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Interactive effects of Clothing, Body Mass, Decomposition and Postmortem interval (PMI) Estimation of Hanged Pig *(Sus Scrofa Domestica)* Carcasses in a Tropical Nigerian Environment

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ABSTRACT

Postmortem interval (PMI) estimation is central to forensic death investigation, yet taphonomic data from tropical West Africa remain scarce. Furthermore, only a few published Nigerian studies have examined how clothing interacts with body mass in hanged decomposing carrion. Four *Sus scrofa domestica* carcasses (two adult, ~38–40 kg; two juvenile, ~25–28 kg), divided into clothed and unclothed pairs, were humanely euthanized and suspended by hanging to mimic death by hanging for 30 days in Cross River State, Nigeria. Total Body Score (TBS), accumulated degree days (ADD), abdominal circumference, and microclimate variables were monitored daily. Trajectories were fitted using Gompertz and logistic growth functions, with clothing, age, and interaction effects evaluated via residual-resampling bootstrap (2,000 iterations). All carcasses exhibited strong Gompertz fits ($R^2 \geq 0.95$). Clothing status and age group interacted significantly on decomposition rate: clothing modestly slowed decay in the adult carcass but nearly tripled it in the juvenile carcass (interaction effect on Gompertz rate constant = −0.289, 95% CI [−0.359, −0.221]). At a TBS of 15, the unclothed juvenile carcass took nearly twice as long (11.6 days) to decompose as the clothed juvenile (6.0 days). Normalised bloat and deflation kinematics did not differ meaningfully by clothing or carcass mass. Body mass and clothing interactively shape the decomposition of hanged carrion in tropical environments, with the direction of the clothing effect depending on body size. Regional PMI models for tropical hanging deaths should treat clothing and age as interacting rather than independent variables.

Keywords: Postmortem interval, taphonomy, forensic entomology, tropical decomposition

INTRODUCTION

Forensic anthropologists and pathologists rely on an accurate estimate of the postmortem interval (PMI) to narrow the window during which a death may have occurred, thereby helping investigators include or exclude suspects and reconstruct the circumstances of death[1,2]. Because decomposition begins almost immediately after death and proceeds through a broadly predictable sequence of physical, chemical, and biological changes, examiners commonly use the degree of decomposition, rather than clock time alone, as their primary evidence[3]. This process is driven jointly by intrinsic factors specific to the body such as age, body constitution, cause of death, and disposal environments and by extrinsic, environmental factors such as ambient temperature, humidity, ventilation, and clothing[4]. Clothing in particular can slow postmortem cooling and hasten the onset of putrefaction by trapping heat and moisture around the body[4].

To compare decomposition across studies, researchers have adopted standardised scoring systems, most notably the Total Body Score (TBS), which is tracked alongside Accumulated Degree Days (ADD), a temperature-based measure of the energy available to drive microbial and insect activity[5,6]. Because pigs (Sus scrofa) share broad physiological similarities with humans, they are widely used as human proxies in taphonomic experiments of this kind[7].

Body mass is among the most extensively studied of these variables. Larger carcasses carry more fat and muscle, decompose with greater residual biomass, and

support more complex, later-colonising insect assemblages than smaller carcasses[8,9]. Larger carcasses also bloat and remain in active decay longer[10], attract greater numbers of arthropods[11], and lose heat more slowly, which can accelerate early bacterial activity[12]. Comparative studies, however, disagree on the net effect of mass on decomposition rate. Some report that larger carcasses decompose faster overall[11,13], while others, working with clothed pig carcasses across a wide mass range, found that smaller carcasses decomposed significantly faster in both sun and shade[14–16]. This inconsistency, evident even within a single climate, underscores the point that decomposition data from one microclimate cannot be assumed to transfer to another[15].

Clothing is a second, less well understood taphonomic variable. Although its influence on the overall pattern and rate of pig carrion decomposition appears comparatively minor[10], clothing meaningfully alters the abiotic microenvironment of a cadaver, its humidity, degree of shading, and the physical access it affords to colonising insects[17]. Clothing has been linked to increased abundance and diversity of carrion insects, enlarged dipteran larval masses, and a prolonged presence of larvae on the body[17], yet these effects are not consistently reported across studies, leaving the practical importance of clothing for PMI estimation unresolved.

Hanging adds a further layer of complexity that is rarely combined with either of the above variables. Hanging is the suspension of the body by a ligature around the neck, producing unconsciousness within seconds and death within minutes through a combination of cerebral anoxia, vagal inhibition, and spinal cord injury[19,20]. It is among the most common methods of suicide worldwide, with a case fatality rate estimated at 70–84%[21,22], and its epidemiological importance is well documented in both Nigerian and international contexts[23–25]. Despite this, forensic knowledge of how a hanged, suspended body decomposes as distinct from a body lying on the surface remains comparatively sparse[18], and locally generated Nigerian data on hanged carrion are limited to only a handful of studies[26, 27].

Taken individually, body mass, clothing, and hanging have each been shown to influence decomposition, yet almost all of the literature above derives from temperate regions of Europe, North America, and southern Africa, with only isolated studies from West Africa[28,29]. Because local climate, insect fauna, and even carcass size distributions shape decomposition timelines, findings from one region cannot be reliably extrapolated to another[15]. No published Nigerian study has yet examined how clothing interacts with body mass in hanged carrion, leaving a clear gap for forensic practice in tropical, hanging-related death investigations. This study therefore examined the combined effect of clothing and body mass on the decomposition of small (juvenile) and large (adult) hanged Sus scrofa domestica carcasses in a tropical Cross River State, Nigeria, environment, quantifying decomposition trajectories, thermal calibration curves, and clothing×age interaction effects to inform regionally appropriate PMI estimation.

MATERIALS AND METHODS

Study location

The study was conducted at the University of Cross River State (UNICROSS) Department of Anatomy Forensic Anthropology Research Facility (DAFARF) in Okuku, Yala Local Government Area, Cross River State, Nigeria, from 1 July to 30 July 2023 (Figure 1). Four domestic pigs *(Sus scrofa domestica)* were used to model decomposition of hanged human remains: two adult carcasses (approximately 6 months old, 38–40 kg) and two juvenile carcasses (approximately 3 months old, 25–28 kg). The pigs were purchased from a local farm in Okuku market, Cross River State, Nigeria, after satisfying institutional animal-use and safety protocols. Ethical clearance for the field study was obtained from the University of Cross River (UNICROSS) Faculty of Basic Medical Sciences Research Ethics Committee (reference number: UNICROSS/FBMSEC/2023-HA 006). Pigs were selected as a model because their body fat content, hair distribution, and fluid composition closely resemble those of humans, consistent with established practice in forensic taphonomy[7].

Study design

Of the four carcasses, one adult and one juvenile were dressed in clothing prior to suspension; the remaining adult and juvenile were left unclothed. All four animals were humanely sacrificed using blunt force trauma achieved via a single, humane blow to the cranium prior to being suspended by a ligature around the neck to mimic death by hanging and were monitored for 30 consecutive days (1–30 July 2023)[8,14,26,27]. Each carcass was assessed using a standardised Total Body Score (TBS) instrument scoring the head/neck, trunk, and limb regions separately[5,6], recorded three times daily for the first two weeks and twice daily thereafter through Day 30. At each observation, colour, size, decomposition stage, insect activity, bone exposure, odour, mummification, and the dimensions of the cadaver decomposition island (CDI) were recorded, together with abdominal circumference and the following microclimate variables: atmospheric temperature, soil temperature, relative humidity, wind speed, and soil pH. Ambient temperature readings were used to compute accumulated degree days (ADD) for each carcass. Photographic documentation was taken at each observation to support subsequent review of decomposition changes.

Statistical analysis

All quantitative analyses were performed in Python (version 3.12; Python Software Foundation, Wilmington, DE, USA) using the SciPy, NumPy, scikit-learn, and Matplotlib (version 3.10) libraries. Prior to analysis, accumulated degree days (ADD) were recalculated for each carcass as the cumulative sum of average daily ambient temperature because the original dataset contained non-monotonic values that were inconsistent with cumulative thermal accumulation and were attributed to data-entry error. All ADD-based analyses used the corrected series.

Because each clothing × age condition was represented by a single carcass, conventional factorial ANOVA was not appropriate. Analyses therefore focused on repeated measurements within carcasses, non-linear modelling with bootstrap resampling to estimate parameter uncertainty, and exploratory analyses of associations between decomposition and environmental variables. Cross-carcass comparisons are interpreted as descriptive rather than confirmatory. Regional decomposition was assessed using Friedman tests to compare total body score (TBS) sub-scores among the head/neck, trunk, and limb regions within each carcass, with study day as the blocking factor (Days 2–30).

Decomposition trajectories were modelled separately for each carcass using three-parameter Gompertz and logistic growth functions fitted by non-linear least squares (Levenberg–Marquardt algorithm; *scipy.optimize.curve_fit*). Model performance was evaluated using the coefficient of determination (R^2) and root-mean-square error (RMSE). The Gompertz inflection point, representing the period of maximum decomposition rate, was calculated as ln(b)/c.

To calibrate postmortem interval, Gompertz models were fitted to TBS as a function of ADD because preliminary linear models produced implausible predictions. ADD was estimated from observed TBS values by numerically solving the fitted Gompertz equation (Brent's method), and approximate 95% prediction intervals were obtained from the residual standard deviation. Associations between TBS and atmospheric temperature, soil temperature, relative humidity, soil pH, and wind speed were examined using multiple linear regression within each carcass. Because TBS is strongly correlated with time, these analyses are interpreted as descriptive. Pearson cross-correlation (lags 0–3 days) was used to assess temporal relationships between soil pH and TBS.

Abdominal circumference data were smoothed using quartic penalized splines (*scipy.interpolate.UnivariateSpline*) to estimate peak bloat, time to peak, and post-peak deflation rate. Bloat magnitude and deflation rate were also expressed as percentages of Day-1 circumference to account for body-size differences. A residual-resampling bootstrap (2,000 iterations per carcass) was used to estimate uncertainty in Gompertz- and spline-derived parameters. Bootstrap distributions were used to estimate descriptive effects of clothing, age, and their interaction, with 95% confidence intervals defined by the 2.5th and 97.5th percentiles. Bootstrap Gompertz models were also used to estimate the time required to reach TBS thresholds of 10, 15, and 20. Statistical significance was set at $\alpha = 0.05$ for all exploratory analyses.

RESULTS

Qualitative decomposition staging

Table 1 summarises the qualitative decomposition observations recorded for the clothed and unclothed hanged carcasses across the five recognised stages of decomposition. Early postmortem changes (pallor, rigor, and livor mortis) followed a near-identical timeline in clothed and unclothed carcasses of the same size. Clothing effects became more apparent from the bloated stage onward, where the clothed small carcass recorded a lower TBS than its unclothed counterpart, and in later stages, where clothing concentrated maggot activity and decompositional fluid at specific sites (notably around the ligature) rather than distributing them evenly across the carcass.

Regional decomposition dynamics

Total body score (TBS) sub-scores for the head/neck, trunk, and limb regions were compared within each carcass using Friedman tests, treating study day as the blocking factor. Regional sub-scores differed significantly across body regions in all four carcasses: unclothed adult, $\chi^2(2) = 26.69$, $p < .001$; unclothed juvenile, $\chi^2(2) = 36.00$, $p < .001$; clothed adult, $\chi^2(2) = 40.37$, $p < .001$; and clothed juvenile, $\chi^2(2) = 35.17$, $p < .001$ (Table 2). The trunk region carried the highest mean TBS in three of the four carcasses, consistent with early gut-driven putrefaction, though the margin over the head/neck and limb regions narrowed in the clothed conditions, plausibly reflecting altered insect and environmental access to the trunk when covered.

Decomposition trajectory modeling

Both Gompertz and logistic growth functions fit the TBS-versus-day data well across all four carcasses ($R^2 \geq .941$; Table 3), with the Gompertz function providing a marginally better fit for three of the four carcasses. The Gompertz inflection point, which represents the day of steepest increase in TBS, occurred earliest in the unclothed adult carcass (Day 3.74) and latest in the unclothed juvenile carcass (Day 5.10), with the clothed adult (Day 4.08) and clothed juvenile (Day 4.25) carcasses intermediate (Figure 2).

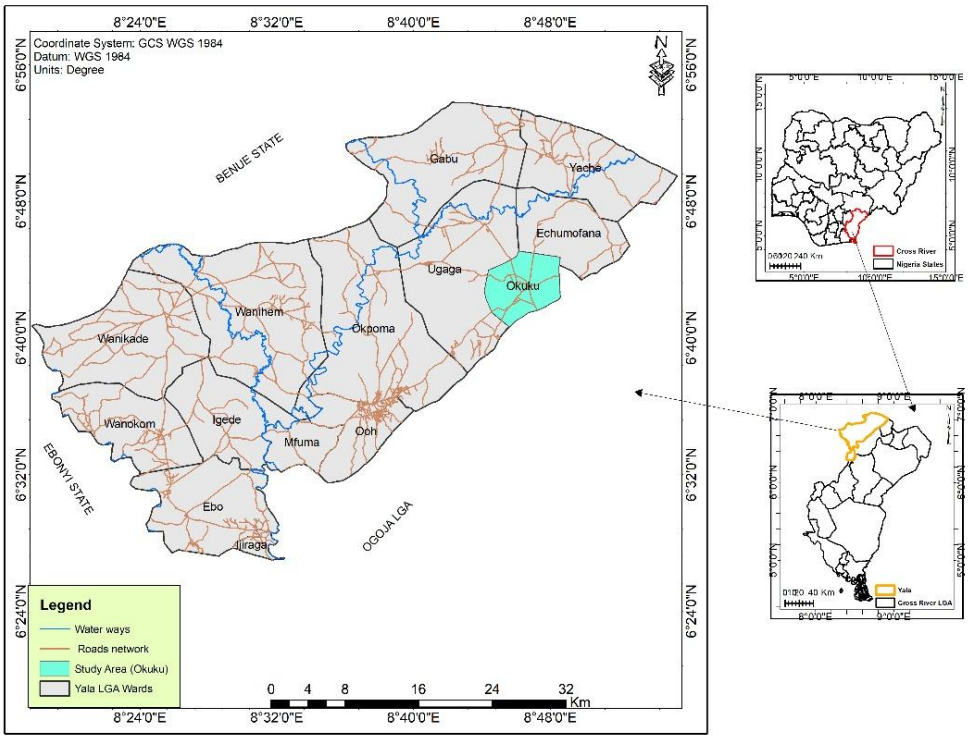

Figure 1. Map of Cross River State (lower right), showing Okuku Town within Yala LGA, where the study site was situated (ArcGIS Version 10.7, © 2019).

Table 1. Qualitative decomposition observations for unclothed and clothed hanged carcasses, by stage.

Stage	Approx. PMI	Unclothed carcasses	Clothed carcasses
Fresh	0–24 h (Day 1)	Pallor, rigor, then livor mortis; small carcass showed earlier limb rigor and fly arrival by evening.	Same early timeline; small clothed carcass showed livor mortis in exposed regions and comparable insect arrival.
Bloated	24–48 h (Day 2)	Abdominal/inguinal distension with onset of maggot activity in both sizes; large carcass outpaced small (TBS = 4).	Small clothed carcass recorded lower TBS (3) than its unclothed counterpart; large clothed carcass showed massive maggot presence and fluid-soaked clothing.
Active decay	3–5 days	Total body prolapse, fluid discharge, prominent ligature marks; large carcass showed more advanced skin leatheriness.	Similar prolapse pattern, but clothing retained fluids/maggots; covered regions visibly lagged exposed regions.
Advanced decay	5–15 days	Scavenger activity, leathery/slippery skin, rib collapse, progressive skin peeling; large carcass reached these changes first.	Comparable leathery skin, but clothing created localized microhabitats, concentrating maggot masses near the ligature/CDI zone.
Mummification	15–30 days	Small carcass mummified; large carcass reached bone-weathering and disarticulation sooner.	Similar trajectories to unclothed counterparts, with endpoints reached at slightly delayed timepoints in the clothed large carcass.

Table 2. Mean regional TBS sub-scores and Friedman test results, by carcass

Carcass	Head/Neck M	Trunk M	Limb M	$\chi^2(2)$	p
Unclothed adult	7.14	7.90	6.76	26.69	< .001
Unclothed juvenile	6.14	6.45	4.28	36.00	< .001
Clothed adult	5.52	6.93	6.59	40.37	< .001
Clothed juvenile	7.41	8.17	6.86	35.17	< .001

Table 3. Gompertz and logistic model parameters for TBS as a function of study day

Carcass	Gompertz a	Gompertz c	Gompertz R^2	Inflection day	Logistic R^2
Unclothed adult	25.68	0.297	.972	3.74	.959
Unclothed juvenile	24.94	0.104	.946	5.10	.941
Clothed adult	23.49	0.222	.967	4.08	.973
Clothed juvenile	26.78	0.315	.988	4.25	.983

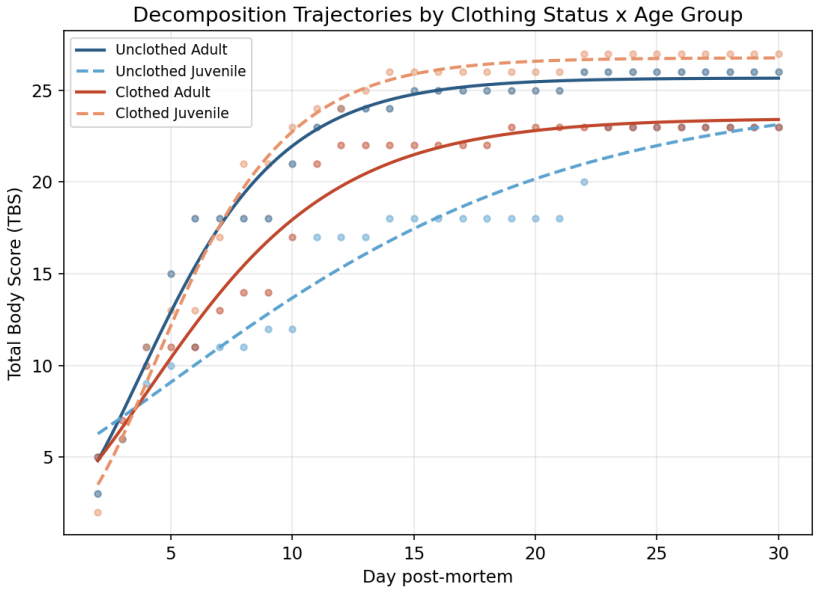

Figure 2. Gompertz-fitted decomposition trajectories for all four carcasses (a = asymptote; c = Gompertz rate constant).

Thermal accumulation and PMI calibration

A Gompertz function fitted to TBS as a function of ADD provided a good fit for all four carcasses (unclothed adult R^2 = .974; unclothed juvenile R^2 = .947; clothed adult R^2 = .966; clothed juvenile R^2 = .990). Table 4 presents inverse-predicted ADD values, with approximate 95% prediction ranges, corresponding to representative observed TBS scores; these calibration curves may be used to convert an observed TBS score into an estimated thermal PMI for each clothing X age condition.

Microclimate associations

Multiple linear regression examined whether five microclimate variables explained variance in TBS beyond the dominant time trend; because TBS is strongly auto-correlated across successive days, these models are descriptive associations rather than confirmatory causal tests. The overall model was significant for the clothed adult carcass, $F(5, 23) = 3.25$, $p = .023$, $R^2 = .414$, and approached significance for the unclothed juvenile carcass, $F(5, 23) = 2.57$, $p = .055$, $R^2 = .358$, but was not significant for the unclothed adult carcass, $F(5, 23) = 1.40$, $p = .260$, or the clothed juvenile carcass, $F(5, 23) = 0.81$, $p = .554$. Soil pH was the only individual predictor to reach significance in any model, in the clothed adult ($\beta = 4.36$, $p = .006$) and unclothed juvenile ($\beta = 1.97$, $p = .032$) carcasses (Table 5).

Cross-correlation analysis of soil pH and TBS at lags of 0–3 days showed the strongest association in the clothed adult carcass, peaking at lag 0 ($r(27) = .61$, $p < .001$), and a moderate association in the unclothed juvenile carcass, peaking at a 2-day lag ($r(27) = .50$, $p = .009$). The clothed juvenile carcass showed the weakest association, non-significant at all lags examined (lag 0: $r(27) = .27$, $p = .157$; Table 6).

Bloat and deflation kinematics

Abdominal circumference rose to a peak within the first 2–3 days postmortem in all carcasses before declining steadily thereafter (Figure 3). Because absolute circumference is confounded with baseline body size, bloat magnitude was additionally expressed as a percentage of each carcass's baseline circumference. Expressed this way, bloat magnitude was similar across all four carcasses (unclothed adult = 18.3%, unclothed juvenile = 16.6%, clothed adult = 18.5%, clothed juvenile = 17.0%), as were peak timing (Days 1.9–2.1) and post-peak deflation rate (−1.2% to −1.5% of baseline circumference per day). A bootstrap factorial comparison (2,000 iterations) found no significant clothing, age, or interaction effect on size-normalised bloat magnitude, peak timing, or deflation rate (all 95% confidence intervals included zero; Table 7). The only significant effect was an age effect on absolute (non-normalised) bloat magnitude (adult − juvenile difference = 4.12 cm, 95% CI [0.29, 7.98]), attributable to the larger baseline body size of the adult carcasses rather than a distinct physiological response, given the absence of a corresponding effect once bloat magnitude was normalised for body size.

Clothing × age interaction on decomposition rate

A residual-resampling bootstrap (2,000 iterations) was used to estimate main effects and an interaction effect of clothing status and age group for each Gompertz curve parameter. No significant effect on the asymptote parameter was found beyond a modest age effect (−1.36, 95% CI [−2.98, −0.17]) and interaction (−3.76, 95% CI [−6.04, −0.57]), indicating that the eventual TBS ceiling reached within the 30-day observation window did not differ substantially by clothing status. In marked contrast, the rate constant showed a large, clearly non-zero interaction effect (−0.289, 95% CI [−0.359, −0.221]): clothing modestly decreased the decay rate in the adult carcass (0.297 → 0.222) but sharply increased the decay rate in the juvenile carcass (0.104 → 0.315), a crossover pattern in which the direction of the clothing effect reversed between age groups (Figure 4, Table 8). A corresponding, though less pronounced, interaction effect was observed for inflection-point timing (1.25 days, 95% CI [−0.01, 2.65]).

Time-to-threshold analysis

To translate curve-parameter differences into a more directly interpretable PMI metric, the number of days required to reach TBS thresholds of 10, 15, and 20 was estimated for each carcass (Table 9, Figure 5). At the TBS = 15 threshold, the unclothed juvenile carcass required 11.60 days (95% CI [10.72, 12.55]), approximately twice as long as any other carcass, whereas the clothed juvenile carcass reached the same threshold in 5.98 days (95% CI [5.78, 6.21]), closely matching the unclothed adult carcass (5.83 days, 95% CI [5.53, 6.17]). The bootstrap factorial decomposition of time-to-threshold at TBS = 15 indicated a significant clothing effect (−1.87 days, 95% CI [−2.41, −1.35]), age effect (−2.04 days, 95% CI [−2.57, −1.52]), and, most notably, a large interaction effect (7.47 days, 95% CI [6.40, 8.56]), confirming that the influence of clothing on the pace of decomposition differs substantially between age groups.

Table 4. Inverse-predicted ADD (°C-days) corresponding to observed TBS values, by carcass, with approximate 95% prediction ranges.

Observed TBS	Unclothed adult	Unclothed juvenile	Clothed adult	Clothed juvenile
5	70.8 [43.8, 93.6]	—	71.9 [31.8, 106.0]	86.8 [70.0, 101.7]
10	125.2 [104.1, 146.5]	183.6 [105.6, 263.6]	149.8 [117.5, 183.3]	136.0 [122.6, 149.4]
15	180.6 [157.2, 206.9]	346.5 [259.0, 450.5]	234.2 [195.8, 280.1]	185.0 [170.4, 200.7]
20	256.1 [221.3, 303.6]	580.1 [444.1, 806.5]	368.6 [299.2, 497.9]	248.4 [227.6, 273.1]

Em dash indicates that a TBS of 5 fell below the observed range for the unclothed juvenile carcass and could not be reliably inverted.

Table 5. Multiple regression of TBS on microclimate variables, by carcass

Carcass	R^2	Adj. R^2	F(5, 23)	p	Significant predictor
Unclothed adult	.234	.067	1.40	.260	None
Unclothed juvenile	.358	.219	2.57	.055	Soil pH (p = .032)
Clothed adult	.414	.287	3.25	.023	Soil pH (p = .006)
Clothed juvenile	.150	−.035	0.81	.554	None

Table 6. Soil pH–TBS cross-correlation coefficients by lag and carcass

Carcass	Lag 0	Lag 1	Lag 2	Lag 3
Unclothed adult	.31 (p = .098)	.29 (p = .141)	.34 (p = .085)	.39 (p = .052)
Unclothed juvenile	.45 (p = .015)	.45 (p = .017)	.50 (p = .009)	.47 (p = .015)
Clothed adult	.61 (p < .001)	.58 (p = .001)	.51 (p = .007)	.44 (p = .023)
Clothed juvenile	.27 (p = .157)	.26 (p = .182)	.23 (p = .256)	.17 (p = .415)

Table 7. Bootstrap factorial comparison of size-normalised abdominal circumference metrics

Metric	Clothing effect [95% CI]	Age effect [95% CI]	Interaction [95% CI]
Bloat magnitude (%)	0.30 [−5.70, 6.01]	1.57 [−4.28, 7.43]	−0.22 [−12.32, 11.95]
Peak day	0.01 [−0.20, 0.20]	0.10 [−0.12, 0.29]	−0.01 [−0.41, 0.41]
Deflation rate (%/day)	0.01 [−0.21, 0.23]	0.14 [−0.11, 0.34]	0.00 [−0.46, 0.45]

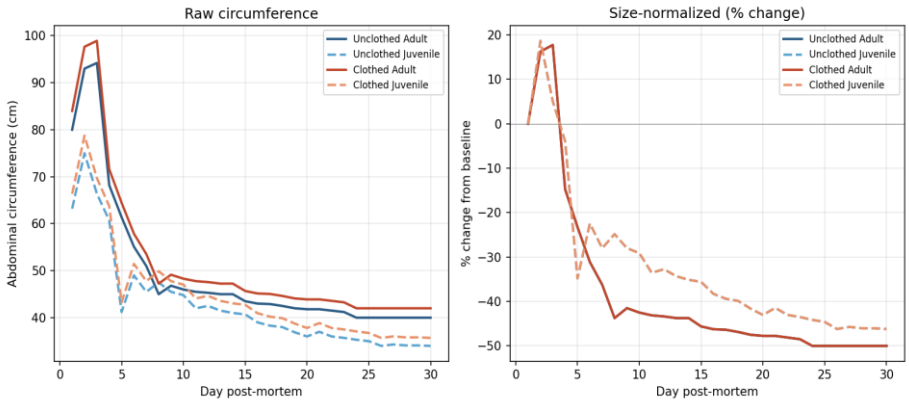

Figure 3: Raw (left) and size-normalised (right, % change from Day-1 baseline) abdominal circumference trajectories, by carcass.

Table 8. Bootstrap factorial comparison of Gompertz curve parameters

Parameter	Clothing effect [95% CI]	Age effect [95% CI]	Interaction [95% CI]
Asymptote (a)	−0.25 [−1.91, 0.93]	−1.36 [−2.98, −0.17]*	−3.76 [−6.04, −0.57]*
Rate constant (c)	0.067 [0.033, 0.102]*	0.050 [0.016, 0.083]*	−0.289 [−0.359, −0.221]*
Inflection day	−0.29 [−1.04, 0.37]	−0.82 [−1.55, −0.17]*	1.25 [−0.01, 2.65]

*95% confidence interval excludes zero.

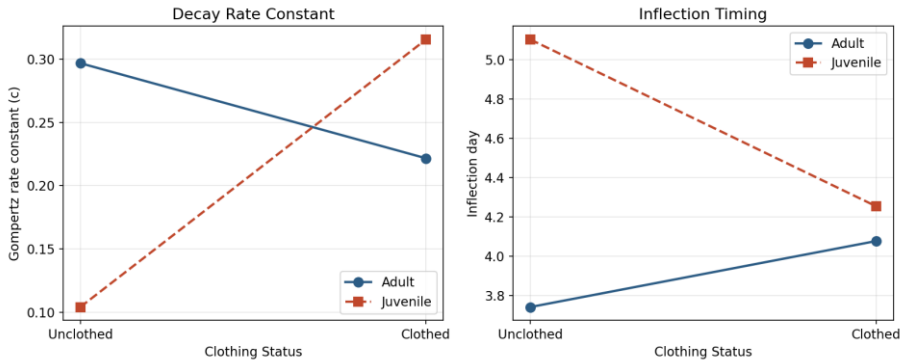

Figure 4. Interaction plots for Gompertz rate constant and inflection timing, by clothing status and age group. Non-parallel lines indicate an interaction effect.

Table 9. Estimated days postmortem to reach TBS thresholds of 10, 15, and 20, by carcass

Carcass	TBS = 10	TBS = 15	TBS = 20
Unclothed adult	3.94 [3.59, 4.28]	5.83 [5.53, 6.17]	8.41 [7.92, 8.97]
Unclothed juvenile	5.97 [5.06, 6.76]	11.60 [10.72, 12.55]	19.62 [18.41, 21.03]
Clothed adult	4.79 [4.35, 5.16]	7.69 [7.25, 8.20]	12.32 [11.53, 13.23]
Clothed juvenile	4.30 [4.09, 4.53]	5.98 [5.78, 6.21]	8.16 [7.87, 8.48]

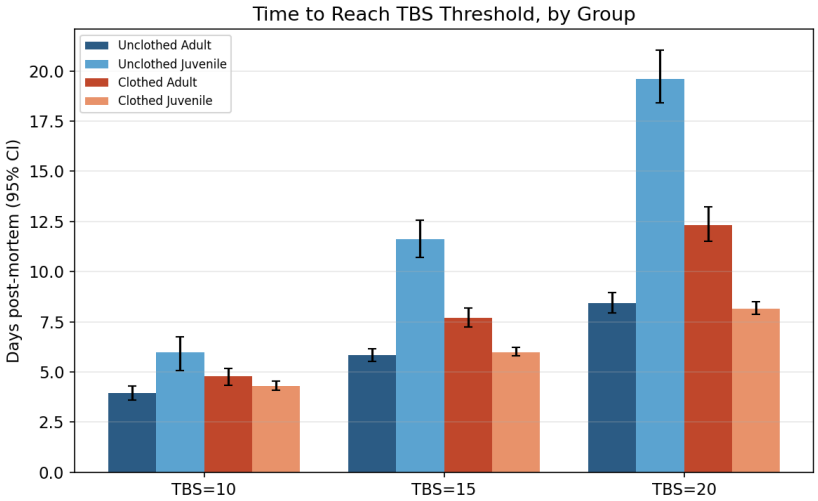

Figure 5. Estimated days to reach TBS thresholds of 10, 15, and 20, by carcass. Error bars are 95% bootstrap confidence intervals.

DISCUSSION

Accurate PMI estimation is central to forensic death investigation. It narrows the pool of possible victims, focuses police inquiries, and can corroborate or refute witness accounts[15]. Decomposition is shaped by environmental conditions, scavenging pressure, and body size, and because these factors vary geographically, locally generated data are essential to forensic validity[15]. This study examined how body mass and clothing jointly, and interactively, influenced the decomposition of small and large hanged pig carcasses used as human proxies in a tropical Nigerian setting.

Across both clothed and unclothed carcasses, the large carcass consistently reached the fresh, bloated, and active decay stages ahead of the small carcass, and progressed to skeletonisation/mummification sooner overall, despite the small carcass showing a higher Total Body Score during the first week (Days 1–7, 0–126 hours PMI). This pattern agrees with Hewadikaram and Goff[11], who found that a larger pig carcass disintegrated faster than a smaller one, and with Roberts, Spencer, and Dabbs[13], who reported the same relationship in outdoor human decomposition. It also broadly matches an earlier hanging study at this facility, in which hanged carcasses decomposed rapidly at first before slowing, in contrast to surface carcasses that accelerated later[26]. Our findings, however, do not agree with previous reports from Komar and Beattie[14], Simmons, Adlam, and Moffatt[30], Spicka et al.[16], and Sutherland et al.[15], all of whom reported that smaller carcasses decomposed faster than larger ones in temperate climates. This divergence is most plausibly explained by climate. The consistently high ambient temperature and humidity of Cross River State likely accelerated microbial and insect activity on the larger carcass's greater fat and muscle mass more than in the cooler, more seasonal environments of those studies, a pattern consistent with reports that larger bodies retain heat and moisture longer, favouring faster initial putrefaction[31,32].

Clothing exerted a more subtle, age-dependent influence, a nuance not previously reported in the literature reviewed here. Early postmortem changes comprising pallor, rigor, and livor mortis occurred on a near-identical timeline in clothed and unclothed carcasses, consistent with reports that clothing has only a minor influence on the broad pattern and rate of pig carrion decomposition[10]. The quantitative curve-fitting and bootstrap analyses reported here, however, reveal that clothing's effect on decomposition rate is not uniform across body sizes: clothing modestly slowed the Gompertz decay rate constant in the adult carcass but nearly tripled it in the juvenile carcass, and this interaction was estimated with high confidence (95% CI excluding zero). Translated into practical PMI terms, this meant the unclothed juvenile carcass took roughly twice as long to reach a TBS of 15 as the clothed juvenile carcass, whereas clothing shifted the adult carcass's timeline only modestly. A plausible, though unconfirmed, explanation is that the juvenile carcass's higher surface-area-to-mass ratio allowed clothing to trap heat and moisture that would otherwise dissipate, amplifying microbial and insect activity, whereas the adult carcass's greater mass may have instead benefited from clothing acting as a partial barrier to insect colonisation. This interpretation should be treated as a hypothesis for future replicated study rather than a demonstrated mechanism.

Where clothing more clearly mattered, consistent with the original qualitative observations, was in the later, insect-mediated stages: the clothed small carcass recorded a lower Total Body Score than its unclothed counterpart during bloating, and covered regions of the clothed carcasses visibly lagged behind exposed regions in prolapse and bone exposure, even while active internal decay continued beneath intact clothing. Clothing also concentrated fluid and maggot activity locally as displaced clothing accumulated maggot masses and decompositional fluid at specific sites, such as around the upper part of the trunk, rather than distributing them evenly across the carcass. This is consistent with evidence that clothing alters the abiotic microenvironment of a cadaver, modifying humidity and insect access in ways that can enlarge larval masses and prolong larval presence at particular sites[17]. By contrast, gross bloat and deflation kinematics, which served as the timing, magnitude, and rate of abdominal distension and collapse, did not differ meaningfully by clothing or age once normalised for baseline body size, indicating that the clothing×age interaction observed here operates at the level of tissue-level decomposition scoring rather than gross purge/gas dynamics.

Both the body mass and clothing×age effects observed here have direct implications for PMI estimation in tropical hanging cases. Where a body is unclothed, examiners in this climate should expect larger individuals to reach advanced decomposition sooner than smaller ones, contrary to the temperate-climate pattern that dominates the international literature. Where a body is clothed, examiners should anticipate that clothing may accelerate decomposition scoring in smaller/juvenile remains while only modestly slowing it in larger/adult remains, a pattern that, if confirmed by replicated study, would carry a meaningful risk of PMI mis-estimation if clothing status is not accounted for, particularly for juvenile remains.

This study is limited by its sample size: each of the four clothing×age conditions was represented by a single carcass, precluding a conventional factorial analysis of variance and limiting all cross-carcass comparisons, including the clothing×age interaction reported above, to descriptive and hypothesis-generating status rather than confirmatory population-level inference. The microclimate regression models are similarly limited by the small number of independent time points and by autocorrelation of TBS with study day, which inflates the apparent precision of associations reported. As with any TBS/ADD-based approach, the precision of the resulting PMI estimates is also inherently bounded by the categorical, observer-scored nature of the TBS instrument itself, an uncertainty that has been previously quantified for insect-succession-based PMI methods more broadly[34,35]. Replication of this design across multiple carcasses per clothing×age condition, and across a wider range of body masses and clothing types, is recommended to confirm whether the clothing×age interaction reported here reflects a generalisable biological phenomenon.

CONCLUSION

In this tropical Nigerian setting, body mass was the primary determinant of hanged-carcass decomposition rate, with the larger carcass consistently reaching advanced decomposition stages ahead of the smaller carcass regardless of clothing status. Clothing exerted a secondary, age-dependent effect, modestly slowing decomposition in the adult carcass while substantially accelerating it in the juvenile carcass.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics statement

All procedures involving animals were approved by the University of Cross River (UNICROSS) Faculty of Basic Medical Sciences Research Ethics Committee (reference number: UNICROSS/FBMSEC/2023-HA 006) and were conducted in accordance with the ARRIVE 2.0 guidelines for animal research. Animals were sourced from a licensed abattoir, judged fit by veterinary inspection, and acclimatised prior to the study.

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