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The relationship between obesity and fractures

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ABSTRACT

There has been very limited analysis of the relationship between obesity and fractures in the orthopaedic literature. It has been established for some years that underweight individuals are at greater risk of proximal femoral fractures but recently there has been interest in the susceptibility of obese post-menopausal females to fracture. We have undertaken an analysis of 4886 adult patients who presented with a fracture and had their BMI assessed. Analysis has confirmed the relationship between underweight individuals and proximal femoral fractures but there is also a negative association between obesity and clavicle fractures in males and females and with calcaneal fractures in females. There is a positive relationship between obesity and proximal humeral, finger phalangeal and ankle fractures in males and with humeral diaphyseal, carpal and ankle fractures in females. There was no relationship found between open or multiple fractures and obesity.

Introduction

Obesity is a major worldwide medical problem. The number of obese adults in the world has tripled since 1975 and it is estimated that there are now approximately 650 million obese adults worldwide and that by 2025 the number will rise to 1 billion [1]. Over 28% of adults in the United Kingdom are obese [2]. The medical problems related to obesity are considerable. It is associated with reduced life expectancy, cardiac disease, diabetes mellitus, psychological dysfunction and many other medical conditions [1,2].

Until recently it was generally accepted that increased weight was responsible for increased Bone Mineral Density (BMD) and thus fractures were less common in obese people. Analysis of the literature shows that there was little discussion of the relationship between obesity and fractures until relatively recently, probably because obesity was not considered to be a major health issue until the 1980s when Daly et al [3] pointed out that obesity was associated with an increased incidence of ankle fractures in middle aged and older patients. Since then there has been an increased interest in the relationship between obesity and fractures, particularly in post-menopausal women as there has been a marked increase in the incidence of fractures in this section of society in the last 30 years.

Most recent studies have shown an association between proximal femoral fractures and underweight females [4–7], but recently it has been postulated that a number of other fractures in post-menopausal females are related to obesity these mainly being humerus and ankle fractures [8]. As a result, it is now believed that obesity is associated with fractures in post-menopausal women, particularly fractures of the upper and lower leg. Caffarelli et al [9] reviewed the literature between 2009 and 2014 and demonstrated significant divergence between researchers. However, in men it was thought that obesity was associated with an increased incidence of upper forearm and ankle fractures but a reduced incidence of hip, spine, wrist, forearm and pelvic fractures. In women the literature suggested a similar pattern but there was an increased incidence of humeral and vertebral fractures.

Apart from ankle fractures there has been very little written in the orthopaedic literature about obesity and fractures. The definition of fracture types has frequently been imprecise and it is often impossible to distinguish between proximal humeral and humeral diaphyseal fractures or between distal radial and carpal fractures. We are not aware of a previous study in a defined adult population of the relationship between obesity and all fracture types and the modes of injury.

Materials and methods

We undertook an epidemiological analysis of all patients presenting to the Royal Infirmary of Edinburgh in a one-year period between mid-2010 and mid-2011. The Royal Infirmary of

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Edinburgh is the only hospital treating fractures in the City of Edinburgh, Midlothian and East Lothian. The demographic details of all patients were recorded, and each fracture was assessed and classified by an experienced orthopaedic surgeon. Where possible the height and weight of the patient was recorded and the Body Mass Index (BMI) calculated [10]. Patients with spinal fractures were not assessed as the patients with spinal fractures who are admitted to hospital are not representative of the whole population as most spinal fractures are insufficiency fractures occurring in older people. The modes of injury were classified as falls from a standing height, low falls from < 6 feet, falls from a greater height, sports, road traffic accidents and direct blows or assaults. The prevalence of open fractures and other fractures related to the index fracture were also recorded.

During the study period data on 6818 fracture patients aged ≥ 16 years were prospectively recorded. A total of 4886 (71.7%) patients had BMI data available. Comparison of the age and gender of the patients whose BMI was known with those in whom it was not showed no statistical difference. Comparison of the fracture prevalence in the two groups showed no difference except in distal radial and metacarpal fractures. Distal radial fractures were commoner ($p < 0.001$) and metacarpal fractures less common ($p < 0.001$) in the group with a known BMI.

For the purposes of analysis the BMI was conventionally divided into underweight (< 18.5), normal weight (18.5–24.9), overweight (25–29.9) and obese (≥ 30) [10]. Fracture severity and morphology was assessed using the AO/OTA classification [11]. The relationship of obesity to fracture prevalence in different age groups was assessed by dividing our patient population into 3 groups these being patients aged < 35 years, 36–54 years and ≥ 55 years. The latter age range was chosen because it has been used in recent literature to delineate post-menopausal females [12].

Statistical analysis

Chi-squared tests or t-tests were used to test bivariate associations between different variables, and the effects of BMI on fracture percentages, adjusted for age and social deprivation, were tested using multiple logistic regression. Chi-squared tests were used to examine fracture morphology.

Results

The prevalence of obesity in males and females presenting with fractures is shown in Table 1. It shows that 11.2% of males and 15.7% of females who presented with fractures during the study year were obese. It also shows the fracture prevalence in different age groups. A comparison of the prevalence of males and females of different ages with a BMI > 30 in the Scottish population [13] with patients with a BMI > 30 who presented with fractures in the study year is shown in Fig. 1. Despite the relatively high prevalence of obesity in the fracture population it is apparent that the prevalence of obesity in the fracture population is consistently lower than the prevalence of obesity in the whole population. In both males and females the prevalence of obesity in fracture patients increases with age this being more apparent in female patients. In males the prevalence of obesity in the population reduces after 65 years with a less marked reduction in the prevalence of obese fracture patients at this age. In females the prevalence of obesity increases until about the age of 50 years and is maintained at a relatively constant level in the overall female population However in the obese female fracture population the prevalence of fractures falls after this age.

Table 1
The overall prevalence of obesity (BMI ≥ 30) in patients presenting with fractures during the study year. The prevalences in different age ranges are also shown.

	BMI ≥ 30 (%)	
Age	Males	Female
≤ 35 years	6.4	14.7
36 -54 years	15.9	23.2
≥ 55 years	15.3	13.9
All patients	11.2	15.7

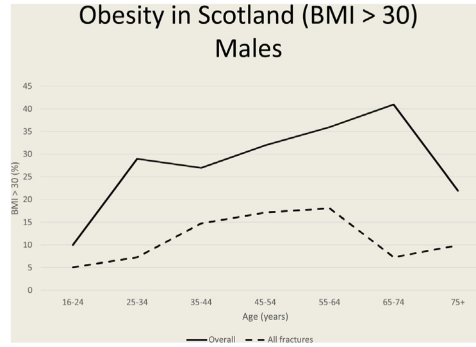

Fig. 1. A comparison of the prevalence of obesity in the Scottish male population with the fracture population during the study year.

Table 2
The prevalence of the different fracture types in each BMI range presenting in males during the study year. The prevalence of the different modes of injury and the average ages are also shown.

	Males (≥ 16 yrs)					
BMI	< 18.5	18.5–24.9	25-29.9	≥ 30		
	%	%	%	%	P value	+/− effect
Clavicle	8.4	7.3	5.1	3.9	0.041	negative
Scapula	1.4	0.8	1.4	0.7	ns	
Proximal humerus	1.4	4.1	3.9	8.1	0.008	positive
Humeral diaphysis	0	1.0	0.8	1.5	ns	
Distal humerus	0	0.6	0.8	0	ns	
Proximal forearm	4.2	5.0	5.1	5.0	ns	
Forearm diaphysis	1.4	1.4	1.4	0.7	ns	
Distal radius/ulna	7.0	10.9	12.0	14.3	ns	
Carpus	1.4	4.5	3.7	4.2	ns	
Metacarpus	12.7	18.3	15.1	14.7	ns	
Finger phalanges	5.6	10.3	13.3	12.7	0.006	positive
Pelvis	2.8	1.1	0.8	0.4	ns	
Proximal femur	26.8	7.2	5.1	3.5	<0.001	negative
Femoral diaphysis	5.6	1.1	0.8	1.5	ns	
Distal femur	1.4	0.2	0.3	0	ns	
Patella	1.4	0.5	0.6	1.2	ns	
Proximal tibia	1.4	1.0	1.0	0.7	ns	
Tibia/Fibula diaphysis	0	3.3	1.7	0	ns	
Distal tibia	0	1.2	0.7	1.2	ns	
Ankle	4.2	7.9	16.1	12.4	<0.001	positive
Talus	0	0.5	0.3	0.4	ns	
Calcaneus	1.4	2.1	1.4	1.2	ns	
Midfoot	0	0.7	0.7	0.4	ns	
Metatarsus	8.4	5.0	6.1	5.8	ns	
Toe phalanges	1.4	1.7	1.7	2.7	ns	
Open fractures	0	3.7	2.4	1.9	ns	
Multiple fractures	12.7	13.8	10.1	11.6	ns	
Falls	49.3	36.6	42.7	46.7	0.007	positive
Low falls	8.5	4.4	5.3	5.4	ns	
Falls height	0	6.0	3.7	3.9	ns	
Road Traffic Accident	12.7	8.3	8.3	9.3	ns	
Sport	12.7	22.2	20.4	11.2	0.011	negative
Direct blow/assault	14.1	22.2	18.7	22.8	ns	
Average age (yrs)	50.5	39.4	44.1	47.7	<0.001	negative

Table 3
The prevalence of the different fracture types in each BMI range presenting in females during the study year. The prevalence of the different modes of injury and the average ages are also shown.

BMI	Females (≥ 16 yrs) < 18.5 %	18.5–24.9 %	25–29.9 %	≥ 30 %	P value	+/− effect
Clavicle	1.6	2.3	1.9	1.2	0.027	negative
Scapula	0	0.1	0.1	0.5	ns	
Proximal humerus	7.3	9.2	9.2	8.4	ns	
Humeral diaphysis	0.8	0.7	0.8	2.7	0.003	positive
Distal humerus	0.8	0.7	0.9	0.2	ns	
Proximal forearm	4.9	4.5	5.9	6.0	ns	
Forearm diaphysis	0.8	0.2	0.7	0.7	ns	
Distal radius/ulna	20.3	26.3	25.0	24.6	ns	
Carpus	0.8	1.5	2.0	2.4	0.034	positive
Metacarpus	3.3	4.2	4.2	3.4	ns	
Finger phalanges	3.3	6.5	8.3	7.5	ns	
Pelvis	0	2.8	1.7	1.7	ns	
Proximal femur	43.1	17.5	10.2	6.7	<0.001	negative
Femoral diaphysis	1.6	1.0	1.1	1.7	ns	
Distal femur	3.3	1.0	0.4	0.7	ns	
Patella	0	1.0	0.9	0.7	ns	
Proximal tibia	1.6	0.5	0.7	1.4	ns	
Tibia/Fibula diaphysis	0	1.1	1.3	1.7	ns	
Distal tibia	0	0.4	0.5	0.2	ns	
Ankle	2.4	7.4	12.8	16.6	<0.001	positive
Talus	0	0.07	0	0	ns	
Calcaneus	1.6	0.7	0	0	0.005	negative
Midfoot	0	0.07	0.4	0.2	ns	
Metatarsus	1.6	7.9	8.6	8.9	ns	
Toe phalanges	1.6	1.6	1.1	1.2	ns	
Open fractures	1.6	0.9	1.9	1.4	ns	
Multiple fractures	8.9	8.8	8.9	7.9	ns	
Falls	87.0	80.9	82.8	83.1	ns	
Low falls	4.1	4.4	5.0	3.4	ns	
Falls height	0	0.8	0.1	0	0.019	negative
Road Traffic Accident	1.6	2.0	2.7	2.7	ns	
Sport	2.4	4.9	3.2	2.7	0.022	negative
Direct blow/assault	3.3	6.5	5.6	6.7	ns	
Average age (yrs)	68.4	61.4	61.3	57.2	<0.001	negative

Tables 2 and 3 show the relationship between obesity and the prevalence of all fracture types. In males (Table 2) there was a positive relationship between obesity and three fractures: fractures of the proximal humerus, finger phalanges and ankle. There was a negative relationship with clavicle and proximal femoral fractures. In females (Table 3) there was positive relationship with obesity in fractures of the humeral diaphysis, carpus and ankle, with a negative relationship being found in fractures of the clavicle, proximal femur and calcaneus.

Analysis of the mode of injury demonstrated a positive relationship between obesity and fall related fractures in males (Table 2) but not in females (Table 3). In males there was a negative relationship between obesity and sports and in females a negative relationship was seen with sports and falls from a height. There was no relationship between open fractures or multiple fractures and obesity in either males or females. Tables 2 and 3 also show a negative relationship between age and fractures in obese patients.

The relationship of obesity to fracture prevalence in the different age ranges shown in Table 1 was also examined. Analysis showed that the only fractures to have an association with obesity in the ≥ 55 year groups were the proximal femoral fracture, which showed a negative association in both males ($p < 0.001$) and females ($p < 0.001$), and the ankle fracture in females were there was a positive relationship with obesity ($p < 0.001$). Analysis of patients aged 35–54 years showed a positive relationship for ankle fractures in females ($p = 0.003$) and analysis of the < 35 years patients showed a negative association in males for ankle fractures ($p = 0.002$), calcaneal fractures ($P = 0.005$) and midfoot fractures ($p = 0.003$).

Tables 4 and 5 show the prevalence of obesity together with the average age and fracture morphology, as assessed by the AO/OTA (13) classification system, for fractures in which there were more than 10 obese patients treated in the study year. The age and fracture morphology of the obese (BMI ≥ 30) patients is compared with the underweight and normal weight (BMI < 25) patients. It shows that the humeral diaphyseal fracture in females is associated with the highest prevalence of obesity and that in females > 20% of obese patients also presented with ankle and carpal fractures (Table 5). In males only proximal humeral fractures occurred in >20% of obese patients (Table 4).

Discussion

We believe that this data strongly indicates that obesity is not a major factor in the causation of fractures. We have shown that, particularly in males, the prevalence of obesity in the overall population is considerably higher than in the fracture population. In obese females the prevalence of fractures decreases after about 50 years of age the same being seen in males after about 60 years of age. The decline in obesity related fractures continues such that only 9.9% of obese males and 9.5% of obese females aged ≥ 75 years present with a fracture.

Traditionally it was always assumed that obesity was protective against fractures as it was assumed that the increased weight

Table 4
A comparison of the average age and fracture morphology, using the AO/OTA classification [11], for obese and underweight/normal male patients. Fractures occurring in > 10 obese patients during the study year have been analysed. The prevalence of obese patients with a BMI ≥ 30 is also shown.

	Males ≥ 16 years BMP ≥ 30: BMP ≥30(%)	Age (yrs)	Type A (%)	Type B (%)	Type C (%)	BMP < 25: Age (yrs)	Type A (%)	Type B (%)	Type C (%)
Proximal humerus	20.8	59.3	71.4	19.0	9.5	59.7	82.7	11.5	5.8
Toe phalanges	17.0	48.1	28.6	42.9	28.6	38.7	40.0	35.0	25.0
Distal radius/ulna	13.9	46.2	43.2	29.7	27.0	39.0	61.3	23.4	15.3
Ankle	13.3	43.3	15.6	65.6	18.7	38.6	18.6	68.3	12.9
Finger phalanges	12.5	50.1	30.3	48.5	21.2	33.7	36.1	54.9	9.8
Metatarsus	11.7	45.5	86.7	13.3	–	31.2	75.4	24.6	–
Carpus	11.5	41.5	100	–	–	28.7	96.6	3.4	–
Proximal forearm	11.2	46.3	38.5	61.5	–	35.3	24.2	69.7	6.1
Metacarpus	9.8	40.3	86.8	5.3	7.9	25.6	82.9	9.2	7.9
Clavicle	6.9	48.1	10.0	70.0	20.0	35.0	4.1	45.9	50.0
Proximal femur	5.8	74.7	28.6	71.4	–	78.8	36.1	64.8	0.9

Table 5
A comparison of the average age and fracture morphology, using the AO/OTA classification (11), for obese and underweight/normal female patients. Fractures occurring in > 10 obese patients during the study year have been analysed. The prevalence of obese patients with a BMI ≥ 30 is also shown.

	Females ≥ 16 years								
	BMP ≥ 30					BMP < 25			
	BMP ≥ 30 (%)	Age (yrs)	Type A (%)	Type B (%)	Type C (%)	Age (yrs)	Type A (%)	Type B (%)	Type C (%)
Humeral diaphysis	40.7	54.2	81.8	18.2	–	59.9	80.0	20.0	–
Ankle	25.7	54.2	24.6	62.3	13.0	54.1	30.8	63.5	5.8
Carpus	21.3	45.8	100	–	–	45.6	100	–	–
Proximal forearm	18.4	54.6	24.0	76.0	–	48.1	14.9	85.1	–
Metatarsus	17.6	46.6	62.2	37.8	–	46.6	71.6	27.5	0.9
Finger phalanges	16.5	46.8	38.7	48.4	12.9	42.2	42.4	53.3	4.3
Distal radius/ulna	15.2	61.5	60.8	16.7	22.5	61.6	72.5	7.0	20.5
Proximal humerus	14.7	67.7	51.4	40.0	8.6	68.0	60.0	30.4	9.6
Metacarpus	13.1	34.2	78.6	14.3	7.1	45.6	87.1	9.7	3.2
Proximal femur	7.1	73.2	46.4	53.6	–	82.1	40.3	59.7	–

improved the BMD whilst in females it was also postulated that as endogenous oestrogen was derived from its androgen precursor in adipose tissue obesity was associated with increased bone density and fewer fractures [14]. This belief persisted until recently when the literature started to publish studies stating that obesity had a positive association with fractures, particularly in post-menopausal females [15–17]. This view has to an extent been extrapolated to include the whole population although virtually all studies have been undertaken in older patients. In younger patients the association of obesity with ankle fractures has been documented [18–20] but we are not aware of a previous study examining the relationship of obesity with all adult fractures in a defined population.

Post-menopausal fractures

The positive association between obesity and fractures in post-menopausal females followed a study in Cambridge (UK) where post-menopausal women who had sustained a low energy fracture were followed up and their BMI was assessed [15]. However, only post-menopausal females of 75 years or less were examined and the authors stated that 27.7% of the post-menopausal female population were obese. Fig. 1 shows that the prevalence of obesity in postmenopausal females falls rapidly with increasing age and analysis of our data shows that 32.7% of all adult females treated in the study year were > 75 years of age. This emphasizes that unless one includes all post-menopausal females the prevalence of obesity will be erroneously high. In the Cambridge study only 10.7% of the patients had proximal femoral fractures whereas 36.4% had wrist fractures. This compares with 22.4% and 26.4% respectively in the Edinburgh study where all patients were assessed. We believe that this indicates that the Cambridge study examined a cohort of younger, fitter patients that was not representative of the entire post-menopausal female population.

There has also been recent interest in other methods of assessing obesity and it has been suggested that the incidence of hip fractures increases with waist circumference [21,22]. It has also been suggested that women with android-like obesity are protected from osteoporosis [23]. However, the overwhelming majority of studies have used the BMI to assess obesity and it is widely accepted that a BMI < 30 is a good measure of obesity [10].

Analysis of our data shows that only five fractures had a positive association with obesity. However, the most important association was the negative relationship with proximal femoral fractures in both males and females with. Many researchers have documented this [4–7] and it has been well established that it is underweight (BMI < 18.5) patients who are prone to this fracture. One of the problems of concentrating on obesity in proximal femoral fractures is that researchers have tended to ignore the real problem which is underweight patients who have sarcopenia. It is well established that patient frailty is a direct consequence of sarcopenia and it is associated with increased falls and risk of fracture [24]. It has been documented that a high protein intake in sarcopenic patients is associated with muscle synthesis [25], a higher BMD, a slower rate of bone loss and a reduced risk of hip fracture [26]. This finding is very important as not only does it suggest treatment, but it probably defines why the incidence of proximal femoral fractures has been declining in the last few decades [27,28]. This decline is often attributed to prophylactic anti-osteoporotic medication but the literature indicates that in many countries this is not usually given to patients prior to a proximal femoral fracture [28,29] and it does seem likely that improved social conditions and nutrition in the last 2–3 generations have resulted in a reduced incidence of proximal femoral fractures.

The literature regarding post-menopausal fractures and obesity has been dominated by the proximal femoral fracture, but there are a number of other fractures which are associated with osteoporosis, particularly in older females. These are listed in Table 6 which also includes ankle and humeral diaphyseal fractures as these were the only fractures to have a positive association with obesity. It shows that the only fracture in females with a higher prevalence of underweight patients than the proximal femoral fracture is the distal femoral fracture which has a similar prevalence of obese patients. This is an uncommon fracture but the similarity to the proximal femur suggests that in a larger series analysis might well show a negative association with obesity. The opposite is true for the femoral diaphyseal fracture which is associated with similar prevalence of obesity to the ankle fracture. A larger series might well show a positive association with obesity. The common distal radial and proximal humeral fractures are associated with a similar obesity prevalence to the normal female population aged

Table 6
The number, average age and prevalence of underweight and obese post-menopausal females (age ≥ 55 years) who presented with the classic osteoporotic fractures during the study year. Humeral diaphyseal and ankle fractures have been included as they have been shown to have a positive relationship with obesity. The prevalence of fall-related fractures is shown.

Fracture	No	Age (yr)	BMI <18.5(%)	BMI ≥ 30 (%)	Falls (%)
Distal femur	26	73.0	20.0	5.0	92.3
Proximal femur	536	81.8	13.4	6.2	95.9
Femoral diaphysis	40	78.1	7.1	25.0	90.0
Distal radius/ulna	631	73.2	4.5	15.3	96.0
Proximal humerus	280	73.3	4.0	14.4	92.9
Pelvis	83	83.3	0	8.4	91.6
Ankle	205	68.2	0.7	24.3	91.7
Humeral diaphysis	24	76.5	0	35.3	76.5

$\geq$ 55 year. In many ways the pelvic fracture is the most interesting. It has the highest average age, but no patient was underweight and only 8.9% were obese. The prevalence of low velocity fall injuries was the same as in the other fractures. This suggests that patients with pelvic fractures are much fitter than patients with proximal femoral fractures. However, it is currently unclear as to why this should be.

Other fractures

There has been very little research into the relationship between obesity and fractures in patients < 55 years of age. The only fracture which has been looked at in detail is the ankle fracture [18–20] and a positive relationship with obesity has been established, particularly in older patients. Our data has shown that in males there is a positive relationship in proximal humeral, finger phalangeal and ankle fractures, whilst in females it is in humeral diaphyseal, carpal and ankle fractures. The study has also shown that the proximal femoral fracture is not the only fracture to have a negative relationship with obesity this association being found in clavicle fractures in males and females and calcaneal fractures in females. It is difficult to know why fractures in the adjacent areas of the clavicle and proximal humerus should behave differently but proximal humeral fractures occur in patients with an average age of about 60 years and usually follow a fall on the outstretched hand. Clavicle fractures usually occur in younger patients following a fall on the shoulder or a road traffic or sports injury. Figs. 1 and 2 show that there is a high prevalence of obesity in males and females at 60 years of age and we think it likely that a fall on an outstretched hand in an obese, osteopenic individual will virtually always cause a proximal humeral rather than a clavicle fracture. Calcaneal fractures usually follow a fall from a height and there were no calcaneal fractures in overweight or obese females in the study year. It would seem obvious that it is younger fitter females who undertake activities that might result in a calcaneal fracture. We believe that the same is true for the ankle, calcaneal and midfoot fractures in 16–34 year males which showed a negative association with obesity.

Tables 4 and 5 show some differences in obese males and females who present with a fracture. In females (Table 5) the average age is very similar regardless of the BMI. However in males (Table 4) fractures that one would expect to see in younger patients, such as finger phalangeal, carpal, metacarpal, metatarsal and clavicle fractures tend to occur in older patients if the patient is obese. We believe that the differences are likely to represent behavioural differences as much as obesity. Two examples of this are female carpal fractures and male finger phalangeal fractures. Table 5 shows that females with carpal fractures have the same average age and fracture morphology regardless of body weight.

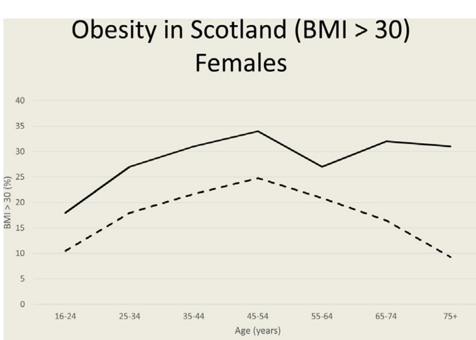

Fig. 2. A comparison of the prevalence of obesity in the Scottish female population with the fracture population during the study year.

The higher prevalence in obese females must simply relate to heavier females falling on their wrist. However, we believe that male phalangeal fractures are different. Table 4 shows that the obese males who sustain a finger phalangeal fracture are older and there is a higher prevalence of AO/OTA Type C fractures. Analysis shows that 47% of obese males sustained a finger fracture as a result of an assault and 75% of the injuries involved alcohol. It therefore seems likely that the main reason for an increased prevalence of finger fractures relates to middle aged male behavioural tendencies.

The literature suggests that obesity increases the severity of ankle [19] and distal radial [30] fractures. We looked for this in the fractures listed in Tables 4 and 5 but although some of the Figures suggest a relationship between fracture morphology and obesity statistical analysis showed no definite correlation. We think it likely that there is a relationship in some fractures, but it seems unlikely that it is a major issue. The severity of the fractures is likely to be multi-factorial depending on the age, gender and health of the patient as well as the mode of injury and the degree of osteoporosis.

Declaration of Competing Interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this study.

Ethical permission

The ethical committee of the hospital decided that this study was audit and ethical permission was not required.

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