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Multiple Injury and Health in Past Societies: An Analysis of Concepts and Approaches, and Insights from a Multi-Period Study

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ABSTRACT Earlier clinical and bioarchaeological studies found that injury recidivists were most likely to be young adult males. Since then, the clinical meaning of the injury recidivist has expanded to include all individuals with multiple injuries, and other aspects of health have been considered. Our study sought to apply these advances to paleopathology and place multiple injuries in a wider context by investigating: the age and sex distribution of those with single and multiple fractures, and if people with multiple injuries had poorer general health. The sample of 213 males and 190 females (≥18 years old) from six populations in England, Siberia, and Sudan ranged in date from the 3rd century BC to the mid-19th century AD. Health variables included cribra orbitalia, porotic hyperostosis, periostitis, Schmorl's nodes, enamel hypoplasias, dental caries, and periodontitis. Antemortem injuries were: fractures (0/1/≥2), myositis ossificans, dental trauma, and sharp-force injuries. The data were analysed using chi-square and hierarchical loglinear analyses ($P = 0.05$).

No significant three-way association between age, sex, and injury was found. There was no difference between the sexes when individuals with single versus multiple injuries were compared. There were significant differences in the age-distribution of people with 0 and 1/≥2 fractures. Males and those 26–35 years old were most likely to have fractures and multiple injuries. Porotic hyperostosis was significantly associated with fractures. There was no significant relationship between general poor health and multiple injuries.

Key words: health; injury recidivism; mortality; multiple injury; polytrauma

Introduction

The clinical injury recidivism model

In 1989, Sims and colleagues introduced the clinical concept of 'injury recidivism' (IR), acknowledging the long-standing observation that many of their patients were admitted on multiple occasions for a range of violent injuries such as gunshot wounds (Sims *et al.*, 1989). The ensuing work of Reiner *et al.* (1990) followed 150 consecutive admissions to the New Jersey Medical School (USA) and found that IRs were more likely to be male and of low socioeconomic status; their average age was 26 years old but at their first admission, their average age was 20 years old.

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This early research was followed by other hospital studies in the United States of America (USA), whose results supported the recidivist profile for young, socially disenfranchised adult males to have repeat visits to trauma centres for injuries caused by violent episodes (amongst others, Brooke *et al.*, 2006; Cooper *et al.*, 2000; Kaufman *et al.*, 1998). Despite many of the young men being classified as IRs because they had received traumatic injuries caused by modern weapons, motor vehicles, and falls, these studies found that they were more likely to be injured during an assault compared to non-repeat patients, because of their life-style choices (Hedges *et al.*, 1995). Females were not immune to injuries from assault, but were typically victims rather than perpetrators of assault and/or intimate partner violence compared to their male peers, although there were exceptions (Kwan *et al.*, 2011). A small number of USA studies confirmed that in rural

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settings, recidivists were also most likely to be young adult males (Toschlog *et al.*, 2007; Williams *et al.*, 1997). One of the few studies outside of North America identified this pattern among rural Israelis (Sayfan & Berlin, 1997).

These early IR studies typically only considered violent injuries, thus the label 'recidivist', from recurring or relapsing (Ln.) typically criminal behaviour. IR (*sensu stricto*) is embedded in male life-style choices, a trend identified from the earliest days of this model. The majority of those conforming to the IR model were more likely to use drugs and/or alcohol, have a criminal record, live in poverty, be single, and were less likely to adopt reformative behaviour (e.g. McCoy *et al.*, 2013; Teplin *et al.*, 2005). A small sub-group of IRs was found to have self-inflicted injuries and had an increased risk of repeat injury, as did those suffering from psychiatric conditions (Caufeild *et al.*, 2004; Worrell *et al.*, 2006).

Since then, IR has taken on new meaning among many clinicians, and their multiple injury studies include all injuries *no matter what the aetiology*, as injury continues to be a major drain on health care systems (e.g. Rittenhouse *et al.*, 2015). Specific groups are targeted for the prevention of multiple injuries owing to worsening social behaviour or vulnerability, amongst others, prisoners, and the institutionalised (e.g. Davis *et al.*, 2013; Kwon *et al.*, 2010; Lewis *et al.*, 2006; Rittenhouse *et al.*, 2015). Very recently, Alghnam *et al.* (2016) conducted a national analysis that tracked 19,134 Americans with one reported injury *of any origin* that required a visit to a physician's office, Emergency Department or a hospital stay. At the end of the two year period, 17.9% of these individuals were classed as IRs. The profile was similar to the traditional IR: young male, unmarried and urban. Their study also incorporated health variables known to affect general health status, and found that (amongst others) diabetes and hypertension were significant health issues for IR, whilst coronary health diseases and alcohol-related issues were common for IR and non-IR groups (Alghnam *et al.*, 2016).

Injury recidivism and osteoarchaeology

Judd (2002) was the first to utilise IR in osteoarchaeology and introduced the concept of IR to the discipline using 333 individuals from urban and rural groups dated to the Kerma period (BC 2500–1500) of ancient Nubia (Sudan). She determined that there were rural/urban differences in the distribution and type of fractures observed; many of the injuries in both settings were caused by inter-personal violence. It was concluded that many of the individuals with multiple injuries fitted the modern IR model (Figure 1). In order for the IR model to be applicable past people, Judd (2002) recommended that there must be at least one violence-related ante-mortem injury in addition to at least one other ante- or peri-mortem injury. Her research concluded that the concept of IR does not replace that of multiple injury, but rather it is an

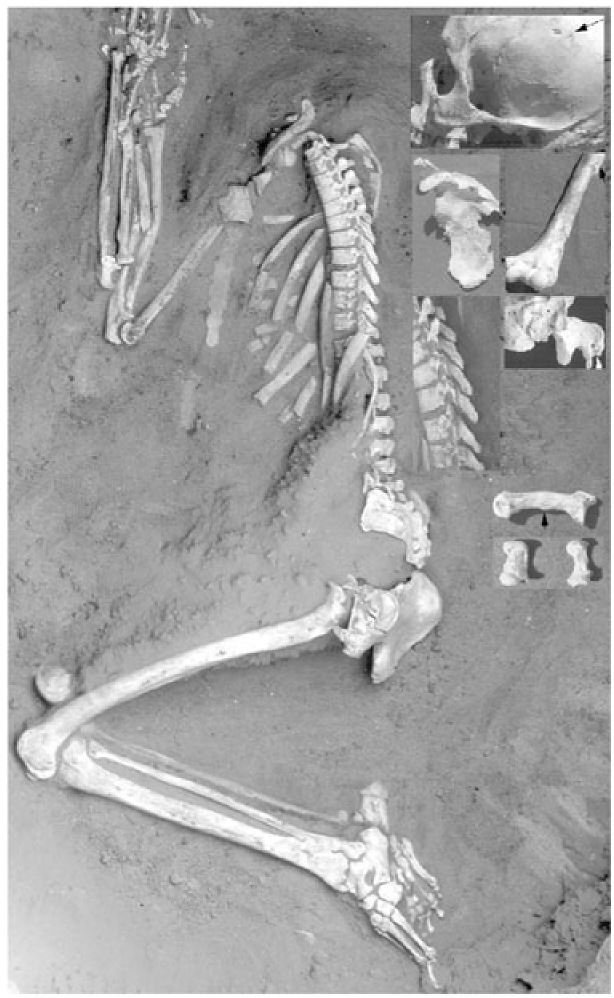

Figure 1. A composite image of a 25 to 35-year-old male excavated from a Kerma period cemetery in Sudan (c. BC 2500–2050) with multiple healed injuries (Judd, 2001). Cranium: six small depressed fractures on right vault. Thorax: myositis ossificans on fifth to eighth and 10th thoracic spinous processes; transverse fractures on four sequential vertebrae; a stone flake projectile embedded in the left side of the 12th thoracic spinous process; ribs: two right ribs have transverse fractures. Upper limbs: crushed body of left scapula; myositis ossificans on the left humeral midshaft; paired rotational left and right forearm fractures, non-union of left radius and right ulna and a left radius Smith's fracture. Hands: four metacarpal shaft fractures and four phalangeal base fractures. Lower limbs: small depressed fracture on the right tibia distal articular surface, incomplete fracture of the right fibula, ossified connective tissue between the distal left tibia and fibula. Feet: three metatarsal base fractures, myositis ossificans to the third metatarsal and the distal fifth phalanx tuft is absent and remodelled.

alternative explanation for why an individual may have multiple injuries. Judd (2002) emphasised that we were likely missing many multiply injured people, because the majority of injuries only affect the soft-tissue, and because observers frequently only record long bone and/or cranial injuries and exclude injuries to the teeth, thorax, and extremities.

The interpretation of multiple injuries among past people and their communities has received attention in the grey and peer-review literature, particularly through case studies (e.g. Boccone *et al.*, 2011; Harrod *et al.*, 2012), although as a discipline we are certainly aware that we need to broaden our understanding of the role of health and lived experience (e.g. de la Cova, 2010; Watkins, 2012).

The tangled relationship between lifestyle factors, risk of early death, and injury is greatly amplified for investigations of ancient multiple injury as the setting, mechanisms, and timing of the injuries, and the person's life experience are unknown (Milner *et al.*, 2015). It is evident that poor physical and/or mental health is associated with multiple injury and although we have yet to identify skeletal co-relates for many of the health problems considered by clinicians to be the consequences of injury (e.g. brain injuries from cranial trauma) (op cit. Harrod & Martin, 2014), we can assess the more commonly observed disease processes and their relation to multiple injury.

To incorporate the trends of clinical research and current directions in osteoarchaeological research, we apply the more recent IR model to osteoarchaeology and place multiple injuries in a wider context. We investigate the age and sex distribution of those with single and multiple fractures, and test the hypothesis that past individuals with multiple injuries had poorer health leading to an earlier death than those with none or one observable injury.

Materials and methods

We included six diverse archaeological populations derived from England (Egging Dinwiddy, 2009, WORD, 2015), Siberia (Murphy, 2003), and Sudan (Judd, 2001, 2012) that ranged in date from the 7th century BC to the mid-19th century AD (Table 1). These populations reflect diverse living environments, social structures, and cultural traditions. The choice of cemetery populations was influenced by the availability of sufficiently detailed information. The use of datasets recorded by multiple osteologists, including one of the authors, raises issues of comparability and reliability which we

Table 1. Samples used in the study by period, location, site name, sex, and age-group

Period, location, and citation	Site name	Sex	18–25 years old	26–35 years old	36–45 years old	≥46 years old	≥18 years old	Total
Roman (3rd–5th centuries AD, Britain); Egging Dinwiddy (1999)	Little Keep	Male	1	2	8	24	—	35
		Female	0	1	4	4	—	9
Iron Age (7th–2nd centuries BC, Siberia); Murphy (2003)	Aymyrlyg	Male	8	15	7	1	1	32
		Female	4	6	4	4	—	18
Medieval (1066–1550 AD, Britain); WORD (2015); Grainger et al. (2008)	East Smithfield	Male	1	18	10	2	—	31
		Female	6	10	5	4	—	25
Post-medieval (1550–1850 AD, Britain) WORD (2015); Henderson et al. (2013)	Lukin Street	Male	7	8	9	6	—	30
		Female	2	11	11	6	—	30
Bronze Age (2500–1750 BC, Sudan) Judd (2001)	Northern Dongola Reach Survey	Male	3	11	7	2	2	25
		Female	3	9	9	1	3	25
Meroitic, post-Meroitic and Medieval periods (2nd BC–11th AD, Sudan) Judd (2012)	Gabati	Male	12	8	24	6	10	60
		Female	19	17	28	4	15	83
		Total	66	116	126	64	31	403

have attempted to mitigate in our data collection (for a full discussion see, Roberts and Cox, 2003, 26–30).

In order for the study to be as robust as possible whilst relying on data recorded by multiple authors, we required that each cemetery contained articulated adults (≥18 years old) from inhumations only, and that the presence/absence of bones/teeth or particular aspects of them (e.g. orbits to score cribra orbitalia) was recorded, with individuals only being selected if they had a cranium and if ≥35% of the postcranial skeleton was present (see Connell *et al.*, 2012, 20). Preservation had been scored using multiple systems, so to balance having a statistically valid sample from each cemetery and to account for differences between taphonomic categories (see Stodder, 2008), we only selected individuals if they were scored as having poor to excellent stages of preservation.

The selected studies employed comparable methods to determine an individual's sex, estimate age-at-death, and osseous responses to disease and injury (Brickley & McKinley, 2004; Buikstra & Ubelaker, 1994). The general health variables selected for analysis included: cribra orbitalia, porotic hyperostosis, periosteal new bone formation, Schmorl's nodes, enamel hypoplastic defects, carious lesions, and periodontal disease (Aufderheide & Rodriguez-Martin, 1998; Ortner, 2003). Recorded peri- and ante-mortem injuries included: fractures, myositis ossificans, dental fractures, joint dislocation and subluxation, and sharp-force weapon injuries (Boylston, 2004; Lovell, 1997; Ortner, 2003), but not decapitation injuries because this was a burial rite in Roman Britain (Crerar, 2014). As with the taphonomic scores, all detailed information is fully published in the site report or archive (see Table 1).

To ensure sufficient cell counts for analysis, data on numbers of ante-mortem and peri-mortem fractures present were pooled into the following categories: 0, 1, or ≥2. For analyses examining age, only individuals who could be assigned to one of the following age intervals were included: 18–25, 26–35, 36–45, and ≥46 years old. Health variables were scored as present, absent, or unobservable if the bone(s) or dentition were not present (e.g. orbital roof). Associations among the variables were assessed using chi-square tests and, given sample sizes for fractures and Schmorl's nodes, hierarchical loglinear analysis (for both types of analyses, $p = 0.05$). Hierarchical loglinear analysis tests the significance of the three-way interaction among categorical (i.e. age-interval) and binary (i.e. presence/absence of pathological conditions and sex) variables, as well as all other lower order interactions (e.g. the interaction between age and sex). Backwards elimination is used to remove non-significant interactions among variables with a statistical significance criterion of $p = 0.05$. Because hierarchical log-linear analysis allows for the evaluation of interactions between more than two variables, it is possible to determine whether a significant association between pathology or injury and sex exists in the absence of an age effect (Green, 1988; for bioarchaeological applications, see DeWitte, 2012 and Yaussy *et al.*, 2016).

Results

Analyses of the data found that fractures were the most frequently occurring injury type; dislocation/subluxation were excluded as only two people had these injuries. Males had higher frequencies of sharp-force weapon injuries, but these were not significantly associated with sex ($P = 0.062$), or age ($P = 0.57$) (Tables 2 and 3). Myositis ossificans was significantly higher for males than females ($P = 0.008$), but there was no significant difference in age distributions between those with/out this lesion ($P = 0.69$) (Tables 2 and 3). Similarly, Schmorl's nodes were significantly higher in frequency among males compared to females ($P < 0.001$), but these were not associated with age ($P = 0.74$) (Table 4). Dental injuries were not significantly associated with sex ($P = 0.31$) or age ($P = 0.58$) (Tables 2 and 3).

Interestingly, hierarchical log-linear analysis revealed no significant difference in the age distribution of fractures between males and females. Analysis of those with a 0, 1, or ≥2 fractures revealed that males

Table 2. Myositis ossificans (MO), dental trauma (DT), and sharp force trauma (SFT) age distributions (% = percentage within each age category with or without injury)

Age (years old)	MO absent	MO present	DT absent	DT present	SFT absent	SFT present
18–25	36 (83.7%)	7 (16.3%)	62 (95.4%)	3 (4.6%)	31 (86.1%)	5 (13.9%)
26–35	79 (81.4%)	18 (18.6%)	104 (92.9%)	8 (7.1%)	69 (92%)	6 (8%)
36–45	72 (87.8%)	10 (12.2%)	110 (93.2%)	8 (6.8%)	56 (87.5%)	8 (12.5%)
≥46	32 (82.1%)	7 (17.9%)	38 (88.4%)	5 (11.6%)	32 (94.1%)	2 (5.9%)
Total	219	42	314	24	188	21

Table 3. Myositis ossificans (MO), dental trauma (DT), and sharp force trauma (SFT) sex distributions (% = percentage of males or females with and without injury)

	MO absent	MO present	DT absent	DT present	SFT absent	SFT present
Males	119 (78.3%)	33 (21.7%)	173 (94.5%)	10 (5.5%)	107 (86.3%)	17 (13.7%)
Females	104 (90.4%)	11 (9.6%)	157 (91.8%)	14 (8.2%)	82 (94.3%)	5 (5.7%)
Total	223	44	330	24	189	22

Table 4. Age and sex distributions of Schmorl's nodes (% = percentage within each age category with or without Schmorl's nodes)

	Male		Female		Both sexes	
Age (years old)	Absent	Present	Absent	Present	Absent	Present
18–25	12 (38.7%)	19 (61.3%)	20 (64.5%)	11 (35.5%)	32 (51.6%)	30 (48.4%)
26–35	30 (49.2%)	31 (50.8%)	31 (67.4%)	15 (32.6%)	61 (57%)	46 (43%)
36–45	30 (49.2%)	31 (50.8%)	40 (70.2%)	17 (29.8%)	70 (59.3%)	48 (40.7%)
≥46	11 (52.4%)	10 (47.6%)	12 (66.7%)	6 (33.3%)	23 (58.9%)	16 (41.1%)
Total	83	91	103	49	186	140

had significantly more fractures than females ($P < 0.001$), but for those with at least 1 fracture, there was no sex difference between those with 1 versus ≥2 fractures (Table 5). There was a significant difference ($P = 0.044$) among the age distributions of people with 0, 1, or ≥2 fractures. The frequency of those without fractures declined with increasing age; there was no significant difference in the age distributions of those with 1 versus ≥2 fractures. The absence of fractures declined consistently with age for both sexes. For males, the frequency of 1 or ≥2 fractures increased consistently with age. For females, the frequency of those with ≥2 fractures increased consistently with age; the frequency of those with a single fracture also generally increased with age, although there was a slight decline among 26–35 compared to 18–25 year olds.

The assessment of general health (0 or ≥1 pathological lesions of any kind) and injury (0, 1, or ≥2 injuries of any kind) revealed no significant relationship ($P = 0.92$) (Table 6). When only fractures were considered in association with general health variables, there were no significant associations between multiple fractures and cribra orbitalia, carious lesions, periodontal disease, or periosteal lesions (Tables 7 and 8). Porotic hyperostosis frequencies differed significantly between those with 1 versus ≥2 fractures, with a higher frequency occurring among those with multiple fractures ($P = 0.026$) (Table 7). In contrast, enamel hypoplastic defects were more common among those without fractures ($P < 0.001$) (Table 7); however, there was no significant difference between those with 1 versus ≥2 fractures (Table 8). A summary of the statistical results is shown in Table 9.

Table 5. Age and sex distribution of fractures (Fx = fracture, % = percentage within age category of 0, 1, or ≥2 fractures)

	Male			Female			Both sexes		
Age (years old)	0 Fx	1 Fx	≥2 Fx	0 Fx	1 Fx	≥2 Fx	0 Fx	1 Fx	≥2 Fx
18–25	20 (62.5%)	5 (15.6%)	7 (21.9%)	29 (80.6%)	4 (11.1%)	3 (8.3%)	49 (72.1%)	9 (13.2%)	10 (14.7%)
26–35	33 (50.8%)	12 (18.5%)	20 (30.8%)	40 (72.7%)	5 (9.1%)	10 (18.2%)	73 (60.8%)	17 (14.2%)	30 (25%)
36–45	27 (40.3%)	16 (23.9%)	24 (35.8%)	40 (63.5%)	11 (17.5%)	12 (19.0%)	67 (51.5%)	27 (20.8%)	36 (27.7%)
46+	6 (27.3%)	7 (31.8%)	9 (40.9%)	14 (60.9%)	4 (17.4%)	5 (21.7%)	20 (44.4%)	11 (24.4%)	14 (31.1%)
Total	86	40	60	123	24	30	209	64	90

Note: age x sex x injury tables are included for fractures and Schmorl's nodes because sample sizes for these injuries were sufficient for hierarchical log-linear analysis. For the other injuries, the sample sizes were not sufficient as there were too many cells with counts of 0–4 (hierarchical log-linear analysis requires cell counts of 1 or more and 80% of cells must have counts of 5 or more). So, for the injuries other than fractures and Schmorl's nodes, there are separate tables for the age and sex distributions that reflect the samples used for chi-square analyses; the sample sizes may differ slightly because there are individuals with injuries but no age estimates who were included in the analyses of the associations between sex and injuries.

Table 6. Association between injury (excludes Schmorl's nodes) and ≥1 other pathology. % = percentage of individuals with/without pathology with 0, 1, or ≥2 injuries

	No pathology	≥1 pathologies
0 injury	19 (46.3%)	142 (49.8%)
1 injury	10 (24.4%)	65 (22.8%)
≥2 injuries	12 (29.3%)	78 (27.4%)
Total	41	285

Table 8. Associations between fractures (Fx) and dental pathology (DC = dental caries, PD = periodontal disease). % = percentage of individuals with/without pathology with 0, 1, or ≥2 fractures

	DC absent	DC present	PD absent	PD present
0 Fx	86 (53.8%)	92 (58.2%)	80 (55.9%)	108 (56.5%)
1 Fx	29 (18.1%)	27 (17.1%)	27 (18.9%)	33 (17.3%)
≥2 Fx	45 (28.1%)	39 (24.7%)	36 (25.2%)	50 (26.2%)
Total	160	158	143	191

Discussion

General health and multiple injury

The results of our analysis support clinical findings that males generally experienced multiple injuries more frequently than females, placing them at a higher mortality risk. Interestingly, we observed concordance between the age-range profiled in the clinical data and our datasets, whereby most of the individuals with ≥2 fractures were aged between 26 and 35 years old. Whilst multiple injuries generally accumulated with age, our study did not reveal a significant association between increasing age and multiple injuries.

Our study found an association between multiple fractures and porotic hyperostosis, which is typically associated with general stress (Mays, 2012). This is consistent with Milner and colleagues findings (2015) of a relationship between poor health, mortality risk, and injuries. However, general diet, enamel hypoplastic defects associated with early childhood physiological stress, and perhaps poor dental hygiene (periodontal disease as a proxy) did not appear to make these individuals more likely to suffer injury. This disconnect between poor health, socioeconomic conditions, and injuries is supported by other research (e.g. Cooper *et al.*, 2000).

Historically documented skeletal collections (e.g. Terry Collection) provide effective segues between clinical and archaeological research owing to the absence of antibiotics during the collection period. For example, Muller (2006) assessed trauma using a structural violence approach among 205 documented African–American adults from the Cobb collection, who died between 1860 and 1969 AD. Of the 205 individuals, 157 had at least one fracture, and of these, 102 (64.97%) had multiple injuries to one body region only (e.g. ribs). She found 12/205 (5.8%), eight males and four females, with a range of injuries from multiple sites. Effectively, half of the group had multiple injuries, because of single or multiple episodes. The average age of the individuals at time of death was 57.5 years old, and the cause of death was documented for 175 individuals that included heart diseases, tuberculosis, and pneumonia; trauma caused the death of only two individuals. These results demonstrate that people can survive long after an injury or recurrent injuries and with poor health, intensified by structural violence (see also, de la Cova, 2012).

Problems and limitations for multiple injury analysis in osteoarchaeology

In clinical settings, many individuals with multiple injuries usually sustained them during an assault. The global range of clinical and dental trauma provides a wealth of cross-cultural and temporally diverse datasets which show that regardless of country, location (rural/urban), or sex, the most commonly sustained assault injuries are to the face; young adult males are the most frequently affected and many injuries result from blows exchanged in alcohol-fuelled fights (e.g. Johansen *et al.*, 2008; Martin & Bachman, 1997). However, there are

Table 7. Associations between fractures (Fx) and pathology (CO = cribra orbitalia, PH = porotic hyperostosis, PL = periosteal lesions, EHD = enamel hypoplastic defect). % = percentage of individuals with/without pathology with 0, 1, or ≥2 fractures

	CO absent	CO present	PH absent	PH present	PL absent	PL present	EHD absent	EHD present
0 Fx	137 (56.8%)	34 (59.7%)	174 (56.9%)	11 (61.1%)	171 (60.9%)	40 (46.5%)	115 (48.5%)	72 (75%)
1 Fx	45 (18.7%)	8 (14%)	56 (18.3%)	0 (0%)	45 (16%)	19 (22.1%)	48 (20.3%)	12 (12.5%)
≥2 Fx	59 (24.5%)	15 (26.3%)	76 (24.8%)	7 (38.9%)	65 (23.1%)	27 (31.4%)	74 (31.2%)	12 (12.5%)
Total	241	57	306	18	281	86	237	96

Table 9. Summary of results of statistical analyses. The following abbreviations are used: cribra orbitalia (CO), dental trauma (DT), enamel hypoplastic defect (EHD), fracture (Fx), myositis ossificans (MO), periosteal lesions (PL), porotic hyperostosis (PH), Schmorl's nodes (SN), and sharp force trauma (SFT). Significant results (at p = 0.05) are indicated in bold

Variables	Chi-square *p*-value	Hierarchical log-linear analysis *p*-value
Fx (0, 1, or 2+) × sex × age		0.98
Fx (0, 1, or 2+) × sex		<**0.001**
Fx (0, 1, or 2+) × age		**0.044**
Fx (1 or 2+) × sex × age		0.89
Fx (1 or 2+) × sex		0.62
Fx (1 or 2+) × age		0.83
SN × sex × age		0.95
SN × sex		<**0.001**
SN × age		0.74
DT × sex	0.31	
DT × age	0.58	
MO × sex	**0.008**	
MO × age	0.69	
SFT × sex	0.062	
SFT × age	0.57	
Any injury × Any pathology	0.92	
Fx (0, 1, or 2+) × Caries	0.71	
Fx (1 or 2+) × Caries	0.84	
Fx (0, 1, or 2+) × CO	0.71	
Fx (1 or 2+) × CO	0.46	
Fx (0, 1, or 2+) × EHD	<**0.001**	
Fx (1 or 2+) × EHD	0.33	
Fx (0, 1, or 2+) × PD	0.93	
Fx (1 or 2+) × PD	0.71	
Fx (0, 1, or 2+) × PH	0.097	
Fx (1 or 2+) × PH	**0.026**	
Fx (0, 1, or ≥2) × PL	0.06	
Fx (1 or ≥2) × PL	0.96	

ever increasing limitations inherent to clinical research that negatively impact these datasets.

The most notable issue is the continuous revision and updating of terminology, and therefore the methods employed. The clinical literature often describes the presence of co-occurring injuries as polytrauma, but this term is not synonymous with multiple trauma; both have been updated since their introduction (Pape, 2012). The definitions of both rely on the use of the Abbreviated Injury Scale (AIS) (Table 10), which determines the threat to life (minor to unsurvivable) caused by an injury rather than its severity (Association for the Advancement of Automotive Medicine, 2008). The Injury Severity Score (ISS) (Baker *et al.*, 1974) refers to the three most severely injured body regions as per the AIS (Table 10), and the resulting score allows clinical staff to determine the type and level of care given to the patient (Brohi, 2007). The majority of polytrauma victims are injured in vehicle-related accidents and like IRs and are typically young and middle-aged males; children and the elderly are the minority of these victims (Lecky *et al.*, 2010). Over the years, ISS has become a proxy for polytrauma with ISS scores of over 15 and 17 the frequently preferred cut-off points for this classification (Butcher & Balogh, 2012).

There is no universal definition of polytrauma, which the clinical literature recognises to be a significant problem, because studies are not comparing like-with-like. Since the 1990s, the term has been adopted by military and civilian medics to describe warfare victims who were severely injured by improvised explosive devices (Butcher & Balogh, 2009, 2014; Butcher *et al.*, 2013, 2014; Lovrić, 2015; Mohta *et al.*, 2008). The most recent definition describes polytrauma

Table 10. Summary of the methods and concepts used to score and define multiple injuries/trauma

Method or concept	Summary	Citation
Abbreviated Injury Scale (AIS)	Anatomical scoring system to determine 'threat to life'. Injuries are ranked on a scale: 1 (minor), 2 (moderate), 3 (serious), 4 (severe), 5 (critical), and 6 (unsurvivable) Body is divided into nine regions: head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, external, and other.	Association for the Advancement of Automotive Medicine (2008)
Injury Severity Score (ISS)	The highest AIS severity code for three of the most severely injured ISS body areas are calculated using the formula, $ISS = A^2 + B^2 + C^2$.	Brohi (2007); Baker *et al.* (1974)
Multiple trauma/injury	Injury to more than one body region.	Butcher & Balogh (2009); Delany & Berlin (1983)
Polytrauma	Significant injuries of three or more points in two or more different AIS regions in conjunction with one (or more) additional variables from the five physiologic parameters. Frequently used physiologic responses to injury are: hypoxia, coagulopathy, hypotension, level of consciousness, and acidosis.	Pape *et al.* (2014); Butcher & Balogh (2014)

as, 'significant injuries of three or more points in two or more different anatomic AIS regions in conjunction with one or more additional variables from the five physiologic parameters' (Pape *et al.*, 2014). As with earlier attempts, this definition rests on the victim having injuries to multiple body systems or cavities that affect uninjured organs (Keel & Trentz, 2005; Tool *et al.*, 1991).

The usefulness and relevance of this definition to osteoarchaeology are problematic, as Lecky *et al.* (2010) observed, 'multiple limb fractures, or a limb and pelvic fracture, will not constitute polytrauma without injuries to either head/abdomen/thorax'. Unless the human remains are naturally mummified, establishing whether body systems and other organs were also impacted by the injuries is problematic. Using this term to describe past individuals with numerous fractures is incorrect because skeletonised remains are unable to provide the evidence necessary to fulfil the clinical criteria. More appropriate terms, because they are not reliant on the presence of both fractures and injuries are 'multiple injury/trauma', described as, 'the presence of injury to more than one body area or system' (Delany and Berlin, 1983).

There are many limitations to trauma analysis, which were recently summarised by Judd & Redfern (2012), but several are particularly relevant to multiple injury research. In addition to archaeological excavation strategies, recovery, and taphonomy (Stodder, 2008), we will always be constrained by the funerary practices of past societies. Individuals may have been excluded from normative community burials grounds because they suffered a violent death or died elsewhere, and therefore may be absent from extant samples (Murphy, 2008). This was particularly true for soldiers, who were at greater risk of recurring violence but were not interred with their residential community if they died elsewhere during a military campaign (Constantinescu *et al.*, early view). We also must accept the absence of evidence for soft-tissue injury, such as abdominal injuries that are fatal but skeletally invisible. Soft-tissue injuries are much more frequent than hard-tissue injuries, even in episodes of assault, and are another casualty of the osteological paradox (Brink *et al.*, 1998; Wood *et al.*, 1992). We will always underestimate trauma.

Our ability to identify past individuals with multiple injuries is directly influenced by which skeletal, and dental changes are considered to be traumatic, and how these data are recorded (Judd, 2002; Judd & Redfern, 2012). For example, although Steyn *et al.* (2010) identified IRs in their sample of modern skeletal material, they excluded injuries to the dentition, extremities, and sternum and therefore, likely under-estimated the number of IRs present. Until quite recently, the thorax, extremities, and dentition were ignored during analysis, although injuries to these regions are ubiquitous in clinical trauma studies (e.g. Lieger *et al.*, 2009). As such, studies that include all skeletal elements offer greater insight into the lived experience of the individual and the community (e.g. Schmidt, 2009).

Clinical studies of IR employ a range of methods, which reduce their comparability. A study can be, temporally limited to some prospective follow-up period (Alghnam *et al.*, 2016), a survey (Cunningham *et al.*, 2015), a retrospective study (Caufeild *et al.*, 2004; Lewis *et al.*, 2006), or a combination of the two (McCoy *et al.*, 2013). By restricting the study period, clinical research focuses on the individual's lifestyle at or around the time of their injuries. The individual's social role or circumstances may change, so that if a similar study commenced 20 years later, they would no longer be considered an IR if they were injury-free during the study period. In contrast, osteoarchaeologists evaluate a life-time of injuries and have no way of knowing the person's life experience at the time these injuries were sustained. Using a modern example, a young woman may have been involved with gang-violence and antisocial behaviour when 19–22 years old, but became a socially responsible adult for the 60 remaining years of her life. Assuming no further medical intervention after the injuries healed, her skeleton would still bear witness to her turbulent youth. We would likely make similar judgements about the individual based on their skeletal remains, when in fact it was only a 'moment' in their lifetime when they were at greater risk because of life choices. It is within this context that the inclusion of health variables may aid our interpretation.

There are issues concerning diagnosis, the most pertinent of which are the accurate identification of peri-mortem injuries and the timing of injuries (e.g. Galloway *et al.*, 2014; Loe, 2008). These frequently rely on macroscopic observations, but if injuries are very well-remodelled then they may be missed altogether, and it may not be possible to determine fracture type. Digital radiography and CT scanning are ideal non-destructive solutions for suspected injuries, but are not always available in the field or laboratory because of cost and logistics. However, whilst sophisticated technologies can provide a more nuanced interpretation for a case study, the results will not be comparable to other research unless similar technologies are routinely used.

Sometimes, both ante- and peri-mortem injuries are present among individuals, who are often linked to warfare or warrior-status groups, emphasising the importance of understanding injury patterns in their bioarchaeological context (e.g. Linduff & Rubinson, 2008). Many of these individuals, such as the soldiers killed at the Battle of Towton (England, 1461 AD) (Novak, 2000), could certainly be considered IRs. However, without this very unique battlefield context, the social identification of individuals with multiple injuries must be carefully made. As discussed earlier, the original meaning of the term *injury recidivist* referred to a person who received their injuries during violent or criminal events. The current broader meaning defines an IR as, anyone who experiences recurrent injuries because of any cause and receives professional medical treatment. We need to question whether or not the term IR is appropriate for all past people with multiple injuries, unless the context of the injuries is historically documented. It may be more prudent and correct, although certainly more cumbersome, to refer to individuals with multiple injuries as just that—individuals with multiple injuries.

Conclusions

There is a collective awareness among clinicians and osteoarchaeologists that injuries need to be studied in the context of a person's health and living environment. Here, we briefly reviewed the original IR model, its current applications, and the implications for osteoarchaeology. Our case study of geotemporally diverse groups assessed the association of several key health indicators with multiple injuries and found that there was a correlation with porotic hyperostosis, which might indicate that those with multiple injuries had poorer health. However, this is a cautious assertion, as it may well be that the injuries predisposed the individual to a decline in health. Although injuries tended to increase with age, the relationship was not significant. As with clinical models, young males experienced more multiple injuries that may be linked with a lifestyle which predisposed them to greater risk of an earlier death.

Our review of the current clinical terminology illustrated that polytrauma is not a 'good fit' for osteoarchaeology. Whilst the IR model provides a useful model for interpretation, it must be used with care because it is not interchangeable with multiple injury. IR can only be used when the aetiology of the injuries is known or if it is explicitly stated by the researchers that the term is used in its broadest sense to include all injuries. We propose that multiple injury is the most appropriate term, because of the biassed datasets available to osteoarchaeologists, and more importantly it eliminates judgement as to the individual's lifestyle.

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