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Received: 11 January 2024 | Revised: 24 April 2024 | Accepted: 26 April 2024

DOI: 10.1111/1556-4029.15540

JOURNAL OF FORENSIC SCIENCES AAFS

TECHNICAL NOTE

Anthropology

The influence of rehydration on decomposition in the Highveld region of South Africa—Using a pig model

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Funding information
American Academy of Forensic Sciences

Abstract

Researchers have observed that rainfall may re-initiate decomposition in desiccated tissue; however, no conclusive research-based evidence exists on the specific effects of rehydration on decomposition. Therefore, this study aimed to assess the effects of artificial rehydration on the progression of decomposition following the advanced stage of decomposition. Twelve adult pig cadavers (8 experimental; 4 controls) were placed in the central Highveld of South Africa during cooler (April–July 2021) and warmer (August–November 2021) months. Decomposition was scored approximately biweekly to obtain the total body score, and accumulated degree days (ADD) were calculated for each pig. All pig cadavers were covered by chicken wire cages with transparent tarps to control for natural rehydration and scavenging. Once the experimental pig cadavers reached a three-visit stasis in the advanced phase of decomposition, they were artificially rehydrated, and changes in the progression of decomposition between the control and experimental groups were plotted (ADD against TBS) for observation. The rehydrated experimental pig cadavers showed re-initiation of decay and insect re-colonization, while the control cadavers mainly remained in a state of stasis with insect activity ceased altogether. Greater cadaver decomposition islands and a color change post-rehydration were also noted in some experimental cadavers. This supports the need for future research on the impact of rehydration, including associated soil moisture on decomposition rates, progression, and invertebrate colonization, which will enhance our understanding of the effects these environmental factors have on the accuracy of post-mortem interval estimation.

KEYWORDS
decomposition, forensic anthropology, pig model, post-mortem interval, rehydration, taphonomy

Highlights

- Rehydration in the advanced stage of decomposition reinitiates the decay process.
- Insect prevalence increased, and recolonization was triggered following rehydration.
- Cadaver decomposition islands increased post-rehydration.

Presentation: This study was presented at the 49th Annual Conference of the Anatomical Society of Southern Africa (ASSA), April 19–21, 2022, held virtually.

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1 | INTRODUCTION

A major focus in forensic taphonomy is the process of decomposition and the biotic and abiotic elements that play an active role in its progression and cessation. Soft tissue decomposition is described as a systematic breakdown of a whole body until the point of skeletonization [1]. The process of decomposition consists of various stages, and although these stages have been delineated, there is significant overlap [2]. Knowledge of the decomposition process, and the various factors that influence the progression thereof, is vital when assessing the post-mortem interval (PMI).

PMI estimation is a critical tool utilized in death investigations that can provide context regarding recovered remains. It can allude to the post-mortem environmental conditions a body may have been exposed to, and PMI could help to narrow down the list of unidentified individuals logged in missing person databases based on the time these remains were found, estimated times of death calculated and the date individuals that have been reported missing [3]. In South Africa, the number of unidentified remains is high, and of the 18,324 bodies stored at 11 medico-legal laboratories across Gauteng in 2020, approximately 1173 (6.4%) remained unidentified [4]. However, the high number of cases involving unidentified decomposed individuals is also a global problem [5], highlighting the need for better means of identification, including more accurate methods to estimate the PMI.

Current methods used to estimate the PMI are linked to the stages of decomposition and require a thorough knowledge of the factors that can influence the progression and rate of decay of human remains [3, 6, 7]. Temperature, humidity, rainfall, soil, invertebrate colonization, vertebrate scavenging, trauma, clothing, body size and weight are some of the main factors influencing the decomposition process [8]. Rainfall/moisture has been attributed to influencing decomposition [9]. However, there is limited research looking at the direct effects of rainfall/moisture on the progression of decomposition. The effects of rain (rehydration) have mainly been observed as a part of seasonal variation and it has been suggested that rehydration will result in the re-initiation of active decomposition after desiccation [9]. This is forensically significant, as remains are likely to dry out and stall in the advanced stage of decomposition during dry seasons and resume decomposition after rehydration (rainfall) in the wet season. If these remains are, therefore, only discovered in the wet season, a shorter PMI estimation than the actual PMI might be calculated, resulting in inaccurate estimations. This is specifically the case in the Highveld region of northern South Africa, with its colder and drier winter months (June–August) and warmer, wetter summer (December–February). This study, therefore, aimed to assess the influence of rehydration on remains that have entered a state of stasis in the advanced stage of decomposition.

2 | MATERIALS AND METHODS

This study was conducted at the Forensic Anthropology Body Farm (FABF) on the Miertjie Le Roux experimental farm, University of Pretoria. The experimental farm consists of 570 hectares (5.7 km^2), with a ±0.5 hectare (5000 m^2) fenced-off section designated to the FABF in the Cullinan District, Gauteng Province, in the central Highveld plateau of South Africa [9]. The Köppen-Geiger climate classification of this region is Cwb; (C) temperate, (w) dry winter, (b) warm summer [10, 11]. Rainfall mainly occurs during the summer months in this area, with limited winter showers [12].

A total of 12 domestic pig (*Sus scrofa domesticus*) cadavers (deceased remains) weighing approximately 40–100 kg were used in this study. Ethical clearance for the use of animal material in this study was obtained from the animal research ethics committee, the University of the Witwatersrand (AESC20-05-003; 2020/05/05/O) and the University of Pretoria research ethics committee (REC104-20). The specific weight of the pig cadavers was chosen to represent the average weight of an adult human, as body size and weight have been shown to affect the rate of decomposition [13]. Pigs were collected within 1 day of death in the fresh stage of decomposition. Only pig cadavers with no external trauma or wounds were accepted for this research, as an increase in invertebrate colonization has been observed in cases with trauma or external wounds [14]. Pigs that died of natural causes, including diseases such as *Lawsonia intracellularis* and *Haemophilus parasuis*, which are common amongst pig farms [15], were used. A pig model was used due to the similarities between human and pig decomposition and the similarities regarding the skin, weight, diet, and intestinal flora [16]. Pigs are still not the perfect proxy for human decomposition studies due to the difference in limb proportions and body composition [17]. However, due to South Africa's lack of human decomposition facilities, the use of pig models is necessary. They provide valuable information on the factors that influence decomposition, which can then be used to support PMI estimations in human cases.

Four placements occurred (Table 1), with three pigs placed each time (April, July–August, and early September 2021). The placement

Temperature (°C)	Trial 1 (April)	Trial 2 (July)	Trial 3 (August)	Trial 4 (September)
Minimum	2	2	4	10
Maximum	27	36	36	36
Daily average	15.4	19.9	21.1	21.9
Total rainfall (mm)	22.2	23.4	23.4	22.3

TABLE 1 Comparison of minimum, maximum, and average daily temperatures, as well as total rainfall for each trail, over each experimental period respectively, including the month of placement.

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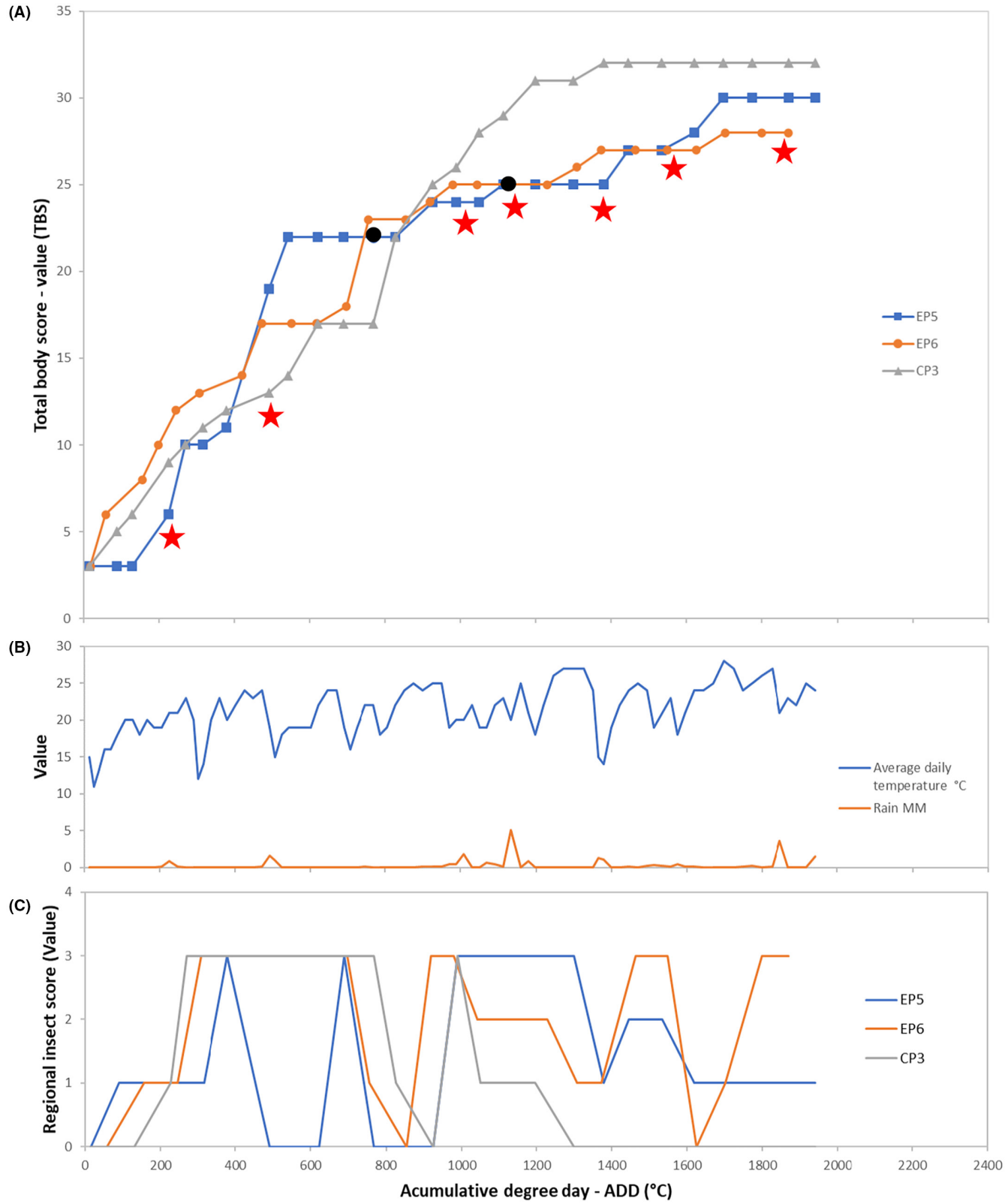


FIGURE 6 (A) Scatter plot representing accumulative degree days (ADD) against the TBS for the decomposition cycle of Trial 3 with the blue and orange lines indicate the experimental pigs (EP5 and EP6 respectively), and the gray line the control pig 3 (CP3). The rehydration event is represented for EP5 and EP5 with a black dot, and indirect rehydration events (rain) identified with stars. (B) Represents the average daily temperature and total daily rainfall against ADD, and (C) a graphical representation of the insect activity scored by regional the presence of insects (head and neck, trunk, and limbs). A score of 1 represents the presence of insects in one region, 2 means the presence in two regions, and 3 on all regions. The regional scores represent insect activity over the experimental phase plotted against ADD as a timeline.

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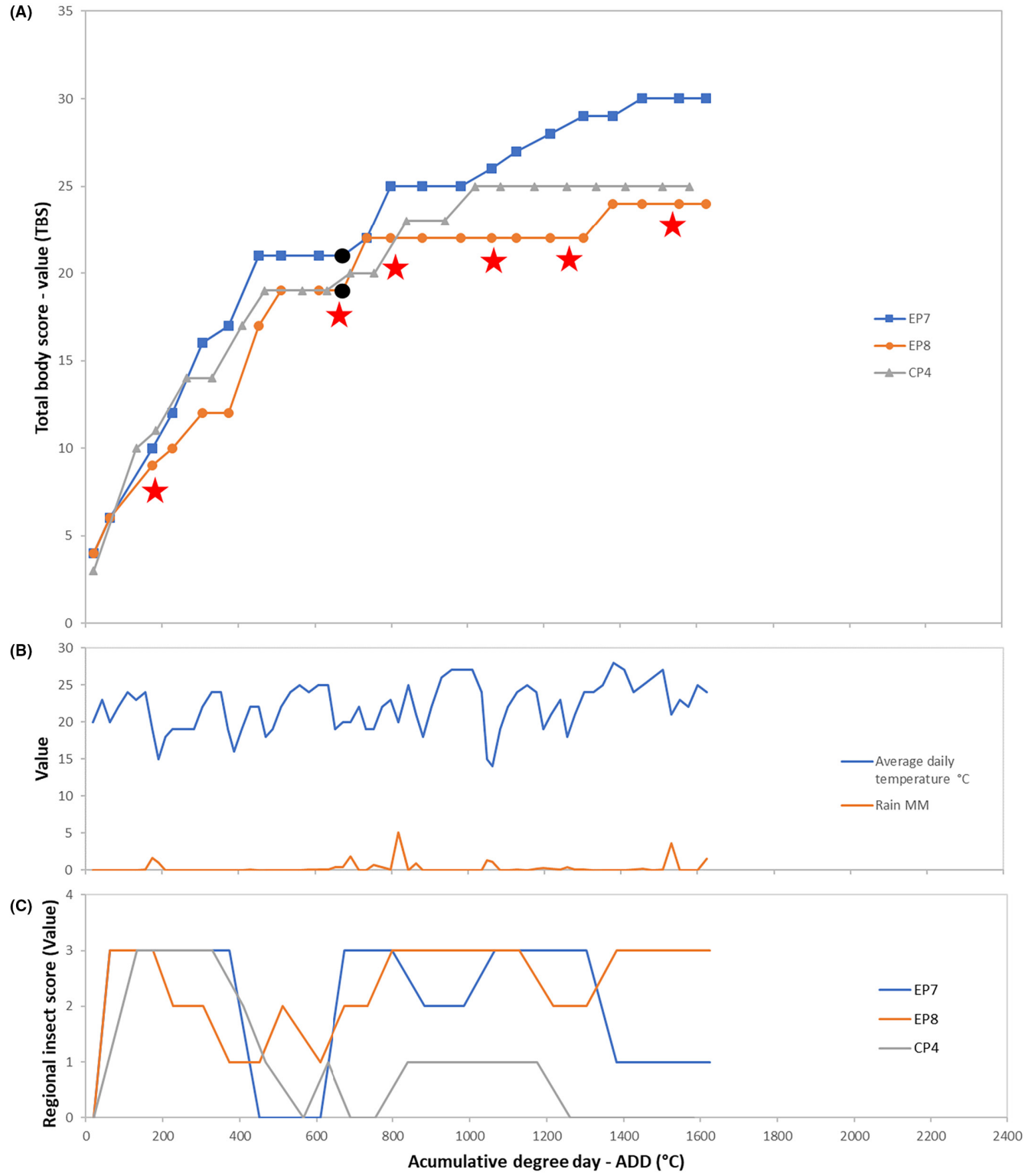


FIGURE 7 (A) Scatter plot representing accumulative degree days (ADD) against the TBS for the decomposition cycle of Trial 4 with the blue and orange lines indicate the experimental pigs (EP7 and EP8 respectively), and the gray line the control pig 4 (CP4). The rehydration event is represented for EP7 and EP8 with a black dot, and indirect rehydration events (rain) identified with stars. (B) Represents the average daily temperature and total daily rainfall against ADD, and (C) a graphical representation of the insect activity scored by the regional presence of insects (head and neck, trunk, and limbs). A score of 1 represents the presence of insects in one region, 2 means the presence in two regions, and 3 on all regions. The regional scores represent insect activity over the experimental phase plotted against ADD as a timeline.

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which is the most commonly used method of PMI estimation, attributes temperature as accounting for 80% of the variation seen in physical changes occurring during the decomposition process [3, 26–29]. When assessing the increased temperatures combined with increased humidity in this research study, the progression of decomposition was possibly altered. Temperature, as a factor affecting the progression of decomposition, cannot always be isolated from other factors, such as soil moisture [30], humidity, and rainfall, which are dependent or co-dependent on temperature [1, 8]. The factors played a combined role in the progression of decomposition along with insect and bacterial activity [26]. However, the accuracy of the method is highly variable between seasons, and the possible effects of seasonal variation are not fully understood in the case of rainfall and need to be further explored with longitudinal studies continued from this baseline research [31, 32]. Seasonality was however introduced in this study to assist in the comparison with Myburgh et al. [9], where all variables were replicated with the exclusion of rainfall. The standardized methods of PMI look solely at temperature as a factor to model formulae to establish the time since death [3, 33–35]. Rehydration and, therefore seasonality need to be considered in PMI estimations.

Additional changes noted post-rehydration included color changes in the tissue, which were specifically seen in experimental pig cadavers EP7 and EP8 for Trial 4 (Figures 10 and 11). This has also been noted in other studies where rehydration (exposure to humidity) of desiccated tissue visually changed the tissue appearance with tissue often appearing devoid of pigmentation, white or ashen, like tissue observed in arid environments that was previously browned/blackened before rehydration [36]. Victims whose remains are submerged in water also display a change in skin color [37]. Dalal et al. [37] noted that the pig cadavers that had been submerged appeared "grayish" in color along with sloughing of the skin. Therefore, it is possible that the time of exposure to rainfall might affect the rehydration of the dried decomposed skin, causing a color change. As such, whitened saturated tissue color could be indicative of desiccated tissue exposed to rain, which could affect the interpretation of post-mortem events and the timing of PMI. However, the interpretation depends on the timing of discovery as the color change did not persist once the cadavers were dehydrated once again.

Another qualitative observation made during the study is the greater CDI related to direct rehydration (Figures 8 and 9). The presence of CDIs is not uncommon in taphonomy research [21, 38, 39]. Cogswell and Cross [39] noted that CDIs differed based on the surfaces on which the cadavers were placed, e.g., concrete, grass, and gravel [39]. The authors also noted that CDIs present around a cadaver on a grass surface persisted after being exposed to rainfall compared to other surfaces, such as gravel and concrete. Soil chemistry of CDI is currently being explored as a method of PMI estimation [21, 38]. The current study supports further research into the effect of rehydration on CDI and the subsequent effects on the PMI estimation methods, as the CDI may serve as an indicator of rehydration, including how the size and depth of the pig cadaveric nutrients in the soil could affect the interpretation of PMI estimation after rehydration.

Indirect rehydration occurred during the experimental phase, where the soil around the cages was rehydrated by rain even though the tarps on the cages attempted to limit the area around the cadaver. Following the indirect hydration events, the pig cadavers displayed different progressions of decomposition. In some cases, the extent of the indirect natural rehydration had no direct effect when the pig cadaver (EP3) stalled in decay, as no change was observed until after direct rehydration. Other pig cadavers experienced an increase in decay and insect activity, such as EP1, EP2 and the control pig (CP1), during the fresh to the early stages of decomposition. This may also explain the initial increased progression of decay for Trial 4 pig cadavers who experienced indirect natural rehydration during the early phase of decomposition along with warmer temperatures. This may indicate that both indirect and direct rehydration influence the progression of decomposition due to the saturation of the ground surface underneath the cadaver with increased humidity and soil moisture [1, 8, 30, 32, 40].

Insect activity was altered post-rehydration in the experimental pig cadavers. After the tissue dried, flies no longer deposited eggs on the pig cadavers. In keeping with the literature, this is due to the flesh no longer containing enough moisture to promote maggot growth and, as such, is no longer palatable for maggot consumption [26, 41]. Hide beetles, however, are biologically equipped to consume harder material such as dry skin/hide [42], although the Hide beetle larvae are very susceptible to environmental factors, and cessation of *Dermestidae* can occur once the tissue is entirely devoid of moisture or subject to waterlogging and predation [43]. The current research suggests that the increased visibility of beetles post-rehydration may be due to either an excess of water forcing the beetles inside the pig cadaver to rise to the surface and become visible to the researcher or due to the re-colonization of insects on the pig cadaver post-rehydration of the tissue. This contrasts with the work of Ayers [41], who did not observe any return of fly activity in rehydrated tissue. The current study noted flies' post-rehydration, but no visible eggs or maggot masses. Flies are associated with the fresh to the early advanced stages of decomposition, where the tissue is still moist [6]. A possible reason for the re-attraction of flies without eggs may be associated with the rehydrated tissues releasing volatile organic compounds (VOCs).

The study was limited to the analysis of rehydration during the advanced stage of decomposition. However, the analysis of rehydration during different stages of decomposition is essential to further understand the effects of rehydration on the pattern of decomposition and the possible effects on the estimation of PMI. Direct rainfall and soil moisture were limited as this research project aimed to assess the baseline effects of rehydration on decomposition, allowing a more focused analysis of the subsequent effects of rainfall when introduced during advanced decomposition. Although the effects of soil moisture were noted, this was not specifically assessed and needs to be considered in future research. This study was also restricted to using a pig model; therefore, it is essential to explore the effects

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of rainfall and rehydration on human cadavers. The sample size and number of pigs placed at one time were limited by the availability of the pig cadavers from the pig farm due to the need for fresh cadavers used in the study. The number of pigs per trial were further limited by the number of cages and the need to have a batch placement of the pig cadavers. The sample size of this study limited the statistical robusticity and it is recommended studies with increased samples quantify the differences observed. This pilot study supports the need for further research with placement of cadavers over multiple years as a longitudinal study. The pig cadavers in the current study were placed over two seasons, however, longitudinal studies would allow for a deeper understanding of the effects of seasonality on a larger scale. Larger sample sizes in conjunction with longitudinal studies would allow for more robust statistical analysis and the possible incorporation of rehydration into PMI estimation formulae.

In conclusion, this study found that rehydration influences the progression of decomposition as well as insect activity. The findings of this research have provided baseline data relating to the effects of rehydration on decomposition. However, the limitations associated with this study, which necessarily affected the study design, should be considered when interpreting these results and should be addressed in future studies. Notwithstanding, the study highlights the need for research involving the effect of rainfall due to the possible substantial alterations that could occur in the decomposition process. Also, rehydration (rainfall) should be taken into consideration when a body is found as it can mask the PMI of the remains when calculated based on the degree of decomposition, possibly resulting in a shorter PMI estimation.

ACKNOWLEDGMENTS

We thank Mr Luan Fouche (Farm manager; G.H. Braak farm in Rooipoort, Bronkhorstspruit) for donating the experimental sample (pig carcasses) along with assistant staff sourcing and transporting pig carcasses used in this research. We thank Mr Roelf Coertze (Senior farm manager; Department of Natural Science and Agriculture, University of Pretoria) and his assistant staff for granting access to the Forensic Anthropology Body farm on Miertjie Le Roux Experimental farm. We would also like to thank Mr Jacob Mekwa (Senior technician; School of Anatomical Sciences, University of the Witwatersrand), Mr Alfred Sibara (Workshop/Technical assistant; School of Anatomical Sciences, University of the Witwatersrand), and their team for constructing the cages used in the research.

FUNDING INFORMATION

This work was supported by the National Institute of Justice and the Forensic Technology Centre of Excellence, the American Academy of Forensic Sciences, and the Humanitarian and Human Rights Resource Centre (HHRRC).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to report.

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How to cite this article: du Toit CL, Myburgh J, Brits D. The influence of rehydration on decomposition in the Highveld region of South Africa—Using a pig model. J Forensic Sci. 2024;69:1407–20. https://doi.org/10.1111/1556-4029.15540

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