National incidence of traumatic fractures in China: a retrospective survey of 512 187 individuals

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Summary

Background Traumatic fractures place a substantial burden on health-care systems worldwide. Although detailed information about incidence, distribution, and risk factors for traumatic fractures is vital for planning and prevention, in China, national data are unavailable. We aimed to do an up-to-date national survey on the population-weighted incidence of traumatic fractures in China.

Methods The China National Fracture Study (CNFS) was a retrospective epidemiological study that recruited a nationally representative sample from eight provinces, 24 urban cities, and 24 rural counties in China using stratified random sampling and the probability proportional to size method. All eligible household members who had lived in their current residence for 6 months or longer were personally interviewed by trained research teams about traumatic fractures of the trunk, arms, or legs (not including the skull, sternum, and ribs) that had occurred in 2014. Telephone surveys were used for participants who were non-contactable after repeated visits. Fracture cases were verified by clinical records, medical history, and radiographs by orthopaedic surgeons and radiologists. We estimated incidence rates for traumatic fractures for the overall population and for subgroups by age and sex, as well as by demographic factors such as ethnic origin, occupation, geographical region, and residency category. We also studied potential associations between fractures and various factors of interest, such as age, ethnic origin, education, smoking, alcohol drinking, sleep time per day, and history of previous fracture. Data were weighted during statistical analysis to ascertain the national incidence rate. This study is registered with the Chinese Clinical Trial Registry, number ChiCTR-EPR-15005878.

Findings Between Jan 19, 2015, and May 16, 2015, 535 836 individuals were selected and invited to participate in the study. Questionnaires from 23 649 (4%) individuals were excluded due to missing items, insufficient responses, or logical errors. Following exclusions, 512 187 (96%) individuals participated in the CNFS, consisting of 259 649 (51%) boys and men and 252 538 (49%) girls and women. Of these individuals, 1763 individuals had experienced traumatic fractures during 2014 (n=1833). The population-weighted incidence rate of traumatic fractures of the trunk, arms, or legs was 3·21 (95% CI 2·83–3·59) per 1000 population in 2014 (3·65, 3·12–4·18 in men and 2·75, 2·46–3·04 in women). For all ages, sleeping less than 7 h per day was identified as a risk factor for traumatic fractures. We identified previous fracture history as a risk factor for adults aged 15 years and older. Alcohol consumption incurred a risk effect for men aged 15 years and older and women aged 15–64 years.

Interpretation Our results provide detailed information about fracture incidence, distribution, and risk factors, which can now be used as an up-to-date clinical evidence base for national health-care planning and preventive efforts in China and elsewhere. Specific public health policies that focus on decreasing alcohol consumption, prohibiting drunk driving, promoting smoking cessation, and encouraging individuals to obtain sufficient sleep and maintain a healthy bodyweight should be urgently implemented to help reduce the risk of traumatic fractures.

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Introduction

Traumatic injury is a major cause of global mortality and disability. Injuries also impose a substantial burden for China, being the fifth most common cause of death and resulting in more fatalities than diabetes and infectious disease.[1] Although injury-related fractures constitute a major drain on health-care resources,[2,3] national epidemiological data for fracture incidence rates are scarce. Countries without such data have to infer statistics based on results from other regions, which is highly problematic because of substantial variations in incidence rates. Up to now, most epidemiological studies of fractures have only assessed data from a single hospital or region or have focused on a specific population or body site,[2-4] often with contradictory results. With a population in excess of 1·36 billion, China is a vast country with substantial diversity in terms of economic development, cultural practices, and health-care systems. Some Chinese studies have reported the epidemiology of fractures,[5] but most studies have been limited by small sample sizes, restricted geographic areas, or a focus on a specific fracture site. An exception is the Chinese National Health Services Survey

Research in context

Evidence before this study

Between June 15, 2013, and March 25, 2015, we searched PubMed, MEDLINE, Embase, Google Scholar, Chinese National Knowledge Infrastructure, and Wanfang databases for related studies without language restrictions. The following main search terms were used: ("epidemiology"[Title] OR "incidence"[Title] OR "occurrence"[Title] OR "statistics"[Title] OR "survey"[Title] OR "prevalence"[Title]) AND ("fracture"[Title] OR "fractures"[Title]). We also did a manual search of the reference lists of included articles. The inclusion criteria were as follows: population-based surveys and systematic reviews and meta-analyses with full text, which reported the incidence, prevalence, or epidemiology of fractures in individual or multiple sites. The exclusion criteria were as follows: abstracts, letters, meeting reports, guidelines, and animal studies. More than 200 studies published no later than March 25, 2015, met the inclusion criteria. We found no studies that had recruited a nationally representative sample of individuals to calculate the national incidence of traumatic fractures across China. Although some authors from other countries, such as Norway and the UK, have reported the incidence of traumatic fractures on a national scale, epidemiological differences exist between different populations as they imply different cultures, socioeconomic prosperity, and lifestyles in each region. Therefore, we deemed it necessary to do a national survey on the population-weighted incidence of traumatic fractures in China to provide accurate and up-to-date clinical data for national health-care planning and preventive efforts.

Added value of this study

The China National Fracture Study (CNFS) enrolled 512 718 nationally representative participants using stratified random sampling and the probability proportional to size method, which represents the first detailed epidemiological investigation of traumatic fractures ever done across the entire Chinese population with clinical verification of cases included. The incidence rates for traumatic fractures were estimated for the overall population and for subgroups by age, sex, and other factors of interest. The risk factors for traumatic fractures among children, young and middle-aged adults, and the elderly population were identified, which can help to formulate the targeted preventive tragedies.

Implications of all the available evidence

Evidence from the CNFS combined with research from other regions and countries clearly shows that traumatic fractures represent a major public health issue in the world, although the epidemiological characteristics of traumatic fractures are diverse between different populations due to different cultures, socioeconomic prosperity, and lifestyles in each region. These large-scale epidemiological studies have elucidated various risk factors for traumatic fractures among different populations around the world. Targeted preventive treatments to reduce the risk of fractures should now be implemented accordingly.

done every 5 years, which collects information about self-reported fractures in the 2 weeks before the survey.[6] However, this survey does not capture any information about the type of fracture or body site; and self-reported cases are not confirmed by radiological evidence or medical records. Additionally, the population-weighted incidence rates, the affected bones, the injury mechanisms, and the risk factors for traumatic fractures are not ascertained in the National Health Services Surveys.

Some previous studies have identified fracture risk factors for a specific fracture or subpopulation, with advanced age, excess alcohol consumption, smoking, overweight, osteoporosis, sleep disorder, occupation, and dietary and living environment being associated with fractures at specific sites.[7–10] However, risk factors for traumatic fractures in the entire Chinese population have not been elucidated. We designed the China National Fracture Study (CNFS) to provide the first comprehensive and up-to-date national dataset of traumatic fracture incidence rates, distribution, injury mechanism, and risk factors throughout China.

See Online for appendix

Methods

Sampling method and sample size

A pilot phase was undertaken to estimate the general incidence of fracture within the Chinese population and facilitate more accurate sample size planning based on the probability proportional to size method. 3299 individuals were recruited in two urban communities and three administrative villages in Hebei Province. Sample sizes were estimated to meet recommended requirements for precision in complex survey design,[11] with 510 000 individuals being initially targeted for inclusion within the study.

During the main sampling phase, 31 provinces (municipalities or autonomous regions) in mainland China were categorised into three regions (east, central, and west) according to socioeconomic development and climate, similar to the method used by the Chinese Statistical Bureau.[12] Eight provinces and municipalities were initially selected by stratified random sampling (three from the east region, two from the middle, and three from the west; figure, appendix p 1). Within each targeted province, sampling was done separately in urban and rural areas.

For urban areas, cities were divided into three strata by population size (large, mid-sized, and small cities),[13-15] with a city selected in each urban stratum in all sampled provinces by proceeding geographically from west to east using the probability proportional to size method.

A certain number of streets ranging from one to six were selected in each sampled city, and a range from one

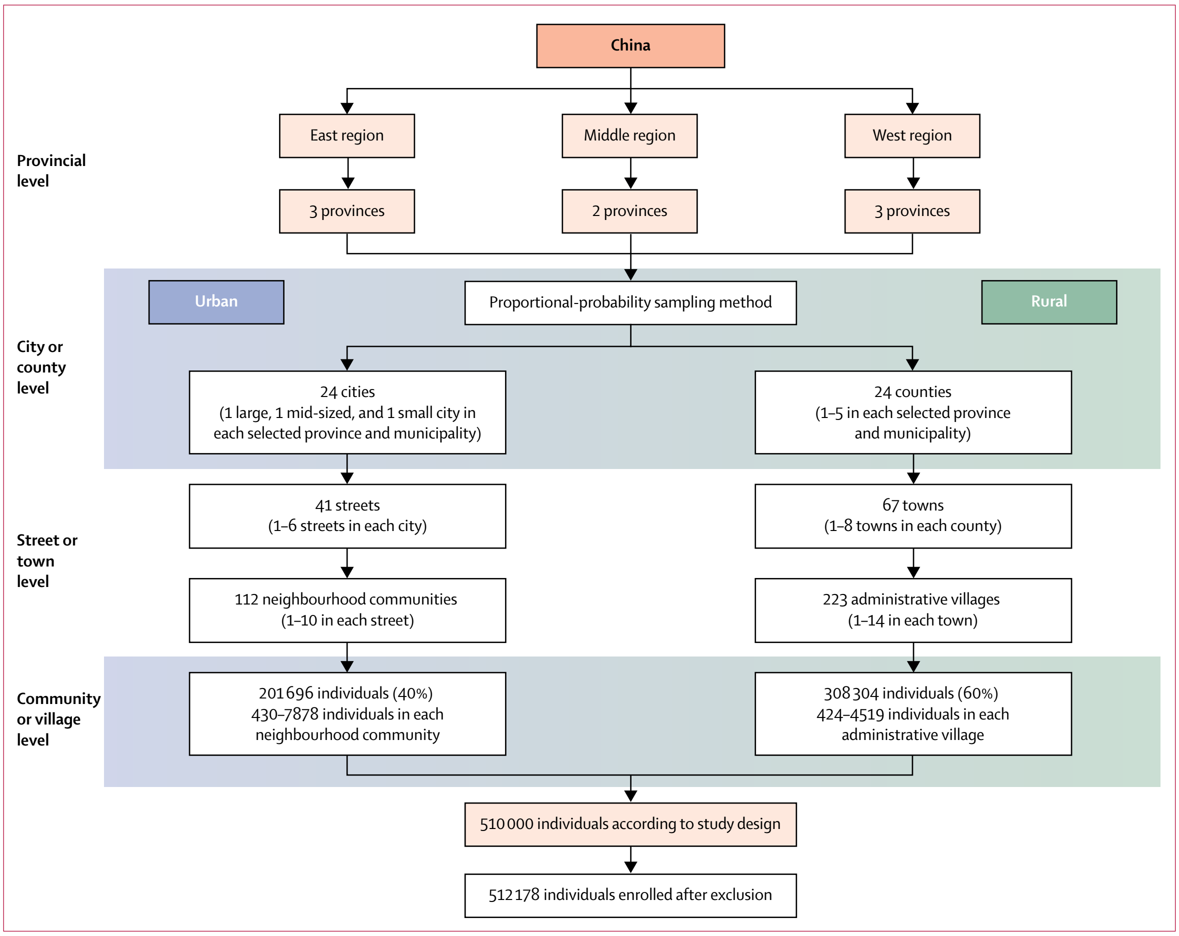

Figure: **China National Fracture Study profile**

to ten neighbourhood communities were then selected from each chosen street, both being stratified from west to east and selected using the probability proportional to size method. In each neighbourhood community, the total number of families to be interviewed was determined by the average number of household members according to the latest official census data, with families being selected using the probability proportional to size method according to their building, apartment, and room numbers until the required sample size was reached. All eligible members in the selected families who had been living in their current residence for 6 months or more were invited to participate in the study. In each neighbourhood community, between 430 and 7878 individuals were targeted, with an aim to recruit a total sample of 201 696 people.

For rural areas, we initially sampled one to five counties in each selected province and then in each county, one to eight towns were selected. In each town, one to 14 administrative villages were sampled, all using the probability proportional to size method. In each village, mean household populations were calculated according to official census records and then sequenced geographically from west to east and from north to south. Households were assigned identification numbers based on probability proportional to size principles, with all members being surveyed until the required sample size was reached. Between 424 and 4519 individuals were sampled in each chosen administrative village, with an aim to recruit 308 304 individuals from rural areas.

Findings of the pilot phase of the CNFS showed that 3·2% of responses were unusable, and therefore we added an extra 5% to the total required sample size in both urban and rural areas for the main study.

Participants and survey

All eligible household members were personally interviewed by trained research teams. For preschool and primary school children, their information was provided by their guardians. For children in junior and senior high school, their information was provided by themselves, as was done in the the Chinese National Health Services Survey. Telephone surveys[16] were used for participants who remained non-contactable after repeated visits. In cases for which the family had moved or refused to participate, an alternative household was randomly

	Sample size	Incidence rate per 1000 population (95% CI)		
		Male	Female	Total
Individuals	512 187	3·65 (3·12–4·18)	2·75 (2·46–3·04)	3·21 (2·83–3·59)
Age (years)				
0–4	26 840	0·72 (0·14–1·30)	0·68 (0·11–1·25)	0·70 (0·21–1·19)
5–14	54 326	2·26 (1·48–3·05)	1·23 (0·85–1·61)	1·79 (1·31–2·26)
15–24	62 020	2·22 (1·66–2·78)	1·13 (0·78–1·48)	1·69 (1·36–2·02)
25–34	93 194	3·04 (2·55–3·53)	1·03 (0·78–1·28)	2·05 (1·74–2·36)
35–44	80 992	4·25 (3·52–4·98)	1·92 (1·32–2·51)	3·11 (2·60–3·61)
45–54	79 565	5·09 (3·91–6·27)	3·61 (2·87–4·36)	4·37 (3·51–5·22)
55–64	58 968	6·01 (4·67–7·34)	7·04 (6·06–8·01)	6·52 (5·60–7·43)
65–74	38 745	5·19 (3·90–6·47)	6·60 (5·16–8·04)	5·89 (4·91–6·87)
≥75	17 537	4·90 (3·09–6·72)	6·89 (4·67–9·11)	6·00 (4·37–7·63)
p value for trend test	..	<0·0001	<0·0001	<0·0001
Ethnic origin				
Han	477 508	3·65 (3·10–4·20)	2·83 (2·51–3·14)	3·25 (2·86–3·64)
Other	34 679	3·87 (3·23–4·51)	2·06 (1·28–2·83)	2·98 (2·33–3·63)
p value for difference test	..	0·60	0·08	0·47
Region				
East	232 998	3·75 (3·11–4·38)	3·26 (2·79–3·72)	3·51 (3·02–4·00)
Central	99 109	3·02 (2·14–3·89)	2·54 (1·91–3·18)	2·78 (2·13–3·43)
West	180 080	3·93 (2·88–4·98)	2·35 (1·80–2·91)	3·15 (2·39–3·92)
p value for difference test†	512 187	0·38	0·03	0·33
Urbanisation				
Urban area	203 101	3·29 (2·76–3·81)	2·62 (2·12–3·13)	2·96 (2·50–3·43)
Rural area	309 086	3·89 (3·16–4·61)	2·85 (2·47–3·23)	3·38 (2·88–3·89)
p value for difference test	..	0·16	0·47	0·21
Occupation				
Office worker	61 919	3·24 (2·29–4·19)	2·20 (1·55–2·86)	2·76 (2·10–3·42)
Farmer	106 484	5·18 (4·35–6·02)	4·38 (3·75–5·02)	4·75 (4·21–5·30)
Manual worker	148 650	4·03 (3·30–4·76)	1·79 (1·36–2·22)	3·05 (2·54–3·57)
Retired	30 366	4·80 (3·41–6·19)	6·82 (5·21–8·42)	5·86 (4·80–6·92)
Unemployed	32 770	7·45 (5·04–9·87)	4·32 (3·29–5·36)	5·24 (4·11–6·37)
Preschool children	35 581	0·77 (0·27–1·27)	0·81 (0·29–1·34)	0·79 (0·37–1·21)
Students	80 443	2·22 (1·68–2·75)	1·27 (0·91–1·62)	1·76 (1·39–2·13)
Other	15 974	3·76 (2·53–4·99)	4·67 (2·35–6·99)	4·14 (3·01–5·26)
p value for difference test†	..	<0·0001	<0·0001	<0·0001
Education (preschool children and students excluded; n=396 163)				
Illiterate	74 937	6·03 (4·85–7·20)	4·98 (4·38–5·59)	5·46 (4·79–6·14)
Primary school	158 970	5·09 (4·17–6·01)	3·33 (2·69–3·97)	4·23 (3·54–4·92)
Junior high school	121 415	2·94 (2·14–3·74)	2·69 (1·88–3·50)	2·82 (2·12–3·52)
Senior high school or above	40 841	3·26 (2·40–4·11)	1·74 (1·25–2·23)	2·56 (1·98–3·13)
p value for trend test	..	<0·0001	<0·0001	<0·0001

*All incidence rates were weighted to obtain nationally representative estimates. †Difference of rate by study factor, such as region and occupation.

Table 1: **National incidence of traumatic fractures in China by demographic, socioeconomic, and geographic factors in 2014***

selected from the list using a modified version of the Kish method.[17] Similarly, in cases for which a selected neighbourhood community or administrative village could not achieve the required sample size or refused to participate in this survey, an alternative community or village was randomly selected.

For the field survey, a standardised questionnaire was administered by trained research teams. This questionnaire sought information about demographic characteristics such as age, sex, Chinese ethnic nationality, marital status, and residence. Individuals who had traumatic fractures of the trunk, arms, or legs between Jan 1, and Dec 31, 2014, then answered a more detailed questionnaire between Jan 19, and May 16, 2015, regarding the date, fracture site, and injury mechanism. Median recall time was 8·6 months (IQR 6·1). Participants were asked to provide medical records of their fractures, including radiographs, diagnostic reports, and medical reports. When such information was unavailable, the survey team paid for individual participants to obtain a new radiograph of their reported fracture site at a local hospital. The fracture sites were recorded according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA) classification of fractures, including humerus, radius and ulna, femur, tibia and fibula, spine, pelvic ring and acetabulum, hand, foot, scapula, clavicle, and patella (appendix p 2). Participants with fractures were asked to report injury mechanisms under the categories of traffic accidents; slips, trips, or falls; falls from heights; crushing injury; sharp trauma; blunt force trauma; and others (appendix p 2); these categories are commonly applied in clinical practice and National Health Services Surveys in China.[6,18] Skull, sternum, and rib fractures were not assessed in this study, because these body sites are treated in different departments of the Chinese health-care system (the neurology and respiratory surgery departments, respectively).

Eight quality control teams were established (one per province), with 10% of all questionnaires collected in the field being sampled by the quality control team to check for omissions and errors. Participants reporting traumatic fractures had their clinical records, medical history, and radiographs interpreted by independent orthopaedic surgeons and radiologists to ensure the accuracy of the original diagnosis. The CNFS was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University, and written informed consent was obtained from all participants before data collection.

Statistical analysis

All data were recorded on a written survey at each selected household and later entered into the EpiData 3.1 software program using the dual import program. Dually imported data were then compared and in cases of mismatched information, the original printed versions were consulted and corrections made accordingly.

Incidence rates for traumatic fractures were estimated for the overall population and for subgroups by age and sex; as well as by demographic factors such as ethnic origin, occupation, geographical region, and residency category (appendix p 3).[15] We also assessed incidence rate by the highest education level attained among the study population (excluding preschool children and students; appendix pp 3, 4). Differences in incidence between categories of nominal variables, such as occupation, regions, residency category, and ethnic origin, were tested using the Rao-Scott χ^2 test. Trends in incidence rates by age and education were tested by including these ordered categorical variables as a continuous variable in a univariate logistic regression model. We also assessed incidence rates for traumatic fracture by fracture sites among children (≤14 years), young and middle-aged adults (15 years and 64 years), and older people (65 years and over).

We then studied potential correlations between fractures and various factors of interest (appendix pp 3–5), including age, ethnic origin, education, occupation, cigarette smoking, alcohol drinking, calcium or vitamin D taking, BMI, sleep time per day, history of previous fracture, and urbanisation, as well as menopause and the number of children per women. Participants considered their status with regard to these factors before the fracture occurrence (for participants with fractures) or before answering the questionnaire (for those without fractures). Five separate design-based multiple logistic regression models were constructed to explore the potential risk factors for traumatic fractures among children, young and middle-aged adults, and older people. In view of the complexity of the study's sample design, weights were calculated for all analyses to reflect the entire population of China.

Sample weighting comprised two components: sampling weight, which accounts for unequal probability of sample selection in each sampling stage, and post-stratification weight, which harmonises the sample structure of the survey with that of the standard Chinese population based on the most recent (2010) census. We specifically considered the age (5-year increments), sex, and geographical region simultaneously when undertaking the post-stratification process. For 95% CIs, we estimated sampling error using Taylor series

	Children (0–14 years)		Young and middle-aged adults (15–64 years)		Older people (≥65 years)		Total
	Boys	Girls	Men	Women	Men	Women	
Humerus	0·38 (0·17–0·58)	0·07 (0·00–0·16)	0·21 (0·13–0·29)	0·13 (0·07–0·18)	0·18 (0·00–0·41)	0·47 (0·16–0·79)	0·20 (0·15–0·24)
Radius and ulna	0·58 (0·34–0·82)	0·51 (0·27–0·75)	0·57 (0·47–0·68)	0·61 (0·48–0·75)	0·53 (0·22–0·84)	1·72 (1·18–2·26)	0·63 (0·55–0·72)
Femur	0·07 (0·00–0·15)	0·01 (0·00–0·03)	0·44 (0·28–0·60)	0·17 (0·10–0·23)	1·11 (0·76–1·46)	1·39 (0·87–1·91)	0·35 (0·27–0·43)
Tibia and fibula	0·29 (0·11–0·47)	0·19 (0·00–0·37)	1·02 (0·85–1·19)	0·63 (0·51–0·74)	1·30 (0·81–1·80)	1·13 (0·76–1·50)	0·76 (0·66–0·86)
Spine	0·06 (0·00–0·17)	0·02 (0·00–0·05)	0·33 (0·20–0·47)	0·23 (0·15–0·30)	0·79 (0·44–1·13)	0·82 (0·38–1·27)	0·29 (0·21–0·37)
Pelvic ring and acetabulum	..	0·02 (0·00–0·06)	0·09 (0·01–0·18)	0·07 (0·04–0·10)	0·17 (0·01–0·32)	0·51 (0·22–0·80)	0·09 (0·05–0·13)
Hand	0·06 (0·00–0·14)	0·12 (0·00–0·23)	0·37 (0·24–0·49)	0·24 (0·17–0·31)	0·29 (0·07–0·50)	0·34 (0·09–0·59)	0·27 (0·21–0·32)
Foot	0·23 (0·06–0·40)	0·03 (0·00–0·08)	0·57 (0·44–0·70)	0·29 (0·20–0·39)	0·45 (0·12–0·78)	0·30 (0·02–0·57)	0·38 (0·29–0·47)
Scapula	..	..	0·08 (0·03–0·13)	0·04 (0·01–0·07)	0·15 (0·00–0·32)	0·06 (0·00–0·14)	0·05 (0·02–0·08)
Clavicle	0·05 (0·00–0·13)	0·05 (0·00–0·12)	0·25 (0·17–0·33)	0·13 (0·08–0·18)	0·12 (0·00–0·30)	0·13 (0·00–0·25)	0·16 (0·13–0·20)
Patella	0·02 (0·00–0·06)	0·03 (0·00–0·07)	0·14 (0·07–0·21)	0·11 (0·05–0·17)	0·27 (0·08–0·46)	0·31 (0·08–0·55)	0·13 (0·08–0·17)

Data are incidence rate per 1000 people (95% CI). All incidence rates were weighted to obtain nationally representative estimates. Double dots indicate no fracture cases recorded in this subgroup.

Table 2: **National incidence of traumatic fractures in China by body site in 2014**

	Children (0–14 years)	Young and middle-aged adults (15–64 years)		Older people (≥65 years)		Total
		Men	Women	Men	Women	
Traffic accident	11·3% (3·5–19·2)	25·2% (21·9–28·5)	19·3% (15·5–23·2)	16·5% (11·3–21·7)	9·9% (6·4–13·3)	20·4% (18·6–22·1)
Slip, trip, or fall	71·7% (61·4–82·0)	43·1% (37·7–48·6)	67·0% (62·9–71·1)	66·1% (57·6–74·7)	83·0% (78·0–88·0)	57·7% (54·3–61·2)
Fall from heights	8·7% (3·7–13·7)	12·8% (10·5–15·2)	5·8% (3·5–8·1)	7·3% (1·0–13·6)	3·5% (1·0–6·0)	9·2% (7·7–10·7)
Crushing injury	5·6% (0·0–12·1)	14·3% (11·4–17·3)	5·4% (3·1–7·7)	10·1% (2·9–17·3)	3·1% (0·3–5·8)	9·7% (7·9–11·5)
Sharp trauma	..	1·8% (0·46–3·0)	1·7% (0·7–2·6)	..	..	1·3% (0·6–2·1)
Blunt force trauma	2·7% (0·0–5·7)	2·7% (1·1–4·3)	0·8% (0·1–1·5)	..	0·6% (0·0–1·7)	1·7% (0·7–2·8)

Data are % (95% CI). All proportion rates were weighted to obtain nationally representative estimates. Double dots indicate no fracture cases recorded in this subgroup.

Table 3: **Proportion of traumatic fractures by causal mechanisms in China in 2014 (% of total)**

	Men	Women
Age (years)		
15–24	Reference	Reference
25–34	1·11 (0·73–1·70)	0·85 (0·52–1·40)
35–44	1·50 (0·98–2·30)	1·46 (0·82–2·60)
45–54	1·55 (0·93–2·58)	1·92 (1·08–3·42)
55–64	1·62 (0·96–2·73)	2·54 (1·41–4·57)
Ethnic origin		
Han	Reference	Reference
Other	1·04 (0·82–1·31)	0·62 (0·47–0·82)
Education		
Illiterate	Reference	Reference
Primary school	1·07 (0·85–1·36)	1·09 (0·86–1·39)
Junior high school	0·68 (0·47–0·99)	0·92 (0·63–1·34)
Senior high school or above	0·88 (0·65–1·20)	1·12 (0·80–1·56)
Occupation		
Unemployed	Reference	Reference
Office worker	0·43 (0·32–0·58)	0·75 (0·53–1·06)
Manual worker	0·51 (0·36–0·74)	0·64 (0·50–0·81)
Farmer	0·51 (0·32–0·83)	0·83 (0·64–1·08)
Retired	0·46 (0·26–0·80)	0·95 (0·60–1·52)
Student	0·64 (0·36–1·11)	1·03 (0·53–1·98)
Other	0·47 (0·28–0·77)	0·70 (0·38–1·29)
Cigarette smoking		
No	Reference	Reference
Yes	1·47 (1·24–1·74)	0·87 (0·45–1·70)
Alcohol consumption		
No	Reference	Reference
Yes	2·27 (1·87–2·75)	2·75 (2·23–3·40)
Calcium or vitamin D supplement		
No	Reference	Reference
Yes	1·25 (0·90–1·74)	0·81 (0·55–1·19)
Urbanisation		
Rural area	Reference	Reference
Urban area	0·93 (0·69–1·25)	1·00 (0·75–1·34)
Region		
West	Reference	Reference
Central	0·89 (0·53–1·47)	1·05 (0·66–1·66)
East	1·06 (0·75–1·50)	1·11 (0·81–1·51)
BMI (kg/m²)		
18·5–23·9	Reference	Reference
24–27·9	1·00 (0·80–1·23)	1·19 (0·97–1·47)
≥28	1·09 (0·75–1·58)	1·39 (1·04–1·88)
<18·5	1·47 (1·02–2·13)	0·91 (0·60–1·37)
Average sleep time per day (h)		
≥7	Reference	Reference
<7	1·88 (1·65–2·15)	1·82 (1·52–2·17)
House facing the sun		
No	Reference	Reference
Yes	1·07 (0·42–2·72)	1·68 (0·41–6·96)
Previous history of fracture		
No	Reference	Reference
Yes	2·52 (1·52–4·18)	3·19 (1·85–5·49)
(Continued from previous column)		
Children		
No	..	Reference
1	..	0·66 (0·39–1·13)
2	..	1·60 (0·97–2·64)
3	..	1·75 (0·97–3·16)
≥4	..	1·11 (0·38–3·24)
Menopause age (years)		
>50	..	Reference
46–50	..	1·13 (0·80–1·58)
<46	..	0·74 (0·40–1·34)
Premenopausal	..	0·85 (0·53–1·35)

(Table 4 continues in next column)

Data are odds ratio (95% CI).

Table 4: **Risk factors for traumatic fractures among young and middle-aged Chinese adults (aged 15–64 years)**

linearisation, considering multistage sampling design.[19] All statistical analyses were done with SAS (version 9.3) and Sudaan (version 11.01).

Results

In the urban areas, we chose 24 cities (one large, one mid-sized, and one small city in every selected province and municipality); 112 neighbourhood communities were sampled from 41 selected streets in these cities. In the rural areas, 24 counties were selected, and 223 administrative villages were sampled from 67 selected towns in these counties. During the sampling phase, ten communities and one village refused to participate, and an additional eight communities and 23 villages contained fewer individuals than expected based on the 2010 census data. These groups were therefore replaced by the resampled neighbourhood communities and administrative villages. This resulted in 535 836 individuals selected and invited to participate in the study; questionnaires from 23 649 (4%) individuals were ultimately excluded due to missing items, insufficient responses, or logical errors. Following exclusions, 512 187 (96%) individuals participated in the CNFS: 259 649 (51%) boys and men and 252 538 (49%) girls and women.

1763 individuals (990 men and 773 women, mean age 48·2 years [SD 18·9]) reported 1833 traumatic fractures that had occurred in 2014 (appendix pp 5, 6). Among them were 117 (6%) children with 117 fractures, 1303 (74%) young and middle-aged adults with 1350 fractures, and 343 (19%) older individuals with 366 fractures. The population-weighted incidence rate of traumatic fractures of the trunk, arms, and legs in China was 3·21 (95% CI 2·83–3·59) per 1000 population (table 1).

We also analysed the population-weighted incidences of traumatic fracture by individual characteristics and regions. There was no significant difference in incidence

	Men	Women
Age (years)		
65–74	Reference	Reference
≥75	1·18 (0·73–1·91)	1·10 (0·75–1·62)
Ethnicity		
Han	Reference	Reference
Other	0·52 (0·25–1·08)	1·18 (0·56–2·50)
Education		
Illiterate	Reference	Reference
Primary school	0·69 (0·48–0·99)	1·31 (0·89,1·93)
Junior high school	0·43 (0·19–0·98)	0·70 (0·37,1·32)
Senior high school or above	0·17 (0·02–1·50)	1·05 (0·40,2·77)
Occupation		
Unemployed	Reference	Reference
Office worker	0·24 (0·03–1·92)	1·70 (0·58–5·00)
Manual worker	0·85 (0·44–1·61)	0·50 (0·23–1·12)
Farmer	1·01 (0·65–1·58)	0·85 (0·55–1·31)
Retired	1·07 (0·62–1·83)	0·75 (0·46–1·22)
Other	0·79 (0·33–1·94)	0·97 (0·48–1·96)
Cigarette smoking		
No	Reference	Reference
Yes	0·81 (0·54–1·23)	0·78 (0·33–1·83)
Alcohol consumption		
No	Reference	Reference
Yes	3·29 (1·92–5·64)	1·67 (0·66–4·23)
Calcium or vitamin D supplement		
No	Reference	Reference
Yes	0·94 (0·50–1·77)	0·80 (0·46–1·40)
Urbanisation		
Rural area	Reference	Reference
Urban area	0·81 (0·55–1·20)	0·87 (0·59–1·27)
(Continued from previous column)		
Region		
West	Reference	Reference
Central	1·32 (0·72–2·41)	2·09 (1·24–3·53)
East	1·27 (0·78–2·07)	2·45 (1·45–4·13)
BMI (kg/m²)		
18·5–23·9	Reference	Reference
24·0–27·9	1·00 (0·65–1·55)	1·36 (1·02–1·81)
≥28·0	0·35 (0·08–1·53)	1·19 (0·68–2·10)
<18·5	1·68 (0·93–3·03)	1·32 (0·76–2·31)
Average sleep time per day (h)		
≥7	Reference	Reference
<7	1·75 (1·18–2·61)	2·81 (1·90–4·17)
House facing the sun		
No	Reference	Reference
Yes	0·63 (0·15–2·64)	2·45 (0·25 –23·64)
Previous history of fracture		
No	Reference	Reference
Yes	4·27 (2·72–6·70)	2·30 (1·27–4·18)
Children		
≤1	··	Reference
2	··	4·97 (2·08–11·85)
3	··	3·22 (1·37–7·61)
≥4	··	4·28 (1·59–11·56)
Menopause age (years)		
>50	··	Reference
46–50	··	1·08 (0·74–1·58)
<46	··	1·09 (0·45–2·65)

(Table 5 continues in next column)

Data are odds ratio (95% CI).

Table 5: **Risk factors for traumatic fractures in older Chinese people (≥65 years)**

between those of Han ethnicity and all other ethnicities combined, nor was there any significant difference according to geographical region or urbanisation (table 1). Stratified by occupation, retired and unemployed individuals had the highest incidence rates: 5·86 (4·80–6·92) and 5·24 (4·11–6·37) per 1000 people, respectively. According to education level, illiterate individuals had the highest incidence rate (5·46, 4·79–6·14 per 1000 population).

The appendix (pp 8–10) shows the distribution of the 1833 traumatic fractures among children, young and middle-aged adults, and older people by body site, and table 2 summarises the population-weighted incidence rates. Among children, fractures of the radius and ulna were the most common for both sexes; among young and middle-aged adults, tibia and fibula fractures were most common for both sexes; among older people, the highest incidence rate was that of tibia and fibula fractures for men and radius and ulna fractures for women (table 2).

Table 3 summarises the population-weighted proportion rates of each category of causal mechanisms for children, young and middle-aged adults, and older people. In all subpopulations, injuries occurred most commonly via slips, trips, or falls; traffic accidents were the second most common cause of injury. Fractures caused by slips, trips, or falls accounted for most fractures in older women but less than half of those in young and middle-aged men (table 3). Fractures caused by traffic accidents accounted for up to a quarter of fractures among young and middle-aged men, but only 10% in older women (table 3).

Table 4 summarises risk factors for traumatic fractures in young and middle-aged adults aged between 15 and 64 years by sex. Compared with women aged 15–24 years, those aged 45–54 years and 55–64 years were more likely to experience fractures (table 4). Compared with Han ethnicity, being another ethnicity had a protective effect for women. Having junior high school as the highest education level compared with illiterate participants acted as a protective factor for men (odds ratio [OR] 0·68, 95% CI 0·47–0·99). When unemployment was used as the occupational referent, being an office worker, manual worker, farmer, retired, or having another job were

	Odds ratio (95% CI)
Age (years)	
0–4	Reference
5–14	1·02 (0·39–2·68)
Sex	
Boys	Reference
Girls	0·63 (0·41–0·97)
Ethnic origin	
Han	Reference
Other	1·34 (0·77–2·35)
Education	
Preschool	Reference
Primary school	2·28 (1·07–4·88)
Junior high school or above	2·28 (0·88–5·93)
Calcium or vitamin D supplement	
No	Reference
Yes	1·12 (0·47–2·69)
Average sleep time per day (h)	
≥7	Reference
<7	2·70 (1·28–5·70)
Urbanisation	
Rural area	Reference
Urban area	0·78 (0·39–1·54)
Region	
West	Reference
Central	0·95 (0·44–2·05)
East	1·51 (0·78–2·91)

Table 6: Risk factors for traumatic fractures in Chinese children (≤14 years)

protective factors for men, while only being a manual worker was found to be a protective factor for women (table 4). Cigarette smoking was a risk factor for men. For both men and women, alcohol consumption, having a previous history of fracture, and an average sleep time of less than 7 h were strong risk factors for traumatic fractures. Compared with a normal BMI, having a BMI of less than 18·5 kg/m² implied a risk factor for men, whereas a BMI of more than 28 kg/m² was a risk factor for women (table 4).

Table 5 shows risk factors for traumatic fractures in older people aged 65 years and over by sex. Alcohol drinking, sleeping less than 7 h per day, and having a previous fracture history were identified as strong risk factors for men. Having a highest education level of primary school and junior high school were protective factors for men. For elderly women, sleeping less than 7 h per day, having a previous history of fracture, and having two or more children were strong risk factors for traumatic fractures. Living in the central and east regions were also strong risk factors for women when compared with living in the west region. Additionally, a BMI ranging between 24 kg/m² and 27 kg/m² incurred a risk effect for elderly women (table 5).

Table 6 summarises risk factors for traumatic fractures in children aged 14 years and younger. When compared with boys, girls had a lower risk of sustaining a fracture. When compared with preschool children, primary school students had a high risk of fractures. Sleeping less than 7 h per day also increased the risk of traumatic fractures among children (table 6).

Discussion

The CNFS is the first comprehensive, national investigation of traumatic fractures with clinical verification of cases ever done in China. The population-weighted incidence rate for traumatic fractures of the trunk, arms, and legs was 3·21 per 1000 people in 2014, which, by extension, suggests that roughly 4·39 million Chinese (2·56 million men and 1·83 million women) had a traumatic fracture.

These findings show that traumatic fractures clearly comprise a major public health issue in modern China. However, comparison of our results with other countries is difficult. Although population-based studies on the incidence of traumatic fracture have been done in some regions, not all have reported consistent results. Epidemiological differences between populations are known to be important because they imply different cultures and lifestyles in each region.[20] A study from Leicestershire, UK, in 1990, for example, reported that the estimated annual incidence of fractures was 0·9%.[21] The overall fracture incidence at all sites and in all age groups was reported to be 2·28% in Norway in 1990.[22] A self-reporting survey of 45 293 individuals from across the UK showed an annual fracture incidence rate of 3·6%, with fractures being more common in white populations than the non-white population.[3] However, results of a recent study regarding the epidemiology of fractures in the UK between 1988 and 2012 showed a fracture rate of 7·33 per 1000 person-years of follow-up in individuals aged 18–49 years and 11·63 in those aged 50 years and older.[23] These studies suggest that fractures are probably more common in developed countries than in China, and these findings may reflect socioeconomic, cultural, and lifestyle differences.

In the current study, the most common injury mechanism for traumatic fractures was low-energy injuries (ie, slips, trips, and falls), followed by traffic accidents. A general ageing of the Chinese population has been recorded in recent years, with the proportion of people aged 65 years or older increasing from 8·9% in 2010 to 10·1% in 2014.[24,25] In view of their strong correlation with age,[26] this finding suggests that the incidence of osteoporotic and fragility-related fractures has increased in recent years. In the current study, 343 individuals aged 65 years and older sustained traumatic fractures, accounting for 19% of 1763 total participants with a fracture. Furthermore, low-energy slips, trips, or falls caused 66% of fractures in elderly men and 83% of fractures in women, which suggests that osteoporotic fractures now comprise a major constituent of fractures in China. In some sense, this is consistent with previous research that has identified fracture risk factors in elderly people and individuals with hip fractures or osteoporotic fractures.[7,26,27] However, the CNFS contrasts somewhat to the aforementioned studies, in that we analysed the risk factors for fractures of the trunk and four extremities across all age groups from a nationally representative sample of Chinese individuals. Statistical analysis of our data showed that sleeping for less than 7 h per day is a risk factor for all age scales, which is consistent with previous findings. Sleep impairment has been identified as a particularly well known risk factor for increased injury risk.[10,28] For example, Stone and colleagues[10] reported that women who slept for 5 h or less or between 5 and 7 h were at significantly higher risk of frequent falls than were women who slept for 7–8 h. Holmberg and colleagues[28] noted that sleep disturbances represented a significant contributor to risk in most fracture subgroups of male individuals.Therefore, it can be suggested that public health interventions should more actively encourage individuals to improve their sleep quality and duration to help reduce the risk of traumatic fractures.

Findings from the CNFS showed that alcohol consumption increased the risk of traumatic fractures for adults aged 15 years and older, while cigarette smoking increased the fracture risk in young and middle-aged men. These findings are similar to those of some previous studies that showed that excess alcohol consumption increases the risk of fractures through metabolic effects, via alcohol-related falls, and having a more hazardous lifestyle generally.[9] For example, Scholes and colleagues[27] reported that consuming more than 8 units of alcohol (for men) or more than 6 units (for women) on the heaviest drinking day in the past week was a risk factor for fractures in individuals aged 55 years and older. Tobacco consumption is a risk factor for fractures in general and hip fractures in particular, with a negative effect on bone mineral density.[7,29] Cornuz and colleagues[7] did a large study of 116 229 female nurses aged 34–59 years at baseline and followed them up for 12 years, elucidating an increased relative risk of 1·3 (95% CI 1·0–1·7) for hip fractures in current smokers when compared with those who had never smoked. Furthermore, they also demonstrated the benefits of quitting with a reduced relative risk of 0·7 (95% CI 0·5–0·9) 10 years after quitting.[7] On the basis of these findings, health policies that focus on decreasing alcohol consumption and helping more smokers to quit smoking should clearly be implemented in China to reduce fracture risk.

Another issue elucidated in this study was that a previous history of fracture was a strong risk factor for adults aged 15 years and older, a finding that is consistent with other investigations showing that one fracture often predicts the next.[26] For example, Holmberg and colleagues[28] reported that low-energy fractures in general were strongly associated with a history of previous fracture in middle-aged women.[28] For the elderly, having a previous fracture history has been identified as a risk factor that predisposes an individual to future fractures.[30] Kanis and colleagues[31] did a meta-analysis that confirmed a strong association between the history of previous fracture and current hip fracture risk in both males and females.[31] Accordingly, education and interventions on the prevention of secondary fractures should be strengthened and recommended among individuals, especially those with a previous fracture history and the increasing elderly demographic of China. Implementation of fall prevention measures and home and behavioural modifications will also be helpful to reduce the risk of secondary fractures.

The potential association between BMI and increased fracture risk has been explored, with low BMI having been shown to increases fracture risk, possibly due to its association with low bone mineral density, less soft tissue, and muscle weakness.[32] High BMI might also increase the risk of all osteoporotic and hip fractures.[33] Results of a previous meta-analysis[34] of women suggested that being underweight increases the risk of hip and osteoporotic fractures, while being overweight may increase the risk of upper arm fractures. Data from the CNFS suggest that low BMI is a fracture risk factor for young and middle-aged men, whereas a high BMI might incur an increased risk for women aged 15 years and older. As such, maintaining a healthy bodyweight with a normal BMI is clearly important to help minimise the risk of sustaining a traumatic fracture.

Other risk factors for traumatic fractures were also identified for different subgroups during the current study. When compared with unemployed participants, young and middle-aged men who held a job and women engaged in manual work had a reduced fracture risk. This finding is consistent with a previous study by Reimers and colleagues,[35] who examined elderly people living in the Stockholm metropolitan area. In that study, the investigators reported a high risk of hip fractures in regions with low economic status (defined as those with a high proportion of unemployment, low-wage earners, social welfare recipients, and single parent families).[35] The importance of securing stable employment combined with occupational safety education must therefore become a central component of any fracture reduction protocols for the wider community in China, as elsewhere.

Although the CNFS represents the first national study of traumatic fractures incidence with clinical verification ever done in China, there are some potential limitations that should be considered. First, households rather than individuals were randomly selected using the probability proportional to size method, as selecting individuals randomly in each administrative village or neighbourhood community directly would not have been practical in China. Second, there might have been some selection effect, as the study could not capture information about traumatic fracture cases in which the individual had died following the trauma. For example, individuals who sustained fractures, especially multiple fractures, due to road traffic accidents or other high-energy trauma, might have died and were therefore unavailable for the survey. Individuals in older age groups who sustain fractures, especially hip fractures, often have a high 1-year mortality rate and may have been missed during sampling for the same reason. This selection effect would inevitably underestimate the incidence rate of traumatic fractures of certain subpopulations.

Third, there might have been some recall bias, given that more recent fractures would have been recalled more accurately than events occurring long ago, while low-energy traumatic fractures might have been under-reported. Fourth, some of the fracture case sample sizes were rather small due to the limited number of participants in that particular group. For example, there was only one verified traumatic fracture case confirmed among elderly men with an education level of senior high school or above. This resulted in a large random error and a wide confidence interval for the estimated odds ratio in the multivariate model. Fifth, although the injury mechanisms of traumatic fractures applied in the current study (appendix p 2) have been commonly used in the field of traumatology and orthopaedics, we did not use the International Classification of Disease, 10th edition (ICD-10) codes, which would have given a more detailed description of external causes and nature of injury.

In conclusion, the CNFS represents the first detailed epidemiological investigation of traumatic fractures ever done across the entire Chinese population. The current study provides detailed information about the national population-weighted incidence of traumatic fractures, distribution, and risk factors, which can now be used as an up-to-date clinical evidence base for national health-care planning and preventive efforts in China, as elsewhere. Specific public health policies which focus on decreasing alcohol consumption, prohibit drunk driving, promote smoking cessation, and encourage individuals to obtain sufficient sleep and maintain a healthy bodyweight should be urgently implemented to help reduce the risk of traumatic fractures. Education and interventions for the prevention of falls and other trauma need to be emphasised, especially in the elderly and those with a previous fracture history. The importance of job stability should also be emphasised to help reduce the risk of sustaining a traumatic fracture.

Contributors

YZha conceived the idea for the study and managed the project. YZha, WC, HL, XZ, DS, and SL designed the study. WC, HL, SL, BL, YZhu, XC, GY, LL, TZ, HW, BY, JG, PH, JS, DS, XZ, YL, and YZha conducted the survey across China and collected the data. XZ, YL, and DS performed the statistical analyses and wrote the statistical analysis plan. WC, HL, SL, BL, YZhu, XC, GY, and LL wrote the manuscript. WC, HL, SL, and DS prepared the figures and tables. WC, YL, TZ, HW, BY, JG, PH, JS, DS, XZ, and YZha revised the manuscript. All authors interpreted the data and contributed to preparation of the manuscript. WC, HL, SL, BL, and YZhu contributed equally.

Declaration of interests

We declare no competing interests.

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