

Systematic Review

The Pathology of Starvation: A Systematic Review of Forensic Evidence

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Abstract

Background: Starvation represents a specific pathological entity characterized by severe nutritional deprivation leading to multi-organ failure. Despite its forensic relevance, a comprehensive synthesis of autopsy findings remains lacking. **Methods:** This systematic review was conducted in accordance with PRISMA 2020 guidelines. PubMed, Scopus, and Google Scholar were searched from inception to June 2025 using a pre-specified Boolean query. Eligible studies included case reports, case series and cohort investigations reporting post-mortem evidence of starvation or starvation-related malnutrition. Data extracted encompassed demographic, contextual, macroscopic, histological, and ancillary findings. **Results:** Fourteen studies were included, comprising 20 individual cases and two population-based cohorts (totaling 1647 deaths). Most cases (75%) involved children, predominantly victims of domestic neglect; adults accounted for 25%, mainly due to anorexia nervosa or voluntary fasting. Six cadavers were severely decomposed or mummified. Across studies, consistent autopsy findings included extreme emaciation, near-total loss of subcutaneous and visceral fat, empty gastrointestinal tract, and diffuse organ atrophy, especially of the liver, heart, thymus, and pancreas. Histology revealed hepatic steatosis, myocardial fibrosis, thymic involution and gelatinous transformation of adipose tissue. Ancillary methods (dual-energy X-ray absorptiometry, stable isotope and anthropological analyses) confirmed malnutrition in decomposed or skeletonized remains. **Conclusions:** This review delineates the morphological and histopathological hallmarks of starvation and suggests the possible diagnostic value of ancillary techniques in advanced decomposition. The predominance of neglect-related pediatric cases underscores starvation as a forensic indicator of social and caregiving failure. Establishing reproducible morphological and histological indicators may improve the consistency of forensic diagnosis and strengthen the evidentiary basis for determining starvation as a cause of death.

Keywords: starvation; forensic pathology; autopsy findings; cause of death; child neglect; crimes against humanity



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1. Introduction

Starvation, defined as an extreme nutritional deficiency not primarily associated with inflammatory states, represents a specific nosological entity with significant forensic relevance [1]. Although malnutrition can arise in different clinical settings, such as acute

or chronic inflammation and neoplastic disease, the pathophysiological mechanisms and medico-legal implications of starvation are distinct [2,3]. Historically, the scientific understanding of starvation derives primarily from two pivotal sources: the observation of prisoners in Nazi concentration camps during World War II [4–6], and the Minnesota Starvation Experiment (1944–1945), which systematically studied the effects of prolonged caloric restriction in the condition of healthy volunteers [7,8]. These investigations laid the groundwork for subsequent clinical and pathological characterizations of starvation. In modern industrialized countries, deaths directly attributable to starvation are rare [9], but when they occur, they predominantly affect vulnerable groups, such as children, the elderly, or individuals suffering from neglect, mental illness, or coercive fasting [10,11]. From a forensic standpoint, starvation must thus be interpreted not only as a biological condition but also as a potential marker of abuse or coercion. Moreover, starvation has been historically and contemporarily used as a tool of collective punishment and warfare: international humanitarian law and United Nations bodies classify the deliberate deprivation of food or water as a crime against humanity or, under certain circumstances, a war crime [12–14]. Recent accounts from conflict zones in the Middle East, including the Gaza Strip, have renewed global concern regarding the intentional use of starvation as a method of torture and warfare, reinforcing its ongoing significance in both medical and legal domains [15–17]. International consensus has emphasized the need to differentiate starvation-related malnutrition from other forms of undernutrition. In 2010, the American Society for Parenteral and Enteral Nutrition (ASPEN) and the European Society for Clinical Nutrition and Metabolism (ESPEN) proposed an etiology-based nomenclature distinguishing three entities: starvation-related malnutrition; acute disease or injury-associated malnutrition; chronic disease-associated malnutrition [18].

Within the forensic setting, starvation-related malnutrition may be further classified into intentional and unintentional forms, with intentional restriction being distinguishable into voluntary (e.g., hunger strikes) and forced (e.g., coercive deprivation in armed conflicts or neglect). This distinction provides essential circumstantial information of medico-legal relevance. From a forensic pathology standpoint, starvation must be assessed through an integrated evaluation that combines circumstantial evidence, clinical history, and post-mortem findings. The autopsy examination should document the general state of nutrition, including body weight, height, and body mass index, and determine the degree of emaciation through anthropometric indices such as the Waterlow classification, which compares actual to expected body weight for age and height. Gross and histological examinations typically reveal generalized organ atrophy, loss of adipose and muscle mass, and serous atrophy of fat in characteristic locations. Complementary biochemical and ancillary analyses may assist in confirming nutritional deprivation and excluding alternative cachectic processes such as malignancy or infection [19]. Ancillary methods reported in the literature include postmortem biochemical analyses, mainly aimed at detecting starvation-related ketoacidosis and metabolic imbalance. These tests, focusing on parameters such as β -hydroxybutyrate, glucose, and protein catabolism markers, complement morphological findings and contribute to a more comprehensive interpretation of starvation-related deaths [20].

Although previous forensic reports have mainly described starvation-related findings in a narrative or case-based manner, the present review systematically analyzes documented cases across different age groups and stages of decomposition. It integrates classical autopsy and histological data with ancillary, biochemical, and instrumental investigations, including emerging diagnostic methodologies, to delineate a comprehensive forensic framework for the post-mortem assessment of starvation.

2. Materials and Methods

We conducted a systematic review in accordance with the PRISMA 2020 recommendations. The protocol prespecified the research question, the search strategies, eligibility criteria, selection workflow, and data items before screening commenced. We searched PubMed/MEDLINE, Scopus, and Google Scholar from database inception to 31 July 2025.

To address the extremely high number of results, the search strings were adapted for each database and additional limitations were applied. We then conducted the following searches:

SCOPUS: TITLE-ABS-KEY (starvation) OR TITLE-ABS-KEY (inanition) OR TITLE-ABS-KEY (“food deprivation”) OR TITLE-ABS-KEY (“prolonged fasting”)) AND (TITLE-ABS-KEY (“forensic pathology”) OR TITLE-ABS-KEY (forensic) OR TITLE-ABS-KEY (medicolegal) OR TITLE-ABS-KEY (postmortem) OR TITLE-ABS-KEY (autopsy) OR TITLE-ABS-KEY (“cause of death”)) limited to 2015–2025, human, English, articles, all open access.

PUBMED: (“starvation”[Title/Abstract] OR “inanition”[Title/Abstract] OR “prolonged fasting”[Title/Abstract] OR “food deprivation”[Title/Abstract] OR “malnutrition”[Title/Abstract]) AND (“forensic”[Title/Abstract] OR “medicolegal”[Title/Abstract] OR “forensic pathology”[Title/Abstract] OR “postmortem”[Title/Abstract] OR “cause of death”[Title/Abstract]) limited to 2015–2025, human, English, articles, free full text, preprints excluded.

SCHOLAR: (“starvation death” OR “death by starvation” OR “fatal inanition” OR “food deprivation death”) AND (“forensic pathology” OR “forensic medicine” OR “medicolegal” OR “postmortem examination” OR autopsy) limited to 2015–2025, scientific articles.

Eligible studies were original contributions, including case reports, case series, and observational designs, that reported autopsy or post-mortem findings in deaths attributed to starvation or starvation-related malnutrition, and that provided clinical, histopathological, biochemical, or radiological information relevant to forensic diagnosis. Studies were excluded if they consisted of narrative or systematic reviews, editorials, or letters, as well as conference abstracts or papers lacking primary autopsy data. Further exclusion criteria included investigations focusing on malnutrition without a forensic or post-mortem perspective, studies based on non-human subjects, and articles not published in English.

Records retrieved from the three sources were collated and deduplicated. According to the PRISMA 2020 flow:

- Records identified: $267 + 3 = 270$;
- Duplicates removed: 4;
- Removed for other reasons: 214;
- Records screened (title/abstract): 52;
- Records excluded at abstract screening: 31;
- Full-text reports assessed for eligibility: 21;
- Studies included in the review: 15.

Articles “removed for other reasons” were eliminated because it was clear from the title that they were not relevant to our research questions or were narrative reviews. Following completion of the systematic search, 3 additional articles meeting inclusion criteria were identified through reference screening and manual update and were therefore incorporated into the synthesis.

The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure 1).

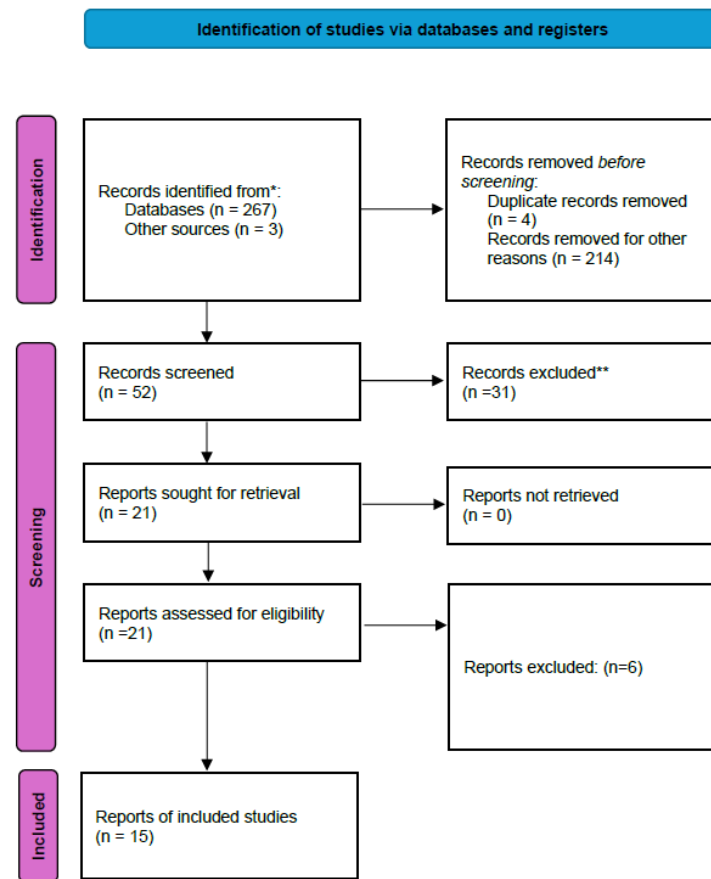


Figure 1. PRISMA 2020 flow diagram for new systematic reviews which include searches of databases and registers only.

Protocol and Registration—The review protocol was defined a priori but was not prospectively registered in a public database (e.g., PROSPERO/OSF) because the study involved qualitative synthesis of published autopsy evidence only, with no meta-analysis or use of unpublished data.

Data Extraction and Items—For each included study, we extracted the following information: study design; country or jurisdiction; decedent demographics (age, sex); social and circumstantial context of death; category of case (e.g., neglect, voluntary fasting, anorexia nervosa); post-mortem interval and preservation state; external and internal autopsy findings; organ-specific histopathology; and ancillary investigations. Differential diagnoses and the authors’ medico-legal conclusions were also recorded. Data extraction was performed independently by two reviewers, with discrepancies resolved through consensus discussion.

Risk of Bias and Reporting Quality—Given the predominance of case reports and small case series, and the inherent heterogeneity in forensic documentation, no formal quantitative risk-of-bias assessment tool was applicable. Instead, we evaluated reporting completeness across key forensic domains, including availability of scene information, detail of autopsy and histological protocols, use and description of ancillary analyses, and clarity in diagnostic reasoning and cause-of-death attribution. In addition, each article was evaluated using an adapted version of the JBI (Joanna Briggs Institute) critical appraisal checklist, tailored to autopsy case reports (8 items) and case series (10 items), as outlined in Sheet 2 of the review spreadsheet (Table 1). Each item was scored as “Yes” (1 point) or “No/Unclear” (0 points), yielding a total score (maximum 8 or 10 points, respectively). Studies were then classified as high quality ($\geq 75\%$ “Yes”), moderate quality (50–74%), or

low quality (<50%). This scoring system allowed a structured assessment of reporting completeness and methodological robustness across forensic autopsy studies.

Table 1. Adapted version of the Joanna Briggs Institute (JBI) critical appraisal checklist for autopsy-based studies of starvation and malnutrition.

Adapted Version of the JBI (Joanna Briggs Institute) Critical Appraisal Checklist, Tailored to Autopsy Case Reports (8 Items)	Yes	No
Were the circumstances of discovery/death and the relevant anamnestic history clearly described and presented in temporal sequence?	1 point	0 points
Were the conditions of the body at the time of examination (e.g., nutritional status, external signs) clearly described?	1 point	0 points
Were the autopsy examinations (macroscopic, histological, toxicological, laboratory) and their results clearly described?	1 point	0 points
Were the autopsy/methodological procedures adopted clearly described?	1 point	0 points
Were subsequent findings (histology, toxicology, other specialized assessments) clearly reported?	1 point	0 points
Were any unexpected events or confounding elements (e.g., comorbid diseases, substance use) identified and described?	1 point	0 points
Were any unexpected events or confounding elements (e.g., comorbid diseases, substance use) identified and described?	1 point	0 points
Does the case report provide useful lessons or takeaways for forensic-autopsy practice?	1 point	0 points
Adapted version of the JBI (Joanna Briggs Institute) critical appraisal checklist, tailored to autopsy case series (10 items)	Yes	No
Were clear inclusion criteria for the cases in the series reported?	1 point	0 points
Was the diagnosis of “starvation” defined in a standard manner and applied uniformly across all cases?	1 point	0 points
Were valid and consistent methods used to determine the cause of death in all cases?	1 point	0 points
Were the cases included in the series collected consecutively?	1 point	0 points
Was case inclusion complete (i.e., free from arbitrary selection)?	1 point	0 points
Were the demographic characteristics of the deceased subjects clearly reported?	1 point	0 points
Were the relevant clinical and circumstantial details (e.g., socio-environmental context, medical history) clearly reported?	1 point	0 points
Were the autopsy findings and histological/toxicological results clearly described?	1 point	0 points
Were the characteristics of the setting or context (e.g., prison, home, hospital) clearly reported?	1 point	0 points
Was the comparative/statistical analysis of cases (if applied) appropriate?	1 point	0 points

Synthesis Methods—Due to the clinical and methodological heterogeneity of the included reports, meta-analysis was not feasible. Evidence was instead synthesized through a structured qualitative approach within a systematic review framework. Findings were organized by analytic domains: (i) demographic and contextual variables; (ii) external and internal autopsy findings; (iii) histopathology; (iv) ancillary post-mortem investigations; (v) age-related patterns (pediatric vs. adult); and (vi) cause and mechanism of death.

3. Results

A total of 15 articles were included in the review. All included articles contained cases in which malnutrition or starvation represented a common determinant in the causal sequence of death, as documented by clinical, pathological or forensic evidence. The collected results pertain primarily to the field of forensic pathology, with particular emphasis on autopsy findings and ancillary post-mortem investigative methods applied to cadavers. Table 2 summarizes the study characteristics and main findings (Table 2).

The studies were published between 1999 and 2024, with a predominance in the last decade. The majority originated from Japan, Italy, Germany and the United States, while other reports were scattered across America, Europe, Africa and Asia. Of these, 13 were case reports or case series, while 2 were cohort studies.

Regarding methodological quality, 9 studies (60%) were rated as high quality ($\geq 75\%$ “Yes”), 6 studies (40%) as moderate quality (50–74%), and none as low quality ($< 50\%$), according to the adapted Joanna Briggs Institute (JBI) checklist for autopsy case reports and case series (Table 3).

Across the case reports and case series, 20 subjects were analyzed. The age of the subjects ranged from infancy (a few months) to adulthood (up to 47 years), with a predominance of pediatric cases. Among them, 5 were adults (25%) and 15 were children (75%). Regarding sex distribution, 5 were male (25%), 13 were female (65%), and in 2 cases (10%) sex was not reported. Notably, 6 cases involved cadavers in an advanced state of decomposition, of which 3 were skeletonized and 2 were mummified (Table 4).

In addition to these, 2 studies were cohort- or population-based investigations, which provided aggregated data on larger samples. Specifically, Madewell ZJ et al. [21] analyzed 1601 infant and child deaths, identifying malnutrition in the causal chain in 632 of them, with anthropometric parameters reported using z-scores. Similarly, Lutz L. et al. [22] reviewed 46 neglect cases, documenting marasmus in 15.2% and starvation or malnutrition with intestinal findings in 8.6%.

In the case reports reviewed, 12 cases involved child neglect, representing the predominant category among individual reports. In adults, the literature documented one case of neglect, one case of anorexia nervosa, and three cases of death associated with hunger strikes. Regarding cohort studies, one focused on elder abuse and neglect in the elderly population [22], whereas another, conducted within the Child Health and Mortality Prevention Surveillance (CHAMPS) network [21], specifically investigated the contribution of malnutrition to infant and child deaths in low- and middle-income countries of Sub-Saharan Africa and South Asia.

Among infants and children, anthropometric parameters consistently indicated severe growth retardation. Weight was below the 1st percentile in all cases, while length/height was also markedly reduced, ranging from below the 1st percentile to approximately the 25th percentile. All recorded BMI values in adults ranged between 11.3 and 13.8 kg/m², which corresponds to severe thinness according to WHO criteria (< 16 kg/m²).

Comorbid conditions included congenital disorders, HIV infection, and chronic neglect, while in several cases no relevant comorbidities were reported. The most frequent ante-mortem symptoms were vomiting, diarrhea, progressive undernourishment, and reduced consciousness, occasionally culminating in coma.

Table 2. Summary of the study characteristics and main findings.

Reference (Author, Year, Journal)	Country	Case ID		Age/Sex	Comorbidities	Anthropometric Parameters	Main External Findings	Main Internal Findings (Organs)	Histology/Microscopy	Ancillary Investigations
Yamada L. et al., 2021, Forensic Science International [23]	Japan	1.1	Child neglect	10, M	-	114 cm × 16.8 kg, BMI 21.6 kg/m ²		Liver: Buff-colored, severe hepatic steatosis Muscle: Poor muscle development	Liver: hepatic glycogen deposition was incremented	Immunohistochemistry (Liver): p62-positive staining around the central vein (CV) region; LC3 was inconspicuous
Franchetti G. et al., 2024, Forensic Science International [24]	Italy	2.1	Neglect	47, F	Unspecified circulation disorders; severe scoliosis and bilateral flexed ankylosis of the hips and knees	176 × 35 kg, BMI 11.3 kg/m ²	Adipose panniculus: Reduced and with gelatinous fat transformation Adipose panniculus: Atrophic	Brain: Not atrophic Heart: Atrophic Lungs: Atrophic Liver: Atrophic Spleen: Atrophic Kidneys: Atrophic Thyroid: Atrophic Muscle: Atrophic muscle masses Surrenal Gland: Atrophic Bones: Costal bones-iliac-knee protrusions Other: Anasarca	Heart: Atrophic, significant cellular shrinkage, reduced diameter of myocardiocytes and subepicardial adipocytes, mucoid interstitial alteration in myocardium and subepicardial adipose tissue Lungs: Atrophic, significant cellular shrinkage, capillary congestion and atrophic emphysema Liver: Atrophic, reduced diameter of hepatocytes Spleen: Atrophic Kidneys: Atrophic Thyroid: Atrophic, colloidal condensation and collapse of the follicle Muscle: Atrophic Surrenal Gland: Vacuolar degeneration of the adrenal medullary cells Bones: Atrophic	
Yamada Y. et al., 2001, Internal Medicine [25]	Japan	3.1	Anorexia nervosa	41, F	Anorexia nervosa, paralytic ileus, dehydration	154.5 cm × 29.1 Kg, BMI 12.2		Colon: ileum and cecum with transmural infarction Other: ascites, pleural effusion, bleeding in gastrointestinal tracts	Colon: mucosal and submucosal with severe hemorrhagic necrosis, degeneration of muscle layer	
Cundiff D.K. et al., 2006, Nutrition Journal [26]	USA	4.1	Child neglect	5 months, F	Suspected DiGeorge Syndrome	3180 mg × 57 cm, Head circumference: 38 cm		Lungs: congested and atelectasis, postmortem changes Liver: passive congestion, no fatty changes Thymus: absent Parathyroid glands: inconspicuous Brain: No abnormalities	Pancreas: normal histology Parathyroid glands: no tissue submitted Adrenals: spent	Immunohistochemistry (spleen): immunochemistry for CD3 demonstrates the presence of Tymphocytes towards the periphery of the Malpighian corpuscles and scattered throughout the red pulp. NOTE: The presence of Tymphocytes in the spleen excludes the possibility of DiGeorge syndrome."
Steyn M. et al., 2023, Journal of Forensic and Legal Medicine [27]	South Africa	5.1	Child mal-treatment	11, F	evidence of sharp trauma on several bones					Anthropologic studies (bones): cribria orbitalia, No areas of subperiosteal bone growth subperiosteal bone growth
		5.2	Child mal-treatment	Less than 3 years, not determined	ulnar osteomyelitis					Anthropologic studies (bones): slight cribria orbitalia
Madewell ZJ et al., 2024, BMJ Global Health [21]	USA (Georgia, Maryland) Mali Kenya Sierra Leone Nigeria Spain Mozambique South Africa UK Ethiopia Bangladesh	6.1	Child malnutrition in contexts of poverty	1–59 months, Male/Female (54.6% male)	HIV infection (13.4%), infectious diseases (sepsis, pneumonia, malaria, diarrheal disease)	WAZ (Weight-for-Age Z-score, indicator of underweight), LAZ (Length-for-Age Z-score, indicator of stunting), WLZ (Weight-for-Length Z-score, indicator of wasting), MUACZ (Mid-Upper Arm Circumference Z-score, indicator of wasting). Postmortem anthropometry showed: 90.1% underweight, 61.2% stunted, 94.1% wasted.				MITS (Minimally Invasive Tissue Sampling), PCR for pathogens, postmortem anthropometry (Length, weight and mid-upper arm circumference (MUAC) were measured postmortem. WHO Child Growth Standards were used to calculate Z-scores: WAZ (Weight-for-Age Z-score, underweight), LAZ (Length-for-Age Z-score, stunting/chronic malnutrition), WLZ (Weight-for-Length Z-score, wasting/acute malnutrition), MUACZ (Mid-Upper Arm Circumference Z-score, wasting). Z-scores were categorized as: normal (≥ -2), moderate ($-3 \leq Z < -2$), severe (< -3). Any moderate-to-severe malnutrition was defined as WAZ, LAZ, WLZ or MUACZ < -2 ; any severe malnutrition as < -3 . Implausible anthropometric values (WAZ < -10 or >5 ; LAZ < -10 or >6 ; WLZ < -10 or >5 ; MUACZ < -10 or >5) were excluded.): Malnutrition identified as causal or significant in 39.5% of under-5 deaths, most frequently in association with infectious diseases.
Lutz L. et al., 2024, Forensic Science, Medicine and Pathology [22]	Germany	7.1	Elder abuse	Range from 21 to 96 years, most female (71.7%)	Signs of dehydration, infections, infestations (lice, mites, fleas, worms), pressure sores, aspiration	Severe body weight loss consistent with malnutrition		Intestine: small, hard dry stool in the colon		

Table 2. Cont.

Reference (Author, Year, Journal)	Country	Case ID		Age/Sex	Comorbidities	Anthropometric Parameters	Main External Findings	Main Internal Findings (Organs)	Histology/Microscopy	Ancillary Investigations
Eerkens JW et al., 2017, PLOS ONE [28]	USA	8.1	N/A	2, Female	No	90 cm				Stable isotope analysis of hair ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) (Hair): $\delta^{15}\text{N}$ enrichment indicating severe undernutrition; compatible with marasmus/starvation
Hale AR, Ross AH, 2018, Journal of Visualized Experiments [29]	USA	9.1	Child neglect	13, F		Femur length: 355 mm; tibia length: 300 mm (consistent with average 9-year-old values). Estimated stature: 136.2 cm (95% CI 129.8–141.0), corresponding to below the 3rd percentile for age (13 years), indicating pronounced growth deficit.				Dual-energy X-ray absorptiometry (DXA) for Bone Mineral Density (BMD) assessment (Lumbar spine): Total BMD (AP lumbar spine): 0.660 g/cm ² Z-score: −2.2 (cutoff for low BMD < −2) Interpretation: Low BMD for chronological age, consistent with chronic malnutrition
		9.2	Child neglect	14 months		Weight: 6.1 kg (13.4 lbs) Reference comparison (Gómez system): 38% weight-for-age → Grade III (severe malnutrition) Waterlow classification: severe wasting, no stunting (height normal range) Weight plotted on CDC 2000 curve: <3rd percentile for age				Dual-energy X-ray absorptiometry (DXA) for Bone Mineral Density (BMD) assessment (Lumbar spine): Total BMD (lumbar spine): 0.190 g/cm ² (reference mean: 0.399 ± 0.040 g/cm ²) Z-score: −5.225 (well below cutoff of −2; <0.1 percentile for age) Conclusion: Severe malnutrition (starvation), low BMD consistent with fatal starvation
Solarino B. et al., 2012, Journal of Forensic and Legal Medicine [10]	Italy	10.1	Child neglect	16 months, F	No chronic disease identified; malabsorption, neoplasia, intoxication excluded	5.7 kg × 76 cm	Scalp: alopecia skin: inelasticity orbital adipose tissue: atrophic eyes: sunken	Bones: skeletal prominences muscle: severe depletion thymus: atrophic stomach: empty with ulcerative lesions large intestine: empty with ulcerative lesions all organs: 20–50% of weight reduction	Lungs: focal acute hypostatic bronchopneumonia brain: massive oedema liver: hepatic steatosis	PAS stain (liver): no glycogen
		10.2	Child neglect	7 years, F	No chronic disease identified; malabsorption, neoplasia, intoxication excluded	9.6 kg × 105 cm	Skin: no lividity due to several anemia; extreme exsiccosis: when pinched up between the fingers, skin folds on the upper arm remained elevated and did not return to their flat position	Subcutaneous adipose tissue: absent visceral adipose tissue: absent large intestine: completely obstructed by fecal concretions trachea and bronchi: abundant brown liquid corresponding to stomach contents. kidneys: purulent pyelonephritis all organs: 10–60% of weight reduction	Lungs: confirmed the macroscopic diagnosis of massive aspiration of stomach contents bones: advanced rickets with numerous resorption lacunae and osteoclasts	PAS stain (lungs): Aspirated food constituents corresponding to meat fibers
Fieguth A. et al., 2002, Forensic Science International [30]	Germany	11.1	Child neglect	14 weeks, F	Upper respiratory infection and decreased appetite at 9 weeks	3.8 kg × 57 cm	Skin: tenting of the overall dry and wrinkly skin eyes: sunken oropharynx, esophagus and trachea: brown mucous	Stomach: small amount of brown fluid duodenum and small intestine: small amounts of yellow mucous large intestine: yellowish-brown mucous liver: fatty infiltrate renal pelvises: yellow deposits brain: evidence of increased cranial pressure	Liver: centrilobar hepatic fat deposits lungs: evidence of aspiration heart: cardiac edema muscle: sarcolysis thymus: thymic involution	
		11.2	Child neglect	5 weeks, F		2.4 kg × 48 cm	Skin: dry and wrinkled	Duodenum and upper ileum: devoid of contents small and large intestine: large amounts of yellowish-beige material oropharyngeal cavity and esophagus: minimal amount of whitish puree-like material trachea and bronchial tree: large amount of whitish puree-like material lungs: dry thymus: noticeably shrunken liver: Hepatic fatty deposits brain: evidence of increased intracranial pressure	Lungs: marked aspiration of foreign material thymus: involution liver: centrilobar fatty hepatic deposits	Immunological investigations (blood): BSA-antibody titre of 1.26 mg/ml

Table 2. Cont.

Reference (Author, Year, Journal)	Country	Case ID	Age/Sex	Comorbidities	Anthropometric Parameters	Main External Findings	Main Internal Findings (Organs)	Histology/Microscopy	Ancillary Investigations
Altun G., 2004, Forensic Science International [31]	Turkey	11.3	Child neglect	3.5, F	10.1 kg × 98 cm	Eyes: sunken in their sockets oropharynx, esophagus, and trachea: greenish viscous material	Bones: ribcage and pelvis easily visible under the skin brain: increased volume thymus: involution adipose tissue of abdominal wall and retroperitoneal cavity: markedly reduced stomach: small amounts of green fluid adhering to its wall duodenum and small intestine: minimal amounts of green mucous large intestine: several small, dried fecal masses lungs: inflated, with dry, crumbling, dark green material in the bronchial branches liver: fatty deposits	Lungs: The majority of the bronchial material consisted of sloughed epithelium; only trace amounts of foreign matter colonized with bacteria were in evidence liver: fatty deposits showed a periportal distribution, suggesting toxin-induced damage	Toxicology (blood): Blood alcohol: 0.51% → possible alcohol intoxication 3-methylbutanol-1: detected (commonly associated with bacterial decomposition) Serum acetone: slightly elevated (25 mg/L) swabs (vagina): no evidence of sperm
		12.1	Hunger strike	26, M	39 kg × 172 cm	Skin: thin, dry, sallow, lax, wrinkled, thin, inelastic, pigmented, scaly and hyperkeratotic eyes: sunken in their sockets	pericardium: 40 cc of serous effusion subcutaneous and internal fat storages: reduced to nil gastro-intestinal tract: thin and translucent walls; empty lumen; atrophic, hemorrhagic, and smooth mucosa gallbladders: distended and filled with bile muscles: waisted bones: prominent. Orbital margins and nose tips were sharp. Knee–elbow diameters were wide consistent with the term “camel-like limbs cheeks: sunken brain: edema heart: gelatinoid atrophy in subepicardial fat tissue, brown atrophy in myocardium liver: atrophic lungs: atelectasis spleen: atrophic	Gastro-intestinal tract: Hemorrhagic gastroenteropathy brain: edema heart: interstitial edema, atrophy liver: passive congestion lungs: emphysema and focal intra-alveolar hemorrhage kidneys: hyperemia	
		12.2	Hunger strike	38, M	40 kg × 171 cm	Skin: thin, dry, sallow, lax, wrinkled, thin, inelastic, pigmented, scaly and hyperkeratotic, decubitus ulcers eyes: sunken in their sockets	Peritoneum: 900 cc of serous effusion subcutaneous and internal fat storages: reduced to nil gastro-intestinal tract: thin and translucent walls; empty lumen; atrophic, hemorrhagic, and smooth mucosa gallbladders: distended and filled with bile muscles: waisted bones: prominent. Orbital margins and nose tips were sharp. Knee–elbow diameters were wide consistent with the term “camel-like limbs cheeks: sunken brain: edema heart: gelatinoid atrophy in subepicardial fat tissue liver: fatty change lungs: edema and pneumonia kidneys: Subcapsular petechial hemorrhages	Gastro-intestinal tract: Hemorrhagic gastroenteropathy brain: edema, petechial hemorrhage heart: interstitial edema, Atrophy, fibrosis and lipomatosis liver: passive congestion, fatty change lungs: Edema and pneumonia kidneys: acute tubular necrosis spleen: congestion and stasis bone marrow: hypocellularity	
		12.3	Hunger strike	25, M	40 kg × 170 cm	Skin: thin, dry, sallow, lax, wrinkled, thin, inelastic, pigmented, scaly and hyperkeratotic, decubitus ulcers eyes: sunken in their sockets	Pericardium: 100 cc of white-opaque effusion peritoneum: 400 cc of serous effusion subcutaneous and internal fat storages: reduced to nil gastro-intestinal tract: thin and translucent walls; empty lumen; atrophic, hemorrhagic, and smooth mucosa gallbladders: distended and filled with bile muscles: waisted bones: prominent. Orbital margins and nose tips were sharp. Knee–elbow diameters were wide consistent with the term “camel-like limbs cheeks: sunken brain: edema, atrophy of the frontal lobe liver: fatty change lungs: edema and pneumonia	Pericardium: serofibrinous pericarditis gastro-intestinal tract: Hemorrhagic gastroenteropathy brain: edema, atrophy of the frontal lobe heart: interstitial edema, fibrosis and lipomatosis liver: passive congestion, Fatty change, massive central necrosis lungs: edema and pneumonia spleen: Congestion and stasis, fibrosis	

Table 2. Cont.

Reference (Author, Year, Journal)	Country	Case ID		Age/Sex	Comorbidities	Anthropometric Parameters	Main External Findings	Main Internal Findings (Organs)	Histology/Microscopy	Ancillary Investigations
Tanegashima A. et al., 1999, Forensic Science International [32]	Japan	13.1	Child neglect	1 year and 11 months, M		8 kg × 85.5 cm		Most organs: severe congestion and average weight ↓ serous cavities: effusion ↓ thymus: involuted and reduced of weight	Thymus: cortical involution with marked reduction in cortical thymocytes; clustering of Hassall’s corpuscles in the medulla; septal thickening and partial fatty infiltration.	Flow cytometry (CD3, CD4, CD8, bcl-2 expression in thymocyte subsets) (Thymus tissue (autopsy case) compared with thymus from 6 age-matched controls (surgical biopsies)): Marked reduction in immature CD4+CD8+ double-positive thymocytes, especially CD3 ^{low} bcl-2 ^{low} subset, indicating stress-induced thymic involution from neglect
Mimasaka S., Funayama M., Adachi N., Nata M., Morita M., 2000, International Journal of Legal Medicine [33]	Japan	14.1	Child neglect	6 years, F	Premature birth; no regular medical follow-up	Height: 90 cm; Weight: 10.6 kg (marked growth retardation)	Gums/Teeth: Swollen, bleeding gums; some teeth absent ↓ Skin/Soft tissues: Multiple subcutaneous hemorrhages (face, chest, back, legs) ↓ Gums/Teeth: Alveolar bone resorption; hemorrhage into periodontal membrane (loosening and tooth loss)	Bones (tibia, femur, humerus, epiphyses): Periosteal hemorrhages; bloody subperiosteal fluid (aseptic); epiphyseal plate dislocation; joints easily displaced; soft X-ray: periosteal calcification around epiphyses (halo effect) ↓ Lungs: Distended; foam in airways ↓ Heart: Weight 57 g; no gross malformations ↓ Thymus: Weight 4 g (atrophy)	Bones (tibia, femur, humerus, epiphyses): Periosteal calcification; hemorrhage; cellular hyperplasia; slight fibrosis; no tumor or periostitis	Soft X-ray: periosteal calcification around epiphysis, halo effect, separation of epiphysis; serum: no detectable ascorbic acid (Bones, periosteum, epiphyseal regions, gingiva); Death due to cardiorespiratory failure secondary to scurvy, not drowning; confirmed vitamin C deficiency with characteristic radiological and pathological findings
Milroy, C. M., & Parai, J. L. 2011. Forensic science, medicine, and pathology [34]	Canada	15.1	Child neglect	3 years, F	No other disease identified.	86 cm × 9 kg, both under 3rd percentile.		All organ weights were low.	Thymic atrophy ↓ Liver: steatosis ↓ Muscle: myocyte vacuolation ↓ Lungs: terminal bronchopneumonia ↓ Kidneys: Armanni-Ebstein lesion with fat stains revealed the vacuoles contained fat.	The biochemical findings in blood indicate ketoacidosis, but with no evidence of diabetes mellitus. A post-mortem skeletal survey revealed no fractures but the skeletal survey showed evidence of multiple growth arrests (Harris lines).
Reference	Country	Case ID	Etiology	Age/Sex	Comorbidities	Anthropometry	Main External Findings	Main Internal Findings	Histology	Ancillary
Yamada 2021 [23]	Japan	1.1	Child neglect	10 M	–	Normal height, low weight	–	Steatosis; poor muscle	↑ glycogen, p62+	IHC (LC3/ p62)
Franchetti 2024 [24]	Italy	2.1	Neglect	47 F	Ortho disorders	Severe low BMI	Gelatinous fat	Multiorgan atrophy	Cellular shrinkage	–
Yamada 2001 [25]	Japan	3.1	Anorexia	41 F	Ileus, dehydration	Very low BMI	–	GI infarction	Hemorrhagic necrosis	–
Cundiff 2006 [26]	USA	4.1	Neglect	5 mo F	Suspected DiGeorge	Low weight	–	Lung congestion; absent thymus	Various	IHC CD3
Steyn 2023 [27]	S. Africa	5.1	Maltreatment	11 F	Bone trauma	–	–	–	–	Anthropology
Steyn 2023 [27]	S. Africa	5.2	Maltreatment	<3 y	Osteomyelitis	–	–	–	–	Anthropology
Madewell 2024 [21]	Multi-country	6.1	Malnutrition	1–59 mo	Infectious diseases	90% underweight	–	–	–	MITs; anthropometry
Lutz 2024 [22]	Germany	7.1	Elder abuse	21–96 y	–	Severe weight loss	Dehydration/ sores	Fecal stasis	–	–
Eerkens 2017 [28]	USA	8.1	–	2 F	–	–	–	–	Hair δ ¹⁵ N enrichment	Isotopes
Hale 2018 [29]	USA	9.1	Neglect	13 F	–	Severe growth deficit	–	–	–	DXA
Hale 2018 [29]	USA	9.2	Neglect	14 mo	–	Severe wasting	–	–	–	DXA
Solarino 2012 [10]	Italy	10.1	Neglect	16 mo F	–	Severe underweight	Alopecia	Organ weight ↓	Steatosis	PAS liver
Solarino 2012 [10]	Italy	10.2	Neglect	7 y F	–	Severe underweight	Exsiccosis	Fecal impaction; pyelonephritis	Aspiration	PAS lungs
Fieguth 2002 [30]	Germany	11.1	Neglect	14 w F	URI	Underweight	Dehydration	Fatty liver; aspiration	Fat deposits	–
Fieguth 2002 [30]	Germany	11.2	Neglect	5 w F	–	Very low weight	Wrinkled skin	Aspiration; thymic involution	Fatty liver	Immunology
Fieguth 2002 [30]	Germany	11.3	Neglect	3.5 F	–	Low weight	Sunken eyes	GI residues; liver fat	Bronchial slough	Toxicology
Altun 2004 [31]	Turkey	12.1	Hunger strike	26 M	–	39 kg	Cachexia	Multiorgan atrophy	Edema; gastroenteropathy	–
Altun 2004 [31]	Turkey	12.2	Hunger strike	38 M	–	40 kg	Cachexia + ulcers	Effusions; pneumonia	ATN; edema	–

Table 2. Cont.

Reference (Author, Year, Journal)	Country	Case ID		Age/Sex	Comorbidities	Anthropometric Parameters	Main External Findings	Main Internal Findings (Organs)	Histology/Microscopy	Ancillary Investigations
Altun 2004 [31]	Turkey	12.3	Hunger strike	25 M	–	40 kg	Cachexia	Effusions; pneumonia	Central necrosis	–
Tanegashima 1999 [32]	Japan	13.1	Neglect	1 y 11 mo M	–	Low weight	–	Congestion; thymic involution	DP thymocyte ↓	Flow cytometry
Mimasaka 2000 [33]	Japan	14.1	Neglect	6 F	Prematurity	Severe growth delay	Gingival bleeding	Periosteal hemorrhage	Periosteal calcification	Vit C deficiency tests
Milroy 2011 [34]	Canada	15.1	Neglect	3 F	–	Low height & weight	–	Organ weight ↓	Steatosis; ketosis	Skeletal survey

Legend: ↓ = “reduction”; ↑ = “increase”.

Table 3. Quality assessment of included case reports and case series according to the adapted Joanna Briggs Institute (JBI) checklist. Each item was scored as “Yes” (1 point) or “No/Unclear” (0 points). Studies were categorized as high quality (≥75% “Yes”), moderate quality (50–74%), or low quality (<50%) based on the proportion of affirmative responses.

Article	Total Score	Quality Level	Brief Narrative Review
Yamada et al. (2021) [23]	6/8	Moderate quality (50–74%)	This study is generally well reported, with clear descriptions of the victim’s demographic features, circumstances of death, autopsy findings, and laboratory results. The narrative is detailed and coherent, providing a thorough reconstruction of the clinical and forensic context and introducing an innovative diagnostic criterion based on lipophagy markers. However, the study lacks sufficient detail regarding autopsy procedures and methodological aspects, and potential confounding factors are only briefly addressed. Overall, the report demonstrates high descriptive quality and scientific value, though with minor limitations in procedural transparency and critical discussion.
Franchetti et al. (2024) [24]	7/8	High quality (≥75%)	This study shows excellent reporting quality. The demographic data, clinical history, circumstances of discovery, and ante- and post-mortem findings are described in meticulous detail. Both external and internal autopsy results are supported by clear histopathological and morphometric analyses, and the integration of clinical, forensic and radiological evidence provides a comprehensive reconstruction of the events. The authors also offer a thoughtful interpretation of the forensic significance of the findings, highlighting the implications for detecting abuse and neglect in adults, which represents an underexplored field. The only minor limitation lies in the absence of a concise methodological description of some laboratory procedures, but this does not detract from the overall clarity and rigor. Overall, the study stands out for its exceptional completeness, coherence, and forensic relevance.
Yamada et al. (2001) [25]	5/8	Moderate quality (50–74%)	This study presents a moderately detailed account of a fatal complication of anorexia nervosa associated with ischemic necrosis of the ileum and cecum. The demographic data, clinical history, and circumstances of hospitalization and death are well documented and the autopsy and histological findings are clearly described, including the identification of non-occlusive mesenteric infarction. The discussion effectively contextualizes the case within the literature, highlighting the rarity of bowel ischemia as a fatal complication of anorexia nervosa. However, the methodological details of the autopsy and laboratory analyses are limited, and potential confounding factors, such as concurrent medications or metabolic alterations, are not explored in depth. Despite these omissions, the report remains clinically and forensically valuable, as it broadens the understanding of fatal mechanisms in chronic malnutrition and anorexia-related pathology.

Table 3. Cont.

Article	Total Score	Quality Level	Brief Narrative Review
Cundiff et al. (2006) [26]	5/8	Moderate quality (50–74%)	This study provides a moderately detailed and well-structured description of a controversial forensic case involving alleged child neglect and malnutrition in a family following a raw vegan diet. The demographic details, clinical history and autopsy findings are clearly presented, and the discussion includes an in-depth review of nutritional, metabolic and diagnostic considerations, demonstrating critical engagement with existing medical definitions of malnutrition and rickets. However, the autopsy and laboratory methodologies are only briefly summarized, with limited procedural detail, and the interpretation of confounding variables (e.g., potential congenital anomalies like DiGeorge syndrome) remains somewhat speculative. Despite these gaps, the report's strength lies in its analytical depth and critical discussion of the intersection between nutrition, pathology, and medico-legal interpretation, though it would have benefited from a clearer presentation of forensic protocols and methodological rigor.
Steyn et al. (2023) [27]	8/10	High quality ($\geq 75\%$)	This study demonstrates high reporting quality and offers a detailed forensic-anthropological review of 19 juvenile deaths investigated at the Human Variation and Identification Research Unit in Johannesburg. The inclusion criteria are clearly stated, and the diagnostic approach to cause of death is consistent across cases, supported by standardized anthropological and osteological methods. The cases were collected consecutively over a six-year period, minimizing selection bias, and demographic, contextual, and autopsy data are thoroughly reported. The integration of multiple case studies illustrates both acute and chronic trauma, malnutrition, and neglect, providing strong inferential value for forensic interpretation. The study's main limitations are the limited standardization of the "starvation" definition across cases and the absence of a formal comparative or statistical analysis beyond descriptive reporting. Nevertheless, the series stands out for its clarity, completeness, and scientific rigor, representing a robust example of forensic anthropology applied to child abuse and neglect investigations in a high-violence setting.
Madewell et al. (2024) [21]	8/10	High quality ($\geq 75\%$)	This study exhibits high methodological and reporting quality. The study, conducted within the CHAMPS network across seven countries in Sub-Saharan Africa and South Asia, clearly defines inclusion criteria, standardized diagnostic definitions of malnutrition and consistent postmortem investigative procedures using minimally invasive tissue sampling (MITS). Data collection was systematic and consecutive, ensuring minimal selection bias, and included comprehensive demographic, clinical and environmental details for each decedent. The cause of death was adjudicated by expert panels using WHO standards and ICD-10/11 coding, providing robust internal validity. However, while the anthropometric findings were extensively detailed and the association between malnutrition and infectious diseases was thoroughly analyzed, the study lacked granular contextual information (e.g., socio-environmental or familial dynamics) and statistical comparison across sites was limited by variability in enrollment and diagnostic interpretation. Despite these constraints, the work stands out for its scientific rigor, multicentric scope, and integration of postmortem data, offering valuable insights into the dual burden of malnutrition and infection in pediatric mortality across low-resource settings.
Lutz et al. (2024) [22]	8/10	High quality ($\geq 75\%$)	This study presents a comprehensive and methodologically robust retrospective analysis of 46 autopsied cases of physical neglect. The inclusion criteria were clearly stated, focusing on cases with objective evidence of neglect during the final period of life and the definition and classification of neglect were standardized according to established medico-legal criteria. Data collection was consistent and consecutive over nearly three decades, covering demographic, clinical, environmental, and entomological aspects. The study was strengthened by the integration of forensic entomology, used to determine the ante-mortem duration of neglect through insect developmental stages, an innovative and scientifically rigorous approach. The cause of death was defined in all cases and autopsy findings were detailed with photographic and tabular documentation. Although information on socio-environmental context and statistical analysis was somewhat limited, the case descriptions were comprehensive, and the analytical framework was appropriate for the study design.

Table 3. Cont.

Article	Total Score	Quality Level	Brief Narrative Review
Eerkens et al. (2017) [28]	6/8	Moderate quality (50–74%)	This study demonstrates high methodological quality and presents a multidisciplinary isotopic investigation of hair samples from a mummified child from 19th-century San Francisco. The study provides a clear description of the historical and burial context, an accurate reconstruction of the child's age and physical condition and a comprehensive explanation of the sampling and isotopic analysis procedures. The progressive variations in $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values strongly support a diagnosis of prolonged malnutrition leading to marasmus, consistent with historical death records. The report excels in clarity, analytical rigor and integration of archaeological, historical, and biochemical data, though it is somewhat limited by the absence of full autopsy, histological or toxicological correlations. Overall, it represents an exemplary application of forensic and archaeometric methods to reconstruct historical cases of pediatric malnutrition.
Hale et al. (2018) [29]	5/10	Moderate quality (50–74%)	This study demonstrates moderate reporting quality within the context of a methodological case series describing the preparation and analysis of hair samples for stable isotope evaluation in forensic investigations. The study provides clear inclusion criteria and consistent analytical methodology, detailing the isotopic assessment of carbon and nitrogen for reconstructing nutritional and metabolic status in postmortem cases. However, the definition of starvation is not explicitly standardized, and the selection of cases is not presented as consecutive or representative, limiting reproducibility. While autopsy and contextual information are adequately described in illustrative cases, broader clinical, demographic, and socio-environmental data are scarce. Furthermore, no formal comparative or statistical analysis is conducted beyond methodological validation. Despite these limitations, the study is valuable for its technical rigor, procedural transparency, and relevance to the forensic assessment of malnutrition and metabolic disturbances through isotopic profiling.
Solarino et al. (2012) [10]	10/10	High quality ($\geq 75\%$)	This study demonstrates excellent reporting and methodological quality. The authors present two meticulously documented cases of fatal child neglect and starvation, integrating autopsy, histological, radiological and socio-environmental evidence to establish both cause and manner of death. The inclusion criteria and diagnostic framework are clearly stated, and the definition of starvation follows established forensic references, including the Waterlow Classification for protein-energy malnutrition. Each case is comprehensively described, with detailed anthropometric data, organ weight comparisons, histopathological findings and biochemical analyses. The collection and documentation of cases were consistent and systematic, and the contextual information, including family background, living conditions, and investigative findings, was thoroughly integrated with the forensic evidence. The authors also provide clear differentiation between starvation and potential differential diagnoses, ensuring diagnostic accuracy. Furthermore, the discussion synthesizes the findings with a strong medico-legal perspective, emphasizing the importance of multidisciplinary collaboration between pathology, scene investigation, and social inquiry. Overall, this study exemplifies best practices in forensic case reporting, combining exhaustive clinical-pathological documentation with interpretative clarity and societal relevance.
Fieguth et al. (2002) [30]	10/10	High quality ($\geq 75\%$)	This study represents a model of comprehensive forensic documentation and methodological rigor. The study analyzes three fatal cases of child neglect and starvation, providing clear inclusion criteria, systematic autopsy findings, and consistent diagnostic application across all cases. The definition of malnutrition is explicitly standardized using the Waterlow classification, allowing differentiation between acute and chronic nutritional deficiency. The authors meticulously describe the clinical histories, socio-environmental circumstances, and pathological features, including thymic involution, hepatic fatty change, and aspiration, integrating macroscopic and histological data. Cases were collected consecutively, and the forensic context (home conditions, maternal behavior, substance abuse, and socio-economic background) was thoroughly investigated, providing a holistic understanding of the mechanisms and risk factors underlying fatal neglect. The inclusion of quantitative anthropometric analysis and correlation with established reference curves adds further scientific robustness. The discussion demonstrates strong interpretative depth, addressing medico-legal distinctions between neglect and abuse. Overall, this work exemplifies best practices in forensic case series reporting, distinguished by its clarity, completeness, and integration of pathological, clinical, and social evidence, setting a methodological benchmark for future studies on fatal child neglect.

Table 3. Cont.

Article	Total Score	Quality Level	Brief Narrative Review
Altun et al. (2004) [31]	10/10	High quality (≥75%)	This study demonstrates outstanding reporting quality and scientific rigor. The authors present three meticulously documented cases of fatal hunger strike deaths, providing a comprehensive analysis that combines clinical history, autopsy findings, and pathophysiological interpretation. The inclusion criteria are clearly defined, and the diagnostic framework for starvation is standardized and consistently applied across cases. Each subject is described in detail, with precise anthropometric measurements, organ weights, and both macroscopic and histopathological findings. The autopsy descriptions are exceptionally thorough, documenting consistent features of severe cachexia, organ atrophy, serous effusions, and gastrointestinal mucosal atrophy, alongside complications such as pneumonia, myocardial degeneration, and hepatic steatosis. Importantly, the study contextualizes these findings within the biochemical and physiological mechanisms of prolonged starvation, particularly emphasizing the role of thiamine deficiency following cessation of vitamin supplementation. The clinical and environmental context (prison setting, hunger strike progression, medical supervision) is clearly delineated, and the discussion integrates medical, ethical, and forensic perspectives. Overall, this study exemplifies methodological excellence, with complete documentation, diagnostic coherence, and interpretative depth, making it a reference standard for the forensic investigation of starvation-related deaths in both institutional and voluntary contexts.
Tanegashima et al. (1999) [32]	7/8	High quality (≥75%)	This study represents a significant contribution to forensic pathology in the context of child neglect. The study provides a comprehensive description of the case, including clear demographic information, detailed autopsy findings, and meticulous histological and flow cytometric analyses of the thymus. The authors integrate morphological and immunophenotypic data to demonstrate thymic involution as a biological marker of chronic stress in neglected children, introducing an innovative quantitative approach through CD4/CD8 and bcl-2 expression profiling. The methodological section is particularly robust, outlining sampling, staining, and analytical procedures with scientific precision. The only minor limitation is the limited discussion of possible confounding variables (e.g., pre-existing illness or environmental factors). Overall, this case report stands out for its clarity, methodological rigor, and forensic relevance, providing a strong model for integrating cellular immunology into postmortem evaluation of child neglect.
Mimasaka et al. (2000) [33]	6/8	Moderate quality (50–74%)	This study presents a well-documented forensic investigation of a fatal case of infantile scurvy initially mistaken for child abuse. The demographic characteristics, circumstances of death, and autopsy findings are clearly described, including detailed accounts of periosteal hemorrhages, dental changes, and radiographic evidence of bone calcification consistent with vitamin C deficiency. The authors effectively reconstruct the clinical and social context of neglect, linking parental ignorance and isolation of the child to the fatal nutritional deficiency. However, methodological details of the autopsy and laboratory testing are somewhat limited, and the discussion of potential confounding medical factors (e.g., metabolic or genetic disorders) remains brief. Despite these minor limitations, the report is notable for its clarity, diagnostic precision, and forensic relevance, highlighting the importance of distinguishing neglect-induced malnutrition from physical abuse in pediatric forensic evaluations.
Milroy et al. (2011) [34]	7/8	High quality (≥75%)	This study displays excellent reporting quality, offering a comprehensive and methodologically rigorous forensic investigation into the death of a 3-year-old child from starvation-induced ketoacidosis. The authors provide clear demographic information, a detailed account of the death circumstances and a thorough autopsy description, including macroscopic, histological and biochemical findings that confirm the presence of the Armanni–Ebstein renal lesion in a non-diabetic context. The inclusion of biochemical analyses, histochemical fat staining and radiological documentation of growth arrest lines demonstrates exceptional integration of multidisciplinary evidence. The discussion effectively situates the case within the broader forensic literature, emphasizing the pathophysiological link between ketoacidosis and the Armanni–Ebstein lesion, independent of diabetes. The only minor limitation lies in the brevity of procedural details regarding laboratory techniques. Overall, the report stands out for its clarity, scientific depth, and forensic relevance, serving as an exemplary model of diagnostic accuracy in starvation-related child fatalities.

Table 4. Summary of included studies and subjects (case reports/series).

Category	N	%
Total articles	15	–
Case reports/series	13	86.7%
Cohort studies	2	13.3%
Total subjects (case reports/series)	20	–
Adults	5	25%
Children	15	75%
Males	5	25%
Females	13	65%
Sex not reported	2	10%
Cadavers in advanced decomposition	6	–
Skeletonized	3	–
Mummified	2	–

4. External Examination

At external examination, the most consistent finding across cases was a marked alteration of the skin, reflecting chronic malnutrition and cachexia. The integument was frequently described as dry, thin, wrinkled, and inelastic, with a “tenting” phenomenon resembling dehydration [30]. In several reports, the skin appeared sallow or pale, often in association with severe anemia, with some cases lacking the usual hypostasis due to profound wasting and circulatory compromise [10,31]. These changes were noted both in pediatric and adult subjects, suggesting a shared morphological pattern of starvation-related death.

Moreover, the eyes consistently appeared sunken within their sockets, a feature repeatedly noted across different case reports [10,31].

On external inspection, the skeletal system appeared markedly altered, reflecting the profound wasting associated with chronic malnutrition. In most cases, the bony prominences were sharply visible beneath the skin, including the costal arches, iliac crests, and knees, giving the body a cachectic appearance [24,30,31]. The orbital margins and nasal bridge were often described as prominent and sharp, while the extremities showed disproportionately accentuated diameters at the elbows and knees, features evocatively referred to as “camel-like limbs” [31]. In pediatric cases, the ribcage and pelvis were easily discernible under the skin, underscoring the absence of subcutaneous fat and muscle mass.

5. Autopsy Findings

Examination of the soft tissues revealed a profound reduction in muscle and fat stores, consistent with advanced cachexia. Skeletal muscles were described as poorly developed, atrophic, or severely wasted, in some cases with histological evidence of sarcolysis [24,30,31] or myocyte vacuolation [23]. Similarly, the subcutaneous adipose tissue was markedly diminished or completely absent, and in several cases the internal fat depots of the abdominal wall and retroperitoneum were reduced to nil [10,26,30,31]. Where present, residual adipose tissue frequently showed gelatinous transformation [24].

Across the included reports, a consistent autoptic finding was the description of atrophy of internal organs. Regardless of the specific case, the heart, liver, kidneys, pancreas, spleen and thymus were repeatedly reported as small, shrunk, and underweight for age.

The liver was consistently described as atrophic or markedly altered in morphology across the reviewed cases. Macroscopically, findings included buff-colored parenchyma with severe hepatic steatosis and fatty infiltrates, often localized to the centrilobular region [26]. Other reports described passive congestion without significant fat accumulation [25], whereas in several cases the organ was noted as small, shrunk, and atrophic,

with reduced hepatocyte diameter [24]. Microscopically, the spectrum ranged from simple fatty change to extensive hepatic steatosis and, in severe cases, massive central necrosis [31]. In one report, fatty deposits with periportal distribution suggested possible toxin-related injury [30]. Immunohistochemical analyses revealed incremented glycogen deposition and p62-positive staining around central veins, with LC3 expression inconspicuous, highlighting altered autophagy pathways in starvation-related damage [26].

Overall, the gastrointestinal tract exhibited a pattern of mucosal atrophy, hemorrhagic changes, and altered luminal contents. Macroscopic inspection frequently revealed thin and translucent intestinal walls with empty lumina, accompanied by atrophic, hemorrhagic, and smooth mucosa [33]. These cases were summarized under the description of hemorrhagic gastroenteropathy, a recurrent and distinctive finding in prolonged malnutrition [31]. Smaller amounts of yellowish or green mucous residues were occasionally noted in the duodenum and small intestine [30], while the colon could contain hard, dry stools reflecting chronic constipation and reduced fluid intake [22,32]. Some reports described the large intestine empty with ulcerative lesions, or in contrast, completely obstructed by fecal concretions or dried fecal masses, indicating altered motility and dehydration of bowel contents [10]. In one single case, reported in the context of anorexia nervosa, the ileum and cecum showed transmural infarction and hemorrhage, with microscopic evidence of necrosis of the mucosal and submucosal layers and degeneration of the muscularis propria [33].

Cardiac examination consistently revealed signs of atrophy and interstitial damage. Macroscopically, the most recurrent finding was gelatinous atrophy of the subepicardial fat [24,25], sometimes associated with brown atrophy of the myocardium [31]. In several cases, the heart appeared small and wasted, with cardiac edema reported as an additional non-specific but frequent feature. Microscopically, the myocardium showed interstitial edema and atrophy, often accompanied by fibrosis and lipomatosis [30,31].

In pediatric cases, the thymus was consistently described as absent, atrophic, or involuted. Macroscopically, the gland appeared noticeably shrunken or reduced in weight, far below age-related norms [10,23,25,27,30,32]. Microscopic examination confirmed cortical involution with marked reduction in thymocytes, together with clustering of Hassall's corpuscles, septal thickening, and partial fatty infiltration [27].

In one case, the presence of an Armani–Ebstein lesion was found in the renal tubules, which is a characteristic lesion of ketoacidosis [23], which was indeed evident from blood tests and which is characteristic of prolonged fasting [20].

6. Ancillary Analysis

A subset of the reviewed literature dealt with decomposed or skeletonized bodies, where the diagnosis of starvation and malnutrition relied primarily on anthropological and ancillary investigations. In the South African forensic anthropology series, skeletal remains of neglected children revealed not only traumatic lesions but also cribra orbitalia, a porous lesion of the orbital roof classically associated with chronic anemia and malnutrition, even in cases where the body was otherwise skeletonized [28].

In one case from the late 19th century, stable isotope analysis of a mummified 2-year-old girl demonstrated $\delta^{15}\text{N}$ enrichment compatible with severe undernutrition and marasmus/starvation, showing how biochemical markers preserved in hair can provide decisive evidence of nutritional status long after death [29].

Two further cases of suspected neglect were studied through bone mineral density (BMD) assessment by dual-energy X-ray absorptiometry (DXA), performed on skeletal remains. Both children showed BMD values well below the expected range for age,

with Z-scores < -2 , consistent with chronic malnutrition, and in one infant (14 months) an extremely low BMD (Z-score -5.225), considered compatible with fatal starvation [29].

7. Cause of Death and Forensic Diagnostic Criteria

The determination of cause of death in starvation-related fatalities is inherently complex, as malnutrition may act either as the primary lethal factor or as a decisive contributor within a broader causal chain. In the cases analyzed, the most frequent attribution was to severe malnutrition or neglect, often documented as fatal starvation in both children and adults. In pediatric cases, starvation was frequently compounded by systemic complications such as infections, dehydration, or micronutrient deficiencies (e.g., scurvy), while in adults the spectrum also included anorexia nervosa and hunger strike-related deaths. In all instances, starvation was recognized as a central element of the causal sequence, leading to progressive multi-organ failure.

Diagnosis relied primarily on forensic autopsy, with external and internal examination providing convergent evidence of chronic nutritional deprivation. Externally, emaciation, skeletal prominence, and loss of adipose and muscle mass represented hallmark features. Internally, autopsies consistently revealed diffuse organ atrophy (heart, liver, kidneys, spleen, thymus), frequently accompanied by specific histological alterations such as thymic involution, hepatic steatosis, interstitial edema and gelatinous fat transformation.

Beyond classical pathology, several cases required ancillary investigations to substantiate starvation as the cause of death. In skeletonized remains, anthropological assessment identified cribra orbitalia as a marker of chronic anemia and malnutrition [28]. Bone mineral density (BMD) analysis by DXA allowed recognition of chronic and fatal malnutrition in child neglect cases [29], while stable isotope analysis of hair demonstrated biochemical signatures of prolonged undernutrition in a mummified child [29].

8. Discussion

To our knowledge, this is the first systematic review focusing exclusively on post-mortem evidence of starvation and malnutrition as determinants in the causal chain of death. Limiting the analysis to cadaveric findings reduces clinical confounders that may obscure causal attribution in mixed living–post-mortem studies (e.g., iatrogenic fluid shifts, refeeding effects, or transient metabolic adaptations) [35]. This approach also enables a clearer differentiation between starvation and other cachectic conditions, such as chronic alcoholism, malignancy or inflammatory diseases, through comprehensive autopsy evaluation and systematic exclusion of alternative mechanisms, a methodological rigor often recommended in narrative literature but not previously implemented in a systematic framework [36]. Earlier narrative overviews [19,36] richly described forensic-pathologic findings in starvation and malnutrition but did not employ systematic inclusion criteria, structured bias assessment or a comprehensive, cadaver-only evidence pool. Beyond descriptive characterization, specific autopsy features observed in starvation-related deaths have well-established forensic diagnostic significance. The gelatinous transformation of fat, particularly in the epicardial and bone marrow deposits, is recognized as a reliable morphological marker of prolonged caloric deprivation, reflecting depletion of triglyceride stores and serous infiltration of connective tissue [31]. Similarly, thymic involution, frequently documented in pediatric cases of neglect and starvation [30], indicates sustained metabolic stress and immune suppression rather than acute cachexia. The coexistence of these lesions, together with hepatic steatosis [10,23,26] and myocardial interstitial fibrosis [30,31], provides strong post-mortem evidence supporting a diagnosis of starvation over other wasting etiologies such as malignancy or chronic systemic disease. Collectively, these morphological indicators enable the forensic pathologist to distinguish starvation

and neglect from cachectic or iatrogenic conditions, strengthening causal inference when integrated with circumstantial and investigative data.

A second distinctive contribution of this review lies in the inclusion of ancillary post-mortem methods that retain diagnostic value despite prolonged post-mortem intervals and advanced decomposition or transformative changes, which represent critical challenges in forensic pathology. Across the included reports, skeletal and biochemical analyses, such as cribra orbitalia as a marker of chronic anemia or malnutrition, bone densitometry by DXA demonstrating markedly reduced Z-scores, and stable isotope analysis of hair showing $\delta^{15}\text{N}$ enrichment consistent with prolonged undernutrition, supported starvation diagnoses even in skeletonized or mummified remains. The systematic application of these methods extends the diagnostic window beyond the preservation of soft tissues and provides a foundation for methodological validation, including the establishment of reference ranges, quality control procedures, analytical cut-offs, and standardized reporting criteria. Accordingly, this review supports the structured use of anthropological, densitometric, and isotopic analyses in suspected starvation cases, combined with explicit exclusion protocols for alternative wasting etiologies (e.g., chronic infection, endocrine disorders, neoplastic disease), as endorsed by existing forensic guidelines. In this context, future research should prioritize the standardization and validation of ancillary post-mortem techniques, particularly quantitative bone densitometry (DXA) for dry skeletal material, biochemical assays for post-mortem metabolite stability and isotopic ratio mass spectrometry for carbon and nitrogen isotopes in keratinous tissues. The development of reproducible protocols and population-specific reference datasets for these methods would substantially enhance diagnostic reliability in cases of advanced decomposition, contributing to a more objective and evidence-based framework for determining starvation-related deaths. Finally, it is noteworthy that none of the reviewed studies reported targeted biochemical investigations, such as ketone body quantification, electrolyte profiles, or metabolic markers typically associated with prolonged fasting. The absence of these analyses, despite their recognized relevance in starvation physiology [20], highlights an area where future forensic work could enhance diagnostic accuracy by systematically integrating biochemical data with morphological and anthropometric findings.

Narrative reviews and practical manuals consistently describe a characteristic autopsy constellation: severe emaciation; near-complete loss of subcutaneous and mesenteric fat; empty gastrointestinal tract with dehydrated or scant contents; reduced organ weights; thymic involution in pediatric subjects; and frequent hepatic steatosis and cardiac findings such as gelatinous atrophy of epicardial fat or interstitial myocardial fibrosis and edema. At the same time, autopsic attribution of starvation as the primary cause of death remains inseparable from contextual reconstruction, as information on living conditions, access to nutrition, and pre-mortem caregiving provides essential interpretive support for morphological exclusion of alternative wasting etiologies. The pooled evidence from 20 individual cases, predominantly pediatric, and two cohort studies aligns with this pattern, confirming its reproducibility across different ages and populations. Our findings further refine this description by providing (i) detailed anthropometric data across age groups, showing uniformly sub-1st percentile weights in children, variable height reductions down to approximately the 25th percentile, and BMI values between 11.3 and 13.8 kg/m² in adults, consistent with WHO-defined severe thinness; (ii) decomposition-resistant diagnostic approaches (e.g., DXA on dry bone, hair isotope analysis), which, although recognized in narrative accounts, have rarely been systematically aggregated or compared. Moreover, while narrative frameworks emphasize the use of differential diagnosis and anthropometric classification systems such as Waterlow or Gómez scores, our synthesis demonstrates that in

practical forensic settings, these measurements are complemented by ancillary techniques that remain informative when soft tissues are absent or severely degraded.

9. Conclusions

This systematic review highlights starvation and severe malnutrition as recognizable causes of or decisive contributors to death based on post-mortem evidence alone. By focusing exclusively on cadaveric data, it delineates the morphological and histopathological hallmarks of fatal nutritional deprivation and identifies ancillary methods that extend diagnostic capability beyond soft-tissue preservation. The integration of anthropological, densitometric, and isotopic analyses provides objective and reproducible parameters for assessing nutritional status, even in advanced decomposition. Establishing standardized criteria and reference values for these methods represents a necessary step toward their broader validation and routine forensic application. Future research should aim to develop unified post-mortem diagnostic protocols, integrating classical autopsy findings with validated ancillary techniques to improve diagnostic certainty in starvation-related deaths.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/forensicsci5040074/s1>.

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