Cyclists' fractures in the elderly

Katsuhisa Tanabe [1]

Abstract

Summary Cyclists' fractures were as common in the elderly as in the young. In cyclists' fractures in the elderly, the ratio of women and the frequency of upper extremity fractures were significantly lower, compared with the young group.

Purpose Bicycles are useful for both men and women of any age as a means of transportation. In the present aging society, it is common for elderly people to ride bicycles in their daily lives. There have been no reports describing the characteristics of elderly cyclists' fractures. We conducted this study to elucidate these characteristics.

Methods Data of cyclists' fractures, excluding head or facial injuries, treated in an urban hospital were retrospectively collected. We documented the mechanism of injury, gender, age, and location of each fracture. We compared the gender, age, and location between cyclists' fractures and non-cyclists' fractures treated in the same period in the same hospital.

Results Fifty percent of cyclists' fractures occurred in cyclists over 60 years old (23% in their 60s, 19% in their 70s, and 7% in their 80s). The proportion of women was significantly higher among cyclists' fractures than among non-cyclists' fractures in patients under 60 years old ($p = 0.0001$), but was significantly lower in patients over 60 years old ($p = 0.002$). We found a significant relationship between the fracture location of three categories (upper extremities, lower extremities, and trunk) and CF/NCF ($p = 0.04$). The proportion of upper extremity fractures in cyclists compared with non-cyclists was similar under 60 years, but significantly lower in patients over 60 years ($p = 0.049$).

Conclusions Our study showed that cyclists' fractures were not uncommon in the elderly. In the elderly group, the ratio of women and the frequency of upper extremity fractures were significantly lower, compared with the young group.

Keywords Cyclists · Bicycle · Osteoporosis · Women · Fractures · Elderly

Introduction

Bicycles are used for various purposes all over the world. For some people, they are used as a means of fitness; recreation, such as cycle touring; or sport, such as cycle racing. Others ride bicycles simply as a means of transport, such as for commuting or for shopping. Bicycles are easy to ride and useful for both men and women of any age above 3 or 4 years old.

While bicycles have many advantages as a means of transport, bicycle accidents are common and cause various kinds of injuries including fractures. Some previous reports have

described bicycle-associated injuries in recreation or sport. Kronisch et al. suggested that the risk of injury is greater for women than men in off-road bicycle racing [1]. Fractures in cyclists from recreation or sports were found to be common in the upper part of the body, and the most common location was the clavicle [1–4]. Others reported injuries of cyclists who were not designated to a specific purpose, such as sports or recreation. These reports have shown that children and adolescents of 11–15 years or 5–14 years had a peak incidence of bicycle-related injuries and the injury rate of women was lower than men [5–9]. With regard to fracture locations, Grundill et al. reported that 64% of fractures overall involved the upper limbs and 22% involved the clavicle in cyclists [5]. Sgaglione et al. reported that the sites of injury were the upper extremities (38%), the lower extremities (26%), the trunk (11%), and head/face (25%), and that fractures constituted 12% of all the reported injuries in cyclists including recreation, transportation, and competition [10].

In our city of a developed country, bicycles are used widely by men and women of all ages, including the elderly, as a

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means of transportation. We built three hypotheses about cyclists' fractures. The first hypothesis is that the elderly cyclists' fractures are not as rare as previously described because the elderly still ride bicycles with a risk of fractures due to osteoporosis or physical disability. The second hypothesis is that cyclists' fractures in women are not as rare as previously described because women also ride bicycles in their daily lives and osteoporosis is more common in women. The third hypothesis is that if cyclists' fractures in the elderly are not uncommon, lower extremity fractures may be more frequent than previously described due to osteoporosis or physical disability. We documented the distribution by gender, age, and fracture location of fresh traumatic fractures treated in our hospital during a 3-year period, categorizing them according to whether they occurred in cyclists or in non-cyclists. We compared the results between these two fracture categories and described features of the fractures in elderly cyclists.

Materials and methods

This study was conducted at one hospital. The hospital was in a residential area of an urban city in a developed country, and most patients lived in a residential area less than 5 km from the hospital. This area belonged to a "densely inhabited district," which is recognized by the government. The population density of the "densely inhabited district" in our city was 10,849.8 people/km^2. The population pyramid of our city was barrel-shaped, and the proportion of people over 60 years old was 23% of the whole population (Supplementary material 1).

We investigated patients who were treated in the department of orthopedic surgery in our hospital. Patients with head or facial trauma were excluded from this study. From a retrospective search of patient records, we collected medical records of all patients whose diagnoses included "fracture" in the recent 3 years. 1950 diagnoses including the word "fracture" were collected. We tabulated patient gender, the location of fractures, and the cause of injury in each medical record, and we identified which cases involved fresh fractures caused by definite trauma. We excluded cases without definite fractures, for example, cases suspected of fractures or bone bruise in magnetic resonance imaging. Both old fractures which occurred more than a month before the first visit to our clinic and pathological fractures with other background factors causing fractures were also excluded.

In some cases, one fracture was recorded with multiple diagnoses. We counted these diagnoses as one diagnosis. Multiple fractures in the same area, such as the distal radius and distal ulna, the thoracic body and lumbar body, the distal fibula and distal tibia, the metacarpus and hamate, fractures of fingers side by side, diaphysis of the fibula and tibia, distal end of the clavicle and coracoid, the cervical body and thoracic body, were also counted as one fracture. In total, 1036 fractures in 1004 patients were identified as fresh traumatic fractures. They included 488 fractures in 470 men and 548 fractures in 534 women, with a mean age of 59 years (range, 1 to 100 years). A summary of the patient selection process was shown in Supplementary material 2.

From their medical records, the set of fractures due to bicycle accidents was identified. All the accidents occurred on roads in the city area. There were no patients injured in bicycle racing. We picked up fractures in cyclists from fractures due to bicycle accidents. We divided those 1036 fresh traumatic fractures into two groups: fractures in cyclists and fractures in non-cyclists. We described the fractures of cyclists as "cyclists" fractures (CF) and the fractures of non-cyclists as "non-cyclists" fractures (NCF). In CF, we additionally noted whether the cyclists were injured by themselves or with other persons.

We studied the distribution of age, gender, and fracture locations in NCF and CF. For age distribution, we divided the patients into 11 age groups (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, 80–89, 90–99, 100-). For the distribution of fracture location, we categorized fracture locations into three major locations (the trunk, upper extremities, and lower extremities). The trunk was furthermore subdivided into spine, rib, clavicle, pelvis, sternum, or other. In addition, we collected two common fractures, femoral neck fractures and distal radius fractures. The aggregate number of fractures in each age group, gender group, and fracture location was calculated. Furthermore, for each age group, the number and the proportion of fractures in men and women and the number and the proportion of fractures at each location were calculated. We also defined two age divisions, a division under 60 years old (younger division) and the other over 60 years old (older division), and documented the gender proportion and proportion of fractures in each fracture location in each of two age divisions. We compared these data between NCF and CF and performed a statistical analysis. This study was approved by the Ethics Committee of our institution.

Statistics

We used Student's t test to test the difference of the mean age between NCF and CF. We used a Pearson's chi-square test to test the difference in gender proportion, the relationship between fracture location (upper extremity, lower extremity, and trunk) and CF/NCF, and the proportion of each fracture location (upper extremity, lower extremity, and trunk) between NCF and CF. The p values describing the proportion of each fracture location between NCF and CF were corrected with the Bonferroni correction to counteract the problem of multiple comparisons.

Results

There were 106 fractures due to bicycle accidents (10%) among the 1036 fresh traumatic fractures. These included 48 men and 58 women with a mean age of 54.4 years (range, 2 to 86 years). Ninety-eight fractures (93%) occurred in cyclists, which we described as cyclists' fractures (CF), and 8 fractures (8%) occurred in patients except cyclists. Among 98 cyclists' fractures (CF), 71 fractures (72%) occurred without other people involved, 16 fractures (16%) with cars, 6 fractures (6%) with other bicycles, 4 fractures (4%) with motorbikes, and one fracture (1%) with a pedestrian.

The mean and median ages of CF were 54.9 years and 59 years respectively, and they were similar to those of NCF (55.8 years and 62 years) (Table 1). The age distribution of NCF showed the highest peak in the 80–89 year range and the second highest peak in 70–79 years (Fig. 1). In contrast, in CF, the highest peak was in the 60–69-year range and the second highest peak in 40–49 years. Fifty percent of CF occurred in the elderly over 60 years. The proportion of CF/all traumatic fractures in each age group showed the highest peak in 40–49 years and the second highest peak in 60–69 years.

The gender distribution of fractures showed that slightly more than half occurred in women both in NCF and CF (Table 1). We studied the gender proportion in each age group of NCF and CF. In NCF, the proportion of women increased with the increase of age in groups over 30 years (Fig. 2). It was less than 50% in age groups under 50 years and more than 50% in age groups over 50 years. In CF, the proportion was almost 50% in age groups under 50 years, was highest (85%) at 50–59 years, and then decreased as the age groups became older. In groups over 50 years, the gender proportion showed an opposite trend between NCF and CF. We simplified these 10-year age groups into two age divisions, the younger division under 60 years and the older division over 60 years. We compared the gender proportion between NCF and CF both in younger and older age divisions (Table 1). In the younger
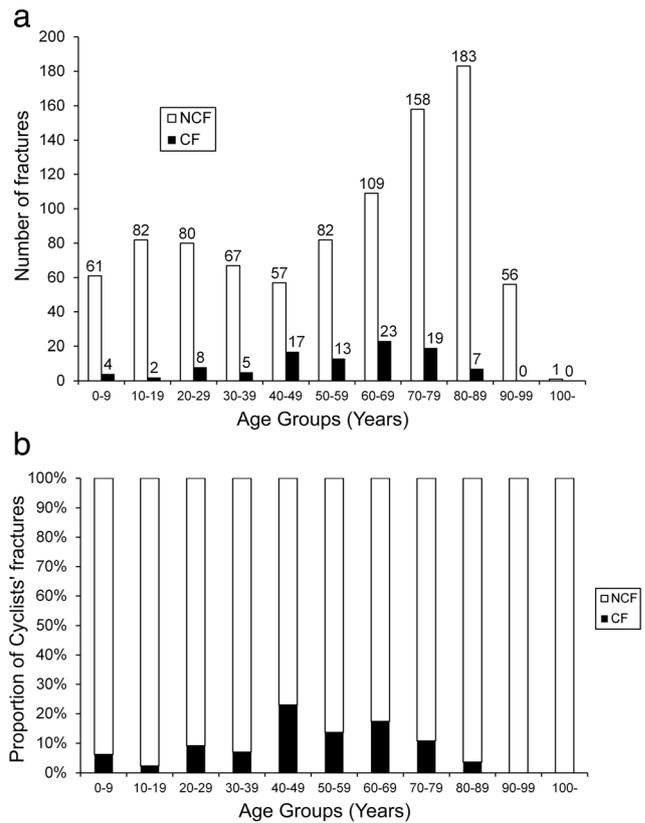

Fig. 1 **a** The number of fractures is shown in each of the 11 age groups. The peak age group in CF was younger than in NCF. **b** The proportion of CF in each age group is shown. The highest peak was seen in the age group of 40–49 years, the second highest in 60–69. The proportion shows high percentage in the middle age groups

division, the proportion of women in CF (57%) was much higher than that in NCF (30%) (χ^2 (1, $N = 480$) = 15.33, $p = 0.0001$). In the older division, the proportion of women in CF (51%) was much lower than that in NCF (72%) (χ^2 (1, $N = 507$) = 9.44, $p = 0.002$).

Table 1 Age and gender distribution of non-cyclists' fractures (NCF) and of cyclists' fractures (CF). The gender proportion was compared between NCF and CF

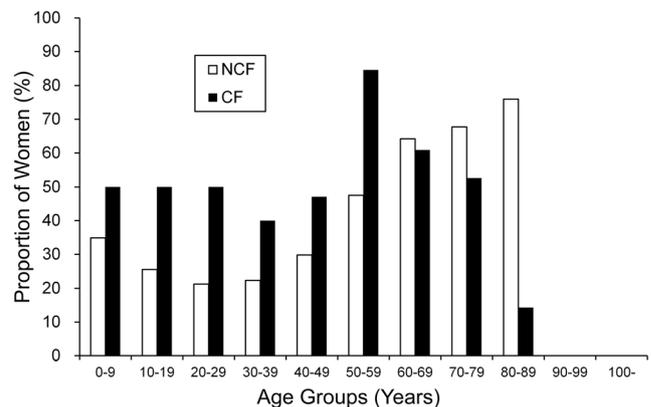|	NCF	CF	p value
Total number	938	98	
Range of age (year)	1–100	2–86	
Mean age (year)	55.8	54.9	1.00
Median age (year)	62	59	
Women	495 (52.8%)	53 (54.1%)	0.80
Total number under 60 years of age	431	49	
Women under 60 years of age	131 (30.4%)	28 (57.1%)	0.0001
Total number over 60 years of age	507	49	
Women over 60 years of age	364 (71.8%)	25 (51.0%)	0.002

Fig. 2 The proportion of women in each age group. In age groups under 60 years, the proportion of women was higher in CF than NCF, and, in age groups over 60 years, the proportion of women was higher in NCF than CF

Distribution of fracture locations showed that fractures were approximately evenly divided between the upper extremities, lower extremities, and trunk, both in NCF and CF (Table 2). No significant relationship between the fracture location of three categories (upper extremities, lower extremities, and trunk) and CF/NCF was detected. We documented the proportion of fractures in each fracture location for each of the 11 age groups (Fig. 3). The proportion of upper extremity fractures in NCF gradually decreased as the age groups became older (Spearman's rank correlation coefficient was − 0.96) (Fig. 3a). The same trend was seen for upper extremity fractures in CF (Spearman's rank correlation coefficient was − 0.86). In CF, the proportion was higher in most age groups under 60 years and lower in most age groups over 60 years than in NCF. The proportion of lower extremity fractures gradually increased as the age groups became older both in NCF and CF (with an exception in the under-10 age group in CF) (Fig. 3b). In NCF, Spearman's rank correlation coefficient was 0.92. In CF, when the > 10 age group and < 90 age group were excluded, Spearman's rank correlation coefficient was 0.95. Compared with NCF, the proportion of lower extremity fractures in CF was lower in age groups from 10 to 19 years through 50–59 years and higher in age groups from 60 to 69 years through 80–89 years.

Then we compared the proportion of the fractures in upper extremities, lower extremities, or trunk between NCF and CF both in the younger division and the older division (Table 3). In the older division, we found a significant relationship between the fracture location of three categories (upper extremities, lower extremities, and trunk) and CF/NCF (χ^2 (2, $N = 556$) = 6.41, $p = 0.04$). No significant difference was found in the proportion of upper extremity fractures in the younger division between NCF and CF. In contrast, the proportion of upper extremity fractures in the older division was significantly lower in CF than in NCF (χ^2 (1, $N = 556$) = 5.74, $p = 0.049$).

Table 2 The number of fractures in each location among NCF and among CF. The proportion of fractures in each location was compared between NCF and CF

Fracture location		NCF (N=938)	CF (N=98)	p-Value
Upper extremities		387 (41%)	33 (34%)	0.44
Lower extremities		307 (33%)	36 (37%)	1.00
Trunk		244 (26%)	29 (30%)	1.00
Trunk	Spine	94 (10%)	5 (5%)	
	Rib	77 (8%)	11 (11%)	
	Clavicle	42 (5%)	9 (9%)	
	Pelvis	15 (2%)	2 (2%)	
	Sternum	10 (1%)	2 (2%)	
	Scapula	6 (1%)	0 (0%)	
Distal radius		97 (10%)	10 (10%)	
Femoral neck		132 (14%)	13 (13%)	

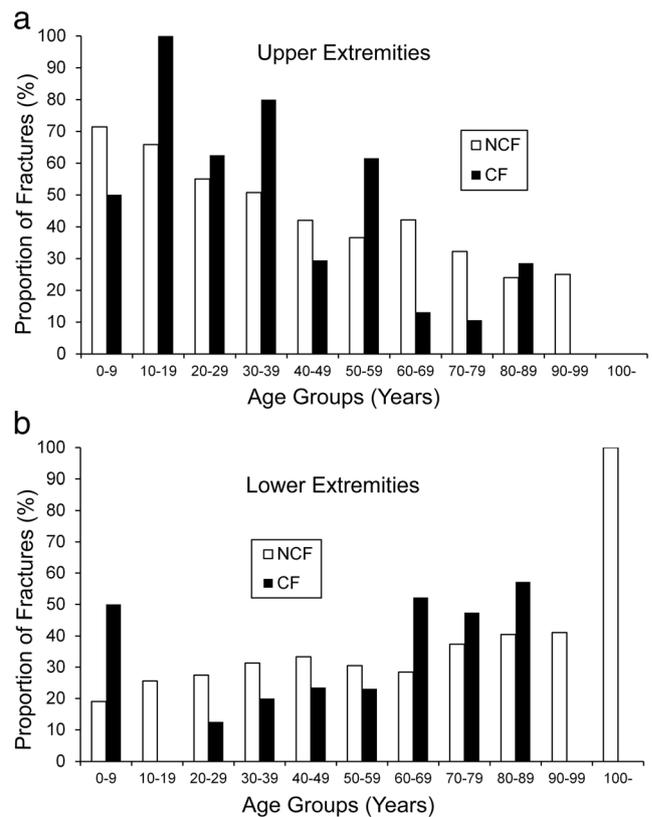**Fig. 3 a** The proportion of upper extremity fractures in NCF gradually decreased as the age groups became older. The same trend was seen for upper extremity fractures in CF. In CF, the ratio was higher in most age groups under 60 years and lower in most age groups over 60 years than in NCF. **b** The proportion of lower extremity fractures gradually increased as the age groups became older both in NCF and CF. Compared with NCF, that proportion was lower in CF for most age groups under 60 years and higher in most age groups over 60 years

Discussion

Our study showed that 93% of fractures due to bicycle-related accidents occurred in cyclists. Among fractures of cyclists, 72% fractures occurred only by cyclists themselves without other persons involved.

CF occurred in the younger population more frequently than NCF. We suggest that this is because the elderly cease to use bicycles because of physical reasons. However, in elderly age groups, there were 23 cyclists' fractures at 60–69 years, 19 at 70–79 years, and 7 at 80–89 years. In the five reports about cyclists for general use, peak incidence of bicycle-related injuries was under 15 years [5–9]. Those reports were from Cape Town, South Africa, in 1984–1985; Calgary, Canada, in 1975; Mikkeli, Finland, in 1980–1981; New Zealand in 1988–2007; and Connecticut, USA, in 1987–1991. In contrast, a report from Shanghai, China, in 2004 showed that age groups of 45–64 years and of 15–44 years had a much higher proportion of bicycle-related injuries than the age group of 0–14 years [11]. Our result was more similar to that from Shanghai. We speculate two reasons for this

Table 3 The number of fractures in each location among NCF and among CF in patients under 60 years and patients over 60 years. The proportion of fractures in each location was compared between NCF and CF

Fracture location		Under 60 years of age			Over 60 years of age		
		NCF (N = 431)	CF (N = 49)	p value	NCF (N = 507)	CF (N = 49)	p value
Upper extremities		231 (54%)	26 (53%)	1.00	155 (31%)	7 (14%)	0.049
Lower extremities		120 (28%)	11 (22%)	1.00	188 (37%)	25 (51%)	0.165
Trunk		80 (19%)	12 (24%)	0.95	164 (32%)	17 (35%)	1.00
Trunk	Spine	16 (4%)	1 (2%)		78 (15%)	4 (8%)	
	Rib	26 (6%)	3 (6%)		51 (10%)	8 (16%)	
	Clavicle	26 (6%)	6 (12%)		16 (3%)	3 (6%)	
	Others	12 (3%)	2 (4%)		20 (4%)	2 (4%)	
Distal radius		35 (8%)	7 (14%)		62 (12%)	3 (6%)	
Femoral neck		7 (2%)	1 (2%)		126 (25%)	12 (25%)	

discrepancy of the age distribution among studied areas. One is the difference of age distribution of cyclists. In our city or Shanghai, the age distribution of cyclists may be much older than in the cities of the other studies. The other is the difference of purposes of cycling. In our area, bicycles are used mostly as a means of transport for all ages, but bicycles might be used mostly as children's recreation in the other cities studied, aside from Shanghai.

Our result showed that the proportion of women in CF was 54%. This differs greatly from the five reports referred above, which showed that the injury rate of women was lower than men, especially in cyclists under 20 [5–9]. However, the report from Shanghai, like our study, showed a higher proportion of women in nonfatal injuries [11]. We speculate two reasons for this discrepancy. One is the difference in the proportion of female cyclists. In our city or Shanghai, the proportion of female cyclists may be much higher than in the other five areas. The other is the difference in the purpose of cycling. In our city, and in Shanghai, bicycles are used mostly as a means of transport both for women and men, but bicycles may be used more frequently for men's recreation or sports in other cities.

When we compared the gender proportion in CF and NCF among patients under 60 years of age, the proportion of women was significantly higher in CF than in NCF (57% vs. 30%, $p = 0.0001$). In each age group under 60 years, the proportion of women was higher in CF than NCF (Fig. 3). This suggests that bicycle riding may pose a great risk of fractures to women under 60 years. We found two reports describing gender difference of bicycle-related injuries in sports or recreation. Kronisch et al. reported the injury rate and fracture rate of women to be higher than those of men ($p = 0.01$ and 0.001) in mountain bike racing [1]. Boeke et al. reported that women required medical assistance more frequently than men during a recreational bicycle tour [2]. In the first report, the age ranged from 15 to 59 years old and, in the latter reports, 87% of participants were under 60 years. These two studies are consistent with our results for cyclists under 60 years. The

first report suggested two possible reasons why the injury rate of women was higher. One reason was gender inferiority of controlling bicycles and lower body mass of women. The other reason was lower bone mineral density in female athletes due to menstrual disturbances. As our study included few athletes, we could not apply the latter reason to our results. Gender inferiority of controlling bicycles and lower body mass of women may be the reasons of higher incidence of fractures in female cyclists. In the age groups over 60 years, the result was reversed. In the older age groups, because osteoporosis is a big background factor of fracture, female cyclists are expected to have a higher risk of fractures. In spite of that, the proportion of women was 51% among fractures in cyclists over 60 years and decreased as the ages increased. One possible reason is that female cyclists may cease to ride bicycles as they become older than 60 or 70 years because they cannot control bicycles. In contrast, male cyclists may continue to ride even after they age over 60 or 70 years and have fractures because of geriatric problems, such as osteoporosis or lower ability to control bicycles.

Previous reports showed that cyclists' fractures were common in the upper part of the body, such as the upper extremities or clavicle [1–5]. In our study, clavicle fractures were also common (9% of the CF compared with 5% of NCF). But the upper extremities were not as common as previously described (34% of the CF compared with 41% of NCF) and this proportion was lower than that of the lower extremities (37%).

In the younger division under 60 years, the proportion of upper extremity fractures was 53% for CF vs 54% for NCF and the proportion of clavicle fractures was 12% for CF vs 6% for NCF. This result suggests that the clavicle and upper extremities were common locations in fractures of cyclists for general use under 60 years of age. One study on the fractures of young cyclists for general use (from 1 to 58 years of age (mean 14.5 years)) showed a similar result: 22% claviclar, 32% radial and/or ulnar, 13% phalangeal, 11% humeral fractures [5]. And also in other reports of cyclists' fractures in sports or recreation, the clavicle and upper extremities were

common locations [1–4]. Aitken et al. reported that there were only 6% lower limb fractures in recreational mountain bike riders but 36% of all the injuries occurred in the lower limbs [3]. This means that less severe injuries other than fractures occur much more frequently in the lower limbs. Boeke et al. suggested that fractures of cyclists in sports or recreation were common above the waistline because of "clipping in" (wearing shoes that attach to the pedal of the bicycle) [2]. Cyclists cannot use their legs for protection and the body above the waistline can be injured without protection. But most cyclists for general use do not use "clipping in." We suggest that the upper part of the body is more susceptible even without "clipping in" because it is higher than the lower part.

Regarding fractures in older cyclists, our study showed that many elderly people ride bicycles for general use and suffered from fractures in accidents. In this group, fractures were more common in the lower extremities and less common in the upper extremities. In patients over 60 years old, lower extremity fractures showed 51% in CF, which was higher than in NCF (37%) ($p = 0.165$), and upper extremity fractures in CF were 14%, which was significantly lower than NCF (31%) ($p = 0.049$). That was contrary to the trend in fractures of young cyclists under 60 years. In both CF and NCF, the proportion of the fractures in the lower extremities increased and that in the upper extremities decreased as the age groups became older. This is probably because of osteoporosis and lower ability of physical response to fall in the elderly. CF showed a steeper increase of the proportion of lower extremity fractures and a steeper decrease of the proportion of upper extremity fractures in accordance with the increase of age. We suggest several reasons why fractures in the lower extremities were common in older cyclists. One reason is osteoporosis. For elderly cyclists, low-energy trauma in the lower extremities causes fractures because of osteoporosis. The second reason is the speed of the bicycle. The speed of bicycle is thought to be slower in elderly cyclists than in young cyclists. When the bicycle falls with high speed, the body falls in front of the bicycle. In such a case, the injury occurs in the upper part of the body because it is difficult to prevent damage with the lower extremities. When the bicycle falls with low speed, the body does not fall in front but to the lateral side of the body. This type of fall has more risk to the injuries in the lower extremities. The third reason is the type of bicycle. Some young cyclists ride sports-type bicycles with a high body position. In such bicycles, the upper part of the body has a higher risk of severe damage. In contrast, elderly cyclists ride bicycles with lower weight center and low body position so that they can touch their feet to the ground while riding on the saddle. In such bicycles, the lower part of the body

has a higher risk of injuries. The fourth reason is that elderly cyclists do not land on their hands during a fall because of a slow response of the body protection. A fall from a bicycle needs more rapid response for protection than a fall from standing or walking.

From these discussions, we speculate that the fractures in young cyclists are caused by high-energy trauma and those in old cyclists are caused by low-energy trauma. Therefore, we have to tell different messages to young and old cyclists for prevention of fractures. To young cyclists under 60 years, we would advise not to ride at high speed, not to use "clipping in," and to ride bicycles with a low body position and low center of mass, enough to use their feet in case of a fall. And to elderly cyclists, we would advise taking extra caution to avoid any kind of fall at all, even at low speed. This is the same policy to prevent hip fractures in the elderly. We would also recommend not riding bicycles to the elderly who cannot control bicycles well.

There are limitations to this study that need to be taken into account. First, we studied the patients in one hospital and did not include all the fractures in one area. If we studied all the patients from multiple centers in one area, the study would be more comprehensive and more valuable. Second, our result may not apply to areas where the population pyramid is triangle-shaped or bell-shaped. The result in the age distribution would be different in these areas.

But even in some of such areas, the proportion of the elderly is expected to be increasing. We speculate that the numbers of female cyclists and cyclists in the elderly will increase in the future and they will be susceptible to bicycle-related injuries. We have to caution the dangerous aspect of bicycle riding not only to men and younger riders but also to women and the elderly to prevent severe injuries due to bicycle accidents.

Compliance with ethical standards

Conflicts of interest   None.

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