

The geographic distribution of the included studies is shown in Figures 4 and 5. The studies were conducted in diverse regions, including Austria, the United Kingdom, Germany, Ecuador, and Turkey (Figures 4 and 5). This geographic diversity allows researchers to account for environmental conditions such as temperature, humidity, and ecosystem characteristics, which are critical factors in PMI estimation.

Methods for PMI Estimation

The retrieved studies employed a range of qualitative and quantitative methods for PMI estimation (Table 1). PMI estimation methods in the studies include protein degradation analysis, where markers such as vinculin and GAPDH were tracked to establish degradation timelines. Entomological techniques examined delayed insect colonization due to wrappings, aiding in determining the minimum PMI. Accumulated degree-days (ADD) and decomposition scoring systems, such as the method by Megyesi et al., were used to quantify decomposition stages systematically. Studies also assessed how containment, such as plastic wrapping or concrete encasement, altered decomposition rates. Radiological imaging (post-mortem CT and X-ray) documented changes in encased remains, while biochemical markers like oxidant-antioxidant levels correlated with PMI under controlled conditions. These methods reflect a multifaceted approach to PMI estimation.

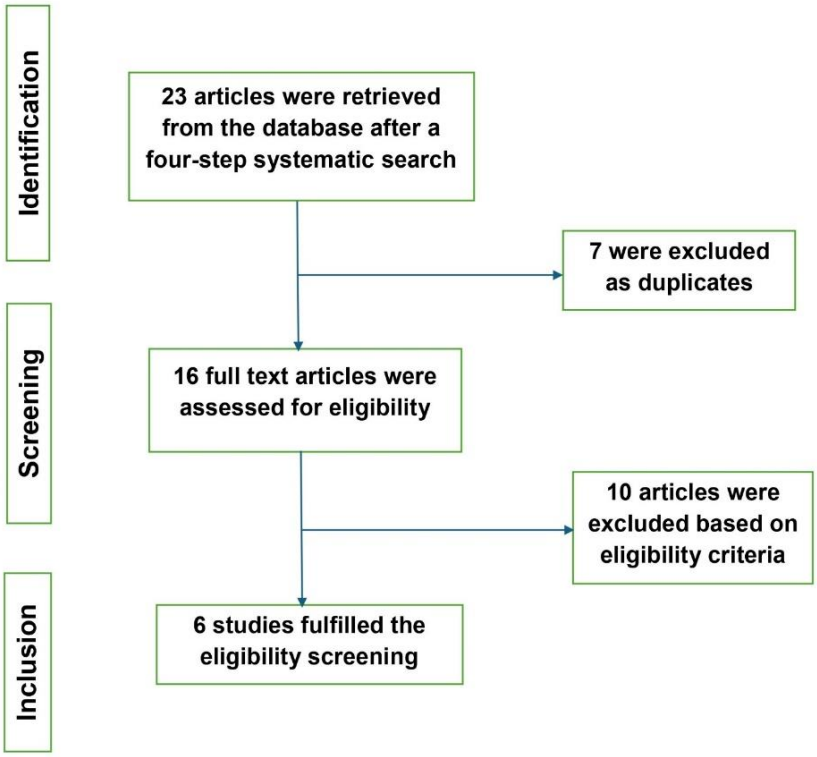


Figure 1: PRISMA flow chart of study selection.

Table 1: General characteristics of included studies.

Author (Year)	Country (Location)	Sample Size: no. of bodies	Type of Study	Aim of Study	Outline of Experimental Methodology(ies)	Key Outcome(s)	Limitations
Delabarde and Ludes (2010)	Amazonian Jungle, Ecuador	Three sets of disarticulated human remains representing two individuals.	Case Report	The primary objective of this study was to recover and analyze three sets of disarticulated and incomplete human remains found in the Amazonian jungle in Ecuador. The study aimed to: Determine the biological profiles of the remains; Analyze the cut marks to identify the tools used and the sequence of events; and reconstruct the sequence of events leading to the dismemberment and disposal of the bodies.	Anthropological Examination: Included bone reassembly and determination of biological profiles. Cut Mark Analysis: Detailed analysis of cut marks on the bones. Experimental Study: Conducted on pig bones to understand the timing and tools used for dismemberment. Forensic Examination: Performed by pathologists and anthropologists, including DNA testing for identification.	The remains belonged to two young Caucasian adult men. The dismemberment was likely post-mortem, aimed at hindering identification and disposal. Tools used included chainsaws and machetes. The forensic team successfully identified the victims through DNA testing and osteological data. The study highlighted the importance of detailed forensic analysis in identifying victims and understanding the circumstances of their deaths.	• Location Challenges: The remote location and lack of laboratory facilities posed significant challenges. • State of Decomposition: Limited the examination of soft tissues and organs. • Incomplete Data: Some body parts were missing, making it difficult to determine the exact cause of death for one of the victims.
Sener et al (2012)	Erzurum, Turkey	60 Albino Wistar male rats	Experimental study	To investigate whether the differences between the levels of endogenous oxidant and antioxidant parameters in liver tissue can be used to estimate the early post-mortem interval (EPI).	Subjects: 60 Albino Wistar male rats weighing between 220-230 grams. Procedure: The rats were divided into six subgroups (n = 10), kept at room temperature (22°C), and then decapitated. Sampling: Liver tissues were extracted at intervals of one hour post-mortem. Biochemical Analysis: Measured levels of Superoxide dismutase (SOD), Malondialdehyde (MDA), Glutathione peroxidase (GPx), Glutathione S-transferases (GST), Total glutathione (tGSH), Catalase (CAT), and Nitric oxide (NO). Statistical Analysis: Linear regression analysis was performed to identify factors predicting the time of death.	The authors performed linear regression analysis in order to search for factors predicting the time of death. The time of death was taken as a dependent variable with SOD, MDA, GPx, GST, GSH, CAT, and NO as independent variables. This model resulted in a high predictive value (adjusted R square = 94.0%). SOD, GST, and NO were found to be significant factors independently affecting the prediction of the death time.	The study found a significant relationship between the levels of oxidant/antioxidant parameters and the early post-mortem interval. SOD, GST, and NO were identified as significant factors independently affecting the prediction of the time of death. The model used for prediction had a high predictive value (adjusted R square = 94.0%).
Scholl and Moffatt (2017)	Northwest England, UK.	34 pigs (median mass: 32.5 kg). 24 dismembered pigs sealed in sacks. 10 whole pigs as controls.	Experimental field study	To investigate how sealing dismembered pig body parts in plastic waste sacks affects decomposition rates, insect ingress, and post-mortem interval (PMI) estimation, comparing	34 pigs (Sus scrofa domestica) sourced from farms and killed by a captive bolt gun. 24 dismembered pigs were divided into torsos, heads, and limbs, sealed in either standard or insect-repellent	Neither standard nor repellent sacks effectively prevented insect entry; all sacks contained insects by the final sampling. Insects entered sacks more slowly compared to exposed carcasses. No significant difference in insect ingress between standard and repellent sacks.	Effects of dismemberment and enclosure could not be isolated. Variation in carcass weights might have confounded results.

				standard and insect-repellent sacks to whole carcasses.	plastic sacks, and placed in a decomposition facility. 10 whole pigs decomposed without containment, serving as controls. Experiments conducted at the University of Central Lancashire's outdoor decomposition research facility, UK. Sacks sealed with nylon cable ties and placed under scavenger-proof mesh cages in random field locations. Sampling occurred at 47, 99, 130, and 743 accumulated degree days (ADD) to measure decomposition stages. Visual inspection of decomposition using a modified scoring system based on Megyesi et al. Presence of insects recorded and collected specimens reared and identified. Statistical analyses included generalized linear models, weighted least squares, and non-parametric tests.	Decomposition in sacks was significantly slower than in exposed whole carcasses ($p < 0.001$). Heads decomposed the slowest within sacks but fastest in exposed whole carcasses. Sacks created humid, anaerobic conditions, leading to the formation of adipocere, particularly on the limbs. Standard PMI estimation methods significantly underestimated PMI for body parts sealed in sacks.	Insect repellents used in sacks were not clearly identified or effective, limiting generalizability.
Matzen et al. (2022)				The study aimed to: Report a rare case of dismemberment and body encasement; Evaluate the effectiveness of radiological imaging techniques (post-mortem CT and X-ray) in visualizing and temporally classifying changes in encased corpses; Conduct an empirical study using pig parts encased in concrete to understand the decomposition process and the utility of imaging techniques.	Case Report: Detailed forensic examination of a dismembered and encased human body. Empirical Study: Encased a pig's head and paw in concrete and scanned them regularly over a year using X-ray and post-mortem CT (pmCT). Radiological Imaging: Used to visualize and document changes in the encased pig parts over time. Environmental Data Collection: Recorded weather conditions to understand their impact on decomposition.	Case Report: The human body was dismembered and encased in concrete blocks; Radiological imaging helped localize and safely remove the body parts from the concrete. The cause of death was determined to be traumatic brain injury from gunshots. The dismemberment was systematic, suggesting defensive mutilation, but the separation of genitals indicated possible offensive mutilation. Empirical Study: X-ray and pmCT were effective in visualizing the encased pig parts; Decomposition was significantly slowed in concrete compared to open environments; Radiological imaging detected minimal changes over time, but could not assign specific time points to these changes; The study highlighted the limitations of using radiological imaging to assess the state of decomposition and post-mortem interval in encased bodies.	Environmental Factors: The specific environmental setting (temperature, humidity, etc.) influenced the decomposition process, making comparisons with other studies challenging. Sample Size: Limited to one pig's head and paw, which may not fully represent the decomposition process in different body parts or under varying conditions. Imaging Limitations: X-ray and pmCT had limitations in detecting detailed decomposition changes and were not fully applicable for

							assessing the post-mortem interval.
Brownlow, et al. (2023)	East Kent, UK	Four treatments of pork (as surrogate body parts), with one as a control and three wrapped in plastic	Experimental field study	To investigate the effects of wrapping methods on the colonization and behavior of necrophagous flies, focusing on the implications for estimating minimum post-mortem intervals (minPMI).	The study utilized field experiments with pig hock sections as proxies for human limbs. Four treatments (unwrapped, wrapped in a plastic sack, enclosed in a zipped wash bag, and combined plastic sack plus wash bag) were exposed under real-world environmental conditions in a rural field in East Kent, UK. Observations on insect attraction, oviposition timing, and progeny numbers were conducted over five replicates. Statistical analyses were performed using linear regression, generalized linear models (GLM), and censored regression models.	Wrapping significantly delayed fly contact and oviposition times. The mean delay for double-wrapped samples (plastic sack + wash bag) was 32 hours compared to unwrapped samples. Rain extended this delay to over 48 hours. Wrapped samples had significantly fewer eggs and larvae, with reductions of up to 99.1% in some cases. Differences in material robustness and permeability (e.g., plastic sacks vs. wash bags) influenced fly behavior, odour release, and insect access.	Conducted in a single rural location with specific environmental conditions. Focused on selected wrapping materials; other materials and real-world scenarios (e.g., hasty wrapping by perpetrators) may yield different results. Trial duration limited to 48 hours, potentially missing long-term effects.
Geissenberger et al. 2023	Salzburg, Austria.	Six sub-adult pigs (German Large White × German Landrace). Dismembered hind limbs vs. hind limbs attached to whole carcasses.	Experimental study with controlled conditions to simulate forensic decomposition scenarios	To evaluate whether dismembered porcine hind limbs can serve as reliable proxies for post-mortem muscle protein degradation, comparing them to whole pig carcasses. The study aimed to provide insights into post-mortem interval (PMI) estimation and to explore protein degradation patterns for forensic applications.	Six pigs were used, with both hind limbs from three pigs dismembered immediately after slaughter. Samples from dismembered limbs and hind limbs attached to whole carcasses were analyzed over a 10-day period under controlled environmental conditions. Muscle samples were taken at predefined time intervals (0 to 240 hours post-mortem) and processed for protein analysis. Western blotting and SDS-PAGE were used to monitor the degradation patterns of specific proteins, including vinculin, GAPDH, alpha-actinin, alpha-tubulin, and tropomyosin. Statistical tools like logistic regression were applied to identify degradation timelines and determine protein stability over time.	• Vinculin and GAPDH showed predictable degradation with characteristic split products forming at specific intervals post-mortem. • Tropomyosin remained stable throughout the study period, serving as a reliable control. • No major qualitative differences in protein degradation patterns between dismembered limbs and attached limbs. • Dismembered limbs demonstrated faster cooling and narrower timeframes for protein degradation events, making them ideal for PMI studies. • Logistic regression confirmed predictable timelines for protein degradation, with variations observed between dismembered and attached samples.	• Conducted at a single ambient temperature (20 ± 2 °C) with fixed humidity (50 ± 5%). • Interspecies differences between pigs and humans limit direct applicability to human forensic cases. Validation on human tissues is necessary for broader forensic relevance.

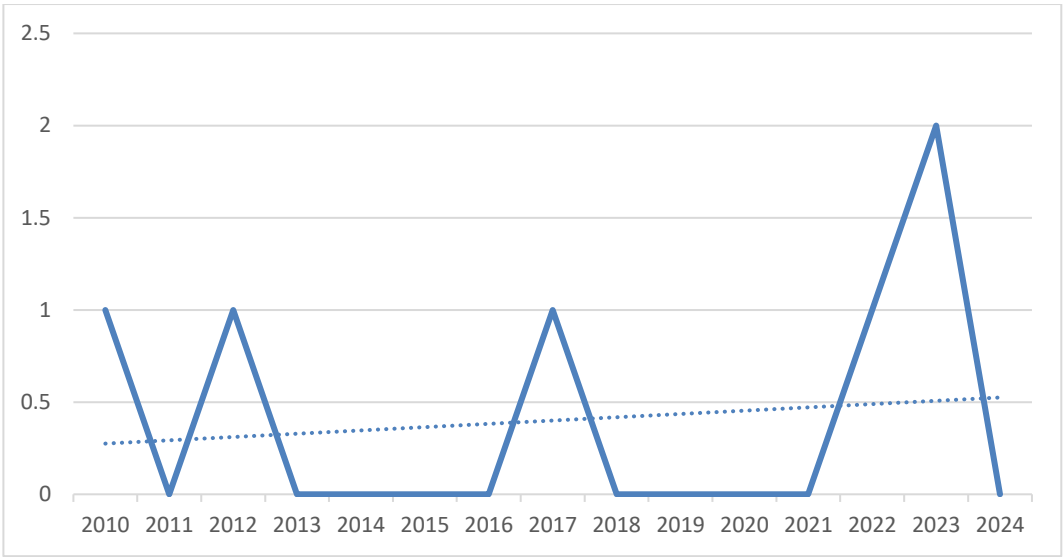


Figure 2: Graph showing the trends in PMI estimation studies for body dismemberment (2010 – 2024).

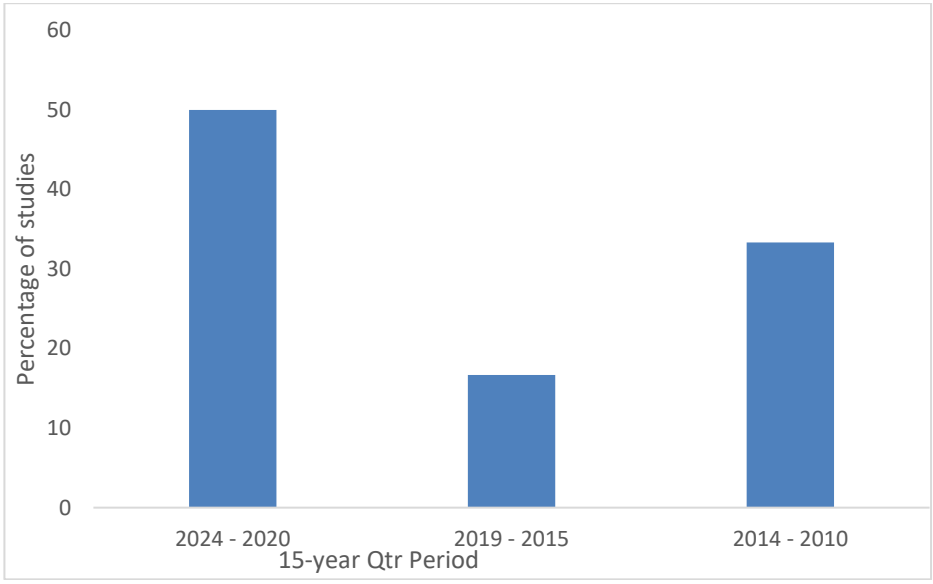


Figure 3: Bar chart showing the distribution of studies on PMI estimation of body dismemberment over the last 15 years.

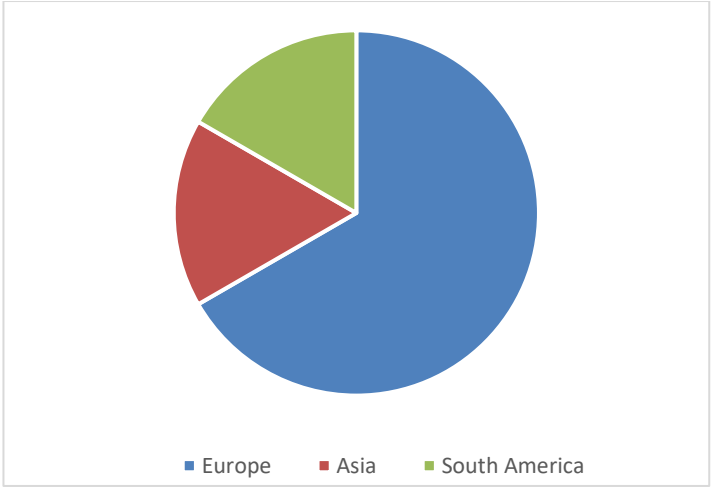


Figure 4: Pie chart showing the regional distribution of studies for PMI estimation of body dismemberment.

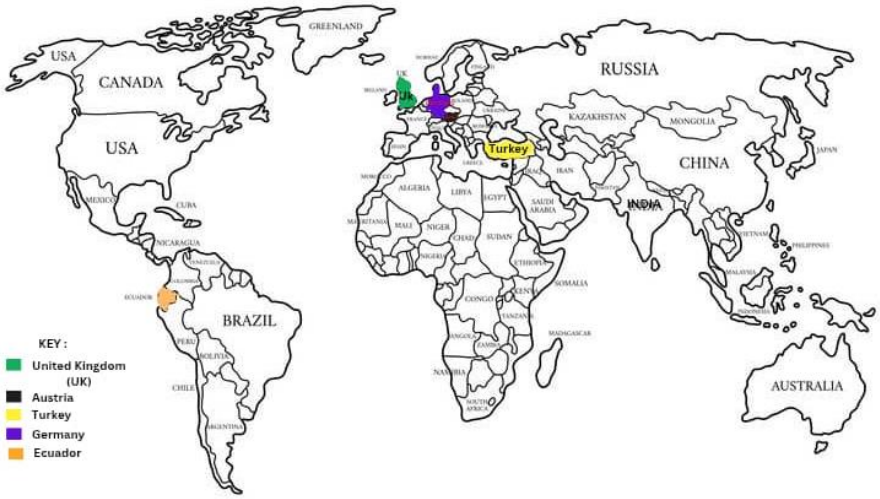


Figure 5: Geographical mapping of countries that have carried out studies on PMI estimation of dismembered bodies.

Limitations of Included Studies

Several limitations were noted across the studies (Table 1). The sample sizes in the studies varied significantly, reflecting the constraints of forensic research. Animal studies typically included between six and sixty models, including pigs or rats, while case studies often focused on one or a few human cases (Table 1). Limited sample sizes in some studies affected the statistical power and generalizability of the results. Another common challenge is the reliance on animal proxies, which introduces interspecies differences that complicate the extrapolation of findings to human cases. Controlled environmental conditions used in many experiments may not fully capture the variability of real-world scenarios. Research focusing on specific conditions, such as wrapping materials or encasement, often has a narrow scope, which may not address the broader forensic context. Radiological imaging techniques demonstrated challenges in detecting detailed decomposition changes, while studies in remote or resource-limited settings faced logistical constraints.

DISCUSSION

This review offers a significant contribution to the forensic science community by synthesizing the existing literature on PMI estimation in dismembered bodies. Estimating PMI in dismembered remains presents unique challenges due to disruptions in natural decomposition processes and varied exposure to environmental factors. Techniques such as protein degradation analysis [**22**], radiological imaging [**20**], and entomological observations [**14**] have enhanced our understanding of decomposition timelines; however, they remain limited by the controlled experimental conditions and the use of animal proxies. Methods such as accumulated degree-days (ADD) and total body scoring (TBS) have standardized decomposition assessments across various environments [**9**]. Containment, such as plastic wrapping or encasement, significantly alters the dynamics of decomposition [**19, 20**], necessitating context-specific adjustments for PMI models. Environmental factors, such as temperature, humidity, and insect activity, often complicate estimations, particularly when remains are concealed [**1, 2**]. Research trends indicate a notable geographic concentration of studies conducted in Europe, South America, and the Middle East [**17, 18, 22**], while tropical and arid regions, including the entirety of South America, remain critically underrepresented. Additionally, small sample sizes in most studies limit the robustness and generalizability of findings, emphasizing the need for larger collaborations.

CONCLUSIONS

This review underscores progress and challenges in PMI estimation for dismembered remains. Advances in biochemical, entomological, and imaging techniques have enriched forensic investigations; however, practical limitations persist, including interspecies variability, the need for controlled conditions, and limited scope. Multidisciplinary approaches and robust validation remain critical to improving forensic methods. While methods like ADD and TBS have improved decomposition assessments, dismembered remains present unique complexities, such as variable exposure and containment effects, requiring refined forensic models. Addressing these challenges will enhance the accuracy of PMI estimation and forensic case resolutions.

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