

Injuries in Japanese high school basketball players during games and practices

KENJI KUZUHARA¹, MASASHI SHIBATA², JUNTA IGUCHI³

¹ Department of Athletic Training and Conditioning, School of Health and Sport Sciences, Chukyo University, Aichi, JAPAN

² Laboratory of Exercise Science, College of Nursing Art and Science, University of Hyogo, Hyogo, JAPAN

³ Department of Health and Sports Sciences, Faculty of Health and Medical Sciences, Kyoto University of Advanced Science, Kyoto, JAPAN

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Abstract

Problem Statement: Although the second largest population of high school athletes in Japan play basketball, prospective studies of injuries in high school basketball are limited. In junior sports, the same sports are played year-round in Japan. Therefore, it is critical to clarify the actual status of injuries in Japanese high school basketball players, who play the same sports throughout the year, to consider measures to prevent injuries of junior athletes. **Purpose:** This study aimed to prospectively examine the incidence, sites, types, and situations of injuries in Japanese high school basketball players during games and practices during the 2016–17 season. **Approach:** A total of 137 players (boys: 78, girls: 59) belonging to the Hyogo Prefectural High School Basketball Federation participated in this study. Data on all game and practice injuries for the one season were collected using an injury report sheet. Injury rates (IRs) were calculated by sex, injury site, injury type, and injury situations. **Results:** The overall IRs for boys and girls were 4.90/1000 athlete-hours and 2.12/1000 athlete-hours, respectively. The game IRs for boys and girls were 13.73/1000 athlete-hours and 5.94/1000 athlete-hours, respectively. The practice IRs for boys and girls were 3.81/1000 athlete-hours and 1.70/1000 athlete-hours, respectively. The game IRs were significantly higher than the practice IRs for both boys and girls ($p < 0.05$). The game and practice IRs for boys were 2.31 times and 2.24 times higher than those of girls, respectively ($p < 0.05$). Of the injuries, the incidence of lower limb injuries was the highest for both boys (58.3%) and girls (86.7%), with sprains being the most common for both boys (37.6%) and girls (53.7%). Furthermore, heat illness was common in both boys (12.9%) and girls (9.3%). Regarding the situation of injury, injuries caused by body contact were the highest during games for both boys (72.2%) and girls (53.3%), with injuries caused by non-contact being the highest for girls. **Conclusions:** The overall game IR was higher than the overall practice IR. The game IRs were higher than the practice IRs for both boys and girls. A future task is to reduce the game injury rates for boys and girls in high school basketball during the season.

Key Words: - injury rates, junior athletes, epidemiology, periodization, heat illness

Introduction

In 2021, the largest number of Japanese high school athletes (16 to 18 years old) played soccer, approximately 164,000 boys and girls combined, followed by basketball, with approximately 140,000, and badminton, with approximately 125,000 (All Japan High School Athletic Federation). Of the top three sports, soccer and basketball are classified as contact sports involving physical contact, and injury analysis of these sports is considered essential from the viewpoint of injury prevention. However, in Japan, to the best of our knowledge, epidemiological studies of injuries in high school basketball players are very limited, and the only prospective study is that of Oniki et al. (Oniki et al., 2015). Furthermore, there have been very few epidemiological studies of multiple sports injuries, including basketball, in high school, and there are only a few retrospective studies based on questionnaire surveys and past medical records (Kinoshita, Kitagawa, Nagano, Morinaga, & Hiroshima, 2014; Yamaguchi Prefecture Committee of Sports Doctor, 2000). As evidenced by the report of Sunagawa et al. (Sunagawa et al., 2020), even in high school soccer and basketball, which are very popular, injury research is limited. For this reason, in Japan, the actual status of injuries have not been sufficiently examined in sports with many players and in junior development sports. Therefore, in junior high school and high school basketball, sufficient injury prevention measures are not taken during games and practices.

However, internationally, there are many studies of basketball-related injuries of high school athletes (Allen et al., 2019; Borowski, Yard, Fields, & Comstock, 2008; Centers for Disease Control and Prevention, 2006; Clifton, Hertel, et al., 2018; Clifton, Onate, et al., 2018; Gomez, DeLee, & Farney, 1996; Knowles, Marshall, Bowling, et al., 2006; Messina, Farney, & DeLee, 1999; Powell & Barber-Foss, 1999; Randazzo, Nelson, & McKenzie, 2010; Rechel, Yard, & Comstock, 2008; Schroeder et al., 2015; Yde & Nielsen, 1990),

and various injury prevention measures have been implemented (LaBella et al., 2011; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2005; Soligard et al., 2008). In these epidemiological studies, various denominators such as 1000 athlete-hours (AHs) (Gomez et al., 1996; Messina et al., 1999; Yde & Nielsen, 1990), 1000 athlete-exposures (AEs) (Allen et al., 2019; Borowski et al., 2008; Centers for Disease Control and Prevention, 2006; Clifton, Hertel, et al., 2018; Clifton, Onate, et al., 2018; Knowles, Marshall, Bowling, et al., 2006; Powell & Barber-Foss, 1999; Rechel et al., 2008; Schroeder et al., 2015), 1000 population (Randazzo et al., 2010), etc. were used for injury analysis. When comparing injury rates (IRs) with previous studies, it is important to consider using the same denominator.

When using 1000 AEs, which is frequently used in the US, 1 athlete-exposure (AE) is defined as one athlete participating in one game or one practice session (Knowles, Marshall, & Guskiewicz, 2006). The AE excludes real activity time during games and practices. In Japan, the activity time tends to be long in sports, and it is appropriate to use AHs, which includes the activity time to reflect the actual activity as the denominator.

The athletic environment for basketball in middle and high schools in the United States is generally based on a season system (held for four months from November to February or December to March). This is significantly different from the environment in Japan, where the same sports are played year-round. At high schools in Japan, official games are held from April to June (spring regional tournaments, prefectural tournaments), August to October (district qualifiers of the national championship, prefectural qualifiers of the national championship), and November to February (fall district tournaments, regional rookie tournaments, prefectural rookie tournaments, Kansai block tournament) (Figure 1). In addition to official games (about 20 games), many cup and friendly games are held by each basketball team. Therefore, it is critical to clarify the actual status of injuries of Japanese high school basketball players who play the same sports throughout the year to consider measures to prevent injuries in junior athletes.

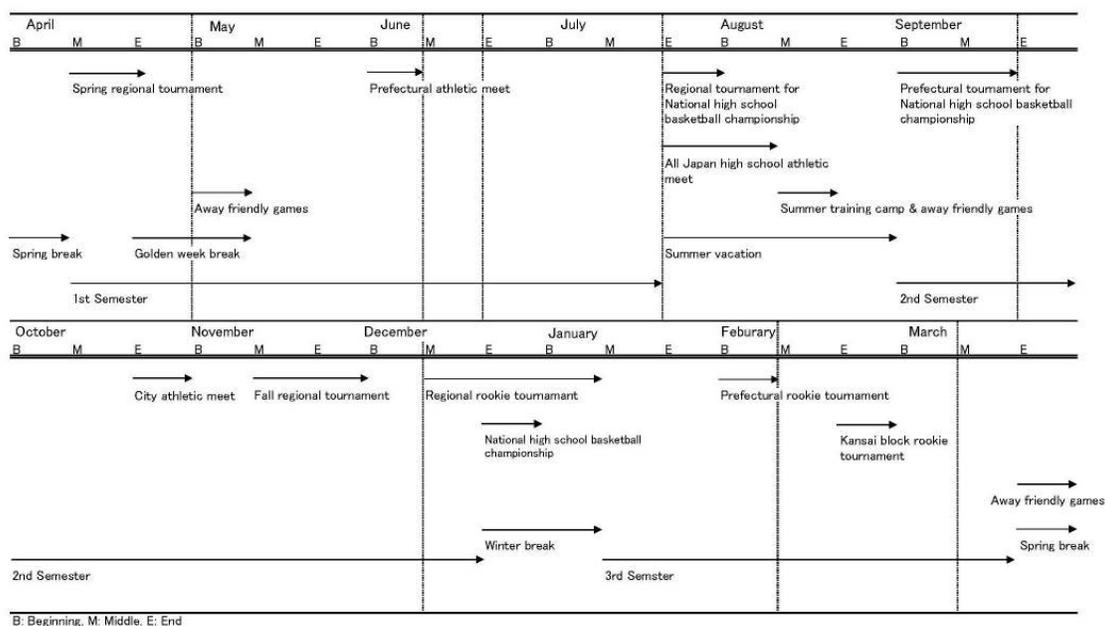


Figure 1. Annual game schedules for high school basketball teams

Therefore, in this study, a prospective study of the occurrence of injuries during games and practices was conducted in high school basketball players during the 2016–17 season using 1000 AHs as the denominator, and sports injuries in boys and girls of this age group were examined. It was hypothesized that the IR of high school basketball players during games is higher than that during practices, and that there is no difference in the IR between boys and girls.

Material and Methods

Participants

A total of 137 players (78 boys, 59 girls) from 6 high school basketball teams (3 boys’ teams and 3 girls’ teams) in Hyogo Prefecture participated in this study. Teams belonging to the Hyogo Prefectural High School Basketball Federation were selected from among boys’ and girls’ teams that were in the best 8 or better in each regional tournament or the best 16 or better in the prefectural tournament.

The average age, height, body weight, and body mass index of the subjects were 16.7 ± 0.9 years, 1.71 ± 0.06 m, 61.6 ± 7.7 kg, and 20.9 ± 1.9 kg/m² for boys, and 16.6 ± 0.9 years, 1.61 ± 0.05 m, 54.9 ± 5.8 kg, and 21.2 ± 1.8 kg/m² for girls, respectively. This study was performed according to the Declaration of Helsinki and was approved by the Ethics Committee of Aichi Toho University (approval No. 28–06, June 16th, 2016). Before participation, each player was informed of the risks and benefits of the study, after which written, informed consent was obtained.

Definition of injury

The definition of injury in this study was any injury that occurred (including a traumatic or overuse injury, and a disease related to sport) as a result of participating in games and practices, including 1) injury resulting in taking a break from or missing one or more team practices or missing a game, 2) injury treated at a medical institution or by alternative medicine after injury, and 3) including head and face injuries (including concussion) even if the injury did not result in missing practices or the game, including one of the above three points (Kuzuhara, Shibata, & Uchida, 2016; Powell & Barber-Foss, 1999). A traumatic injury was defined as an injury caused by an identifiable event (i.e., an injury with sudden onset caused by body contact or other contact with a ball, ground, or other objects). An overuse injury was defined as an injury with gradual onset (i.e., associated with repetitive microtrauma) and without an identifiable responsible event. A recurrent injury was defined as an injury of the same type and at the same site as an index injury that occurred after a player's return to full participation after the initial injury. Illnesses or injuries unrelated to basketball were not included.

Data collection

A full explanation of how to record the team diary and injury record sheet was given to each member of the coaching staff and the student support staff. During one season from April 2016 to March 2017, team diary entries were recorded by the coaching or student support staff after every practice and game, and the coaching or student support staff recorded an injury survey weekly under the supervision of an athletic trainer certified by the National Athletic Trainers' Association-Board of Certification (NATA-BOC).

In the team diary, information about team practices and games (date, place, practice hours, number of games, number of players who participated in each practice and game, etc.) was recorded after every practice and game. Regarding the injury survey, injury date, place of injury, injury area (head and neck, upper limb, trunk and back, lower limb, and others), injury type, and injury situation (body contact, other contact, no contact) were recorded after diagnosis by a physician or alternative medical specialist (Agel et al., 2007; Dick, Hertel, Agel, Grossman, & Marshall, 2007; Kuzuhara et al., 2016; Powell & Barber-Foss, 1999).

As the definition of a game, in addition to official games including the regional tournament, the city tournament and the prefectural tournament, a game was a cup game and a friendly game held between multiple teams. Each team was visited regularly to confirm that the team diary entries were being made and that the injury survey was conducted. Official and cup games usually have four periods of 10 min each, with a half-time of 10 min, and in some cases, 2 to 3 games were held a day. If the game was played in a different format, it was recorded in the team diary each time.

Exposure and incidence of injury

In this study, 1000 AHs, including the activity time of practices and games, were used as the denominator to examine the actual status of injuries during practices and games. One athlete-hour was calculated as when one athlete participates in a game or practice for 1 h. Game AHs were calculated from the total game hours and the number of players who participated in each game, and practice AHs were calculated from the total practice hours and the number of players who participated in each practice (Knowles, Marshall, & Guskiewicz, 2006) (Table 1). The number of injuries that occurred during games and practices was divided by each AH to calculate the IR per 1000 h (game IR, practice IR). A 95% confidence interval (CI) during games and practices was also calculated. The game/practice rate ratio represented the relationship between the game and the practice IRs and was calculated by dividing the game IR by the practice IR with the 95% CI. The boy/girl rate ratio represented the relationship between the boys' IRs and the girls' IRs and was calculated by dividing the boys' IR by the girls' IR with the 95% CI.

Statistical analysis

The χ^2 test was used to compare the number of injuries and their percentages (%). To compare the IRs between games and practices according to injury area, injury type, and injury situation, the game/practice rate ratios and their 95% CIs, and the boy/girl rate ratios and their 95% CIs were calculated. Generally, when the 95% CI includes 1, no significant difference is present at the 5% level, and when the 95% CI does not include 1, a significant difference is present at the 5% level (Albright et al., 2004). Excel Statistics 2015 (version 1.03, Social Survey Research Information, Tokyo, Japan) was used for the data analysis, and the significance level was set at the 5% level in each case.

Table 1. Practice and game athlete-hours in high school basketball teams

Measure	High School Basketball Team								Total
	Boys				Girls				
	A	B	C	Total	D	E	F	Total	
No. of Players	21	25	32	78	14	21	24	59	137
No. of Practice	221	194	141	556	210	192	240	642	1198
Average of Practice Hours	2.7±1.3	2.8±0.8	3.0±1.2	2.8±1.1	2.9±1.2	3.1±0.8	2.8±0.9	2.9±1.0	2.9±1.1
Practice Athlete-Hours, h	7680.5	6270.0	7321.5	21272.0	6781.5	5717.0	10471.0	22969.5	44241.5
No. of Game	89.8	80.3	111.0	281.0	126.0	87.0	91.8	304.8	585.8
Game Athlete-Hours, h	771.7	637.2	1212.9	2621.8	947.0	605.7	970.8	2523.5	5145.3
Total Athlete-Hours, h	8452.2	6907.2	8534.4	23893.8	7728.5	6322.7	11441.8	25493.0	49386.8

h: hours, A B C: Boys teams, D E F: Girls teams

Results

The overall IR was 3.46/1000 AHs. The overall game and practice IRs were 9.91/1000 AHs and 2.71/1000 AHs, respectively. The overall game/practice rate ratio was 3.65 (95%CI: 2.63–5.07); the overall game IR was significantly higher than the overall practice IR (p<0.05, Table 2).

Table 2. Total injury rates in high school basketball teams

Team	Practice				Game				Game/Practice RR (95% CI)	Total			
	N	%	IR (95%CI)	Boy/Girl RR (95%CI)	N	%	IR (95% CI)	Boy/Girl RR (95%CI)		N	%	IR (95% CI)	Boy/Girl RR (95%CI)
Boys	81	67.5	3.81 (2.98–4.64)	2.24 * (1.53–3.29)	36	70.6	13.73 (9.25–18.22)	2.31 * (1.26–4.22)	2.00 * (1.23–3.27)	117	68.4	4.90 (4.01–5.78)	2.31 * (1.67–3.19)
Girls	39	32.5	1.70 (0.57–1.59)		15	29.4	5.94 (2.94–8.95)		3.50 * (1.93–6.35)	54	31.6	2.12 (1.55–2.68)	
Overall	120	100.0	2.71 (2.23–3.20)		51	100.0	9.91 (7.19–12.63)		3.65 * (2.63–5.07)	171	100.0	3.46 (2.94–3.98)	

IR: injury rate, CI: confidence interval, RR: rate ratio
 * significant difference, p < .05

In the comparison between boys and girls, the overall boy/girl rate ratio was 2.31, and boys had significantly higher IRs than girls (p<0.05, Table 2). The boy/girl rate ratios during games and practice were 2.31 and 2.24, respectively, and boys had significantly higher IRs during games and practice than girls (p<0.05, Table 2).

Regarding injury sites, the lower limb was the most common site for boys (N=63, 53.8%) and girls (N=34, 61.1%) overall. Lower limb injury was the most common during games for boys (N=21, 58.3%) and girls (N=13, 86.7%), with the game IR at 8.01/1000 AHs for boys and 4.96/1000 AHs for girls (Table 3). Especially for boys, the head and neck (including face) were commonly injured during games (N=8, 22.2%). Similarly, during practices, the lower limb (boys: N=42, 51.9%, girls: N=21, 53.8%) was the most commonly injured, followed by the upper limb (boys: N=10, 12.3%, girls: N=8, 20.5%) for both boys and girls. Ankle injuries were the most common in boys (N=43, 36.8%) and girls (N=24, 44.4%), followed by face injuries (N=15, 12.8%) and hand and finger injuries (N=12, 10.3%) for boys, followed by knee injuries (N=5, 9.3%) and hand and finger injuries (N=5, 9.3%) for girls.

Table 3. Injuries to anatomical areas in high school basketball teams

Anatomical areas	Practice						Game						Total					
	Boys			Girls			Boys			Girls			Boys			Girls		
	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)
Head & Neck	10	12.3	0.47 (0.18-0.76)	2	5.1	0.09 (-0.04-0.22)	8	22.2	3.05 (0.94-5.17)	0	0.0	0.00	18	15.4	0.75 (0.41-1.10)	2	3.7	0.08 (-0.03-0.20)
Upper Limb	10	12.3	0.47 (0.18-0.76)	8	20.5	0.38 (0.12-0.64)	2	5.6	0.76 (-0.29-1.82)	1	6.7	0.38 (-0.37-1.13)	12	10.3	0.50 (0.44-0.56)	9	16.7	0.38 (0.33-0.43)
Trunk & Back	5	6.2	0.24 (0.03-0.44)	3	7.7	0.14 (-0.02-0.30)	4	11.1	1.53 (0.03-3.02)	1	6.7	0.38 (-0.37-1.13)	9	7.7	0.38 (0.13-0.62)	4	7.4	0.17 (0.00-0.33)
Lower Limb	42	51.9	1.97 (1.38-2.57)	21	53.8	0.99 (0.56-1.41)	21	58.3	8.01 (4.58-11.44)	13	86.7	4.96 (2.26-7.65)	63	53.8	2.64 (1.99-3.29)	34	61.1	1.38 (0.91-1.85)
Others	14	17.3	0.66 (0.31-1.00)	5	12.8	0.24 (0.03-0.44)	1	2.8	0.38 (-0.37-1.13)	0	0.0	0.00	15	12.8	0.63 (0.31-0.95)	5	11.1	0.25 (0.05-0.45)

Sprains were the most common injuries in boys (N=44, 37.6%) and girls (N=29, 53.7%), followed by contusions in boys (N=26, 22.2%) and fractures in girls (N=5, 9.3%) (Table 4). Additionally, heat illness was very common in both boys (N=14, 12.0%) and girls (N=5, 9.3%). With reference to the weather station data (All Japan High School Athletic Federation; Japan Meteorological Agency) of the area where each team belonged, the average temperature, maximum temperature, average humidity, and wet bulb globe temperature (WBGT) on the day when heat illness occurred was 26.8±2.6 °C, 30.5±3.1 °C, 68.9±11.6%, and 27.6±2.6 °C, respectively (Table 5).

Table 4. Injuries to injury types in high school basketball teams

Injury Types	Practice						Game						Total					
	Boys			Girls			Boys			Girls			Boys			Girls		
	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)
Sprain	30	37.0	1.41 (0.91-1.91)	17	43.6	0.80 (0.42-1.18)	14	38.9	5.34 (2.54-8.14)	12	80.0	4.58 (1.99-7.17)	44	37.6	1.84 (1.30-2.39)	29	53.7	1.21 (0.77-1.66)
Contusion	13	16.0	0.61 (0.28-0.94)	1	2.6	0.05 (-0.05-0.14)	13	36.1	4.96 (2.26-7.65)	0	0.0	0.00	26	22.2	1.09 (0.67-1.51)	1	1.9	0.04 (-0.04-0.12)
Inflammation	10	12.3	0.47 (0.18-0.76)	3	7.7	0.14 (-0.02-0.30)	3	8.3	1.14 (-0.15-2.44)	1	6.7	0.38 (-0.37-1.13)	13	11.1	0.54 (0.25-0.84)	4	7.4	0.17 (0.00-0.33)
Wounds	7	8.6	0.33 (0.09-0.57)	1	2.6	0.05 (-0.05-0.14)	3	8.3	1.14 (-0.15-2.44)	0	0.0	0.00	10	8.5	0.42 (0.16-0.68)	1	1.9	0.04 (-0.04-0.12)
Fracture	4	4.9	0.19 (0.00-0.37)	5	12.8	0.24 (0.03-0.44)	0	0.0	0.00	0	0.0	0.00	4	3.4	0.17 (0.00-0.33)	5	9.3	0.21 (0.03-0.39)
Strain	3	3.7	0.14 (-0.02-0.30)	3	7.7	0.14 (-0.02-0.30)	0	0.0	0.00	1	6.7	0.38 (-0.37-1.13)	3	2.6	0.13 (0.10-0.15)	4	7.4	0.17 (0.13-0.20)
Concussion	0	0.0	0.00	0	0.0	0.00	1	2.8	0.38 (-0.37-1.13)	0	0.0	0.00	1	0.9	0.04 (-0.04-0.12)	0	0.0	0.00
Dislocation/ subluxation	0	0.0	0.00	1	2.6	0.05 (-0.05-0.14)	0	0.0	0.00	1	6.7	0.38 (-0.37-1.13)	0	0.0	0.00	2	3.7	0.08 (-0.03-0.20)
Heat illness	13	16.0	0.61 (0.28-0.94)	5	12.8	0.24 (0.03-0.44)	1	2.8	0.38 (-0.37-1.13)	0	0.0	0.00	14	12.0	0.59 (0.28-0.89)	5	9.3	0.21 (0.03-0.39)
Others	1	1.2	0.05 (-0.05-0.14)	3	7.7	0.14 (-0.02-0.30)	1	2.8	0.38 (-0.37-1.13)	0	0.0	0.00	2	1.7	0.08 (-0.03-0.20)	3	5.6	0.13 (-0.02-0.27)

Table 5. Weather conditions at the time of heat illness in high school basketball players

Date	Mean temperature (°C)	Highest temperature (°C)	Mean humidity (%)	WGBT (°C)	
May	21	22.4	28.2	56	
	27	23.6	28.1	63	
		23.6	28.1	63	
June	19	22.4	24.8	83	
	22	24.6	27.2	86	
July	7	28.5	32.2	72	
		28.5	32.2	72	
		28.5	32.2	72	
	8	26.6	29.4	79	
		26	25.8	27.2	85
		27	27.4	30.1	78
August	4	29.5	33.8	68	
		10	29.2	34.4	54
		29.2	34.4	54	
	11	29.1	33.1	49	
		20	31.2	36.3	61
September	1	27.0	31.2	56	
	17	27.6	30.0	73	
	22	23.8	26.4	85	
Mean	26.8	30.5	68.9	27.6	
SD	2.6	3.1	11.6	2.6	

Regarding injury situations, body contact was the most common during games (N=26, 72.2%) and practices (N=28, 34.6%) for boys (Table 6). For girls, body contact was the most common during games (N=8, 53.3%), whereas during practice, body contact (N=14, 35.9%) and no contact (N=14, 35.9%) were similar.

Table 6. Injuries to injury situations in high school basketball teams

Injury Situations	Practice						Game						Total					
	Boys			Girls			Boys			Girls			Boys			Girls		
	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)	N	%	IR (95%CI)
Body Contact	28	34.6	1.32 (0.83-1.80)	14	35.9	0.66 (0.31-1.00)	26	72.2	9.92 (6.10-13.73)	8	53.3	3.05 (0.94-5.17)	54	46.2	2.26 (1.66-2.86)	22	40.7	0.92 (0.54-1.31)
Other Contact	8	9.9	0.38 (0.12-0.64)	5	12.8	0.24 (0.03-0.44)	3	8.3	1.14 (-0.15-2.44)	1	6.7	0.38 (-0.37-1.13)	11	9.4	0.46 (0.40-0.52)	6	11.1	0.25 (0.21-0.29)
No Contact	18	22.2	0.85 (0.46-1.24)	14	35.9	0.66 (0.31-1.00)	4	11.1	1.53 (0.03-3.02)	6	40.0	2.29 (0.46-4.12)	22	18.8	0.92 (0.54-1.31)	20	37.0	0.84 (0.47-1.20)
Others or Unknown	27	33.3	1.27 (0.79-1.75)	6	15.4	0.28 (0.06-0.51)	3	8.3	1.14 (-0.15-2.44)	0	0.0	0.00	30	25.6	1.26 (0.81-1.70)	6	11.1	0.25 (0.05-0.45)

* Body Contact: contact with players
 * Other contact: contact with ball, floor, or other objects

Discussion

Incidence of injury

This was a prospective study of injuries in high school basketball players (16 to 18 years old) using 1000 AHs as the denominator. It was found that the overall game IR (9.91/1000 AHs) was significantly higher than the overall practice IR (2.71/1000 AHs). Regarding the incidence of injuries by sex, the game IRs for boys (13.73/1000 AHs) and for girls (5.94/1000 AHs) were higher than the practice IRs for boys (3.81/1000 AHs) and for girls (1.70/1000 AHs). This result is consistent with the results of previous studies of elementary school age (Kuzuhara et al., 2016) and youth age groups from junior high school to high school (Gomez et al., 1996; Kuzuhara, Shibata, & Iguchi, 2019; Messina et al., 1999; Yde & Nielsen, 1990) and supports the hypothesis that the IR of high school basketball players during games is higher than that during practices. Therefore, it was

demonstrated that the injury rate in basketball with 1000 AHs as the denominator is higher during games than during practices, regardless of age category (elementary school age to high school age).

Regarding the sex comparison of the overall IR including games and practices, the overall IR of boys was 2.31 times higher than that of girls, significantly higher for boys than for girls. This result is consistent with a study of high school players by Knowles et al. (Knowles, Marshall, Bowling, et al., 2006). Therefore, the hypothesis that there is no difference in IRs between boys and girls in high school basketball players was not supported by the results of the present study. According to previous studies that compared the sex differences in IRs in basketball in this age category, some studies found a higher IR for girls than for boys (Borowski et al., 2008; Rechel et al., 2008), whereas some studies found no sex difference (Centers for Disease Control and Prevention, 2006; Messina et al., 1999; Yde & Nielsen, 1990). Based on these findings, no consensus was found regarding sex differences in IR. However, Knowles et al. (Knowles, Marshall, Bowling, et al., 2006) indicated that sex (male) and injury history are strongly associated with the incidence of injury as internal risk factors. In the present study, it was possible that the male sex factor might have affected the IRs. A study by Randazzo et al. (Randazzo et al., 2010) also reported that the number of basketball-related injuries peaked in boys aged 15 to 17 years old, with boys having more injuries than girls. This research pointed out that the physical development of male athletes in this age category is very advanced, and that the larger body size may have increased muscle strength and speed, which may have led to a higher IR (Randazzo et al., 2010). From these findings, it was inferred that the physical development of boys of high school age might result in a higher IR for boys than for girls.

The number of practice sessions (141–240 times) and the number of games (80.3–126.0 games) per year in the teams of this study showed that they played basketball frequently throughout the year. According to a report (Sasagawa Sports Foundation, 2017) that investigated club activities in Japanese junior and high schools, 60.8% of basketball clubs played 5.7 days a week on average. The activity status of the teams in this study was considered average. However, considering the actual number of practices and games per year, it is difficult to determine whether this environment is appropriate for junior athletes. A harmful effect of playing the same sport too often is overtraining, which in addition to the associated overuse injuries, leads to depression, burnout, and dropout (Kuzuhara & Shibata, 2013). Looking at the annual number of practice sessions and the number of games of the teams in the present study, high school athletes play basketball for a long period throughout the year. Calculating the activity period from the number of practices, the period is equivalent to about 6 to 10 months. This is very different from the environment for basketball in middle and high schools in the United States. In the United States, sports are played over four months, from November or December to February or March, according to the sports season system. It may be difficult to fundamentally solve the problem of injuries caused by continuing the same sport for a long period unless there is a change in how Japanese basketball organizations for high schools manage district, prefectural, and national tournaments or championships throughout the year (Figure 1). However, the team management in Japanese high school basketball teams should be improved by introducing an appropriate rest period and periodization so that junior players of this age category can rest physically and mentally.

Injury sites and injury types

The most common site of injury in the present study was the lower limb (boys: 53.8%, girls: 61.1%). This result is consistent with previous studies of US middle school, high school, and college basketball (Agel et al., 2007; Gomez et al., 1996; Hootman, Dick, & Agel, 2007; Messina et al., 1999; Powell & Barber-Foss, 1999; Randazzo et al., 2010). Preventive measures for lower limb injuries, particularly ankle injuries, are essential for junior high school and high school basketball players. In this study, since the foot and ankle joints were the most frequently injured, the introduction of the 11+ program (Bollars et al., 2014; Silvers-Granelli et al., 2015; Soligard et al., 2008) and the implementation of a neuromuscular training program (LaBella et al., 2011; Olsen et al., 2005) should be considered to prevent lower limb injuries.

Lower limb injuries (boys: 58.3%, girls: 86.7%) were also the most common during games. This result is consistent with the results of previous studies in the United States (high school: 60.0-69.0%, college: 57.9-60.8%) (Agel et al., 2007; Dick et al., 2007; Messina et al., 1999; Rechel et al., 2008). The second common site of injury for boys was the head and neck (including face) (22.2%). This is different from previous studies in US high schools (upper limb: 14.8-16.0%) (Gomez et al., 1996; Messina et al., 1999; Rechel et al., 2008) and colleges (upper limb: 14.1%) (Dick et al., 2007). In male athletes of high school age, the peak height velocity is reached at around 11 to 15 years of age, so there are marked individual differences in growth and development between junior high school and high school students. This individual difference in growth and development may have affected injuries to the head and neck (including the face), especially injuries to the face.

Regarding injury types, sprains (boys: 37.6%, girls: 53.7%) were the most common of all injuries, followed by contusions (22.2%) for boys and fractures (9.3%) for girls. These results showed different trends from a previous study (boys and girls: sprains 43.6%-44.5%, strains 15.8%-19.4%) (Borowski et al., 2008) and other studies (boys and girls: sprains 44.8%-56.0%, contusions 15.0%-24.8%) (Messina et al., 1999; Powell & Barber-Foss, 1999). However, it is a common view that sprains are the most frequent injuries for both boys and girls during games and practices in basketball. In this study, there were many sprains of hand/finger and ankle

 joints for both boys and girls; therefore, in the future, injury prevention measures such as improving injury avoidance skills when landing, jumping, and falling, ball handling skills with movement, and balance ability should be recommended.

Heat illness (12.0% for boys and 9.3% for girls) occurred frequently in both boys and girls. A total of 19 cases of heat illness occurred from the end of May to the end of September. The average maximal temperature and average humidity on the days that these events occurred were 30.5°C and 68.9%, respectively. In particular, from July (6 cases) to August (5 cases), when heat illness occurred frequently, the average WBGT was 29.3±1.5°C, and the danger level for heat illness (WBGT of 28.0°C or higher) was observed (Ministry_of_the_Environment). To avoid the risk of heat illness, it is necessary to review team practices during the period from July to August. For example, it is necessary to consider shortening the practice time, changing the practice time zone, or considering this period part of the off-season.

Injury situations

Regarding injury situations, injuries caused by body contact (boys: 72.2%, girls: 53.3%) were the most common during games, followed by no contact injuries (boys: 11.1%, girls: 40.0%). This is similar to previous studies in college basketball (body contact during games: 52.3% for males, 46.0% for females) (Agel et al., 2007; Dick et al., 2007) and in elementary school mini-basketball (body contact during games: 45.5%) (Kuzuhara et al., 2016). Therefore, even if the age and competitive level are different, the frequency of body contact may have increased because basketball players were more aggressive in offense and defense during games.

During practices, body contact (34.6%) was the most common for boys, whereas body contact and no contact (35.9%, respectively) were equally the most common for girls. This showed a trend similar to previous studies of college basketball (males: 43.6% physical contact during practice, females: 47.0% no contact during practice) (Agel et al., 2007; Dick et al., 2007). However, it is different from previous studies (Kuzuhara et al., 2019; Kuzuhara et al., 2016) of junior high school basketball (boys: 33.3% for other contact such as a ball, floor and other objects, girls: 41.2% for body contact) and elementary school mini-basketball (56.5% for other contact such as a ball, floor, and other objects). Therefore, further epidemiological studies of junior basketball athletes are considered necessary.

Limitations

In Japanese high school sports, there are no surveillance systems that collect as much injury data as in the United States (Dompier, Marshall, Kerr, & Hayden, 2015; Kerr et al., 2015; Lam, Valier, Anderson, & McLeod, 2016; Powell & Barber-Foss, 1999). Additionally, in Japanese high schools, only coaching staff such as head and assistant coaches accompany the team, but there are almost no professional medical staff such as certified athletic trainers or physiotherapists, except for some private high schools. Therefore, the collection of detailed data related to injury surveys (injury severity, injury mechanism, recovery period, internal factors of individual athletes, etc.) is limited. It was necessary to visit each team regularly to ensure the reliability of the injury data. Therefore, the number of teams surveyed in this study was restricted. Injury analyses of 137 players from six high school basketball teams were performed. In the future, it will be necessary to accumulate data by increasing the number of basketball teams and other junior sports.

Conclusions

This study is one of the few prospective studies in which injuries of high school basketball players in Japan were investigated. The overall game IR was higher than the overall practice IR. In the comparison between boys and girls, boys had significantly higher IRs during games and practice than girls.

Regarding injury sites, the lower limb was the most common site for boys and girls overall. Lower limb injury was the most common during games for boys and girls. Especially for boys, the head and neck (including face) were commonly injured during games. Similarly, during practices, the lower limb was the most commonly injured, followed by the upper limb for both boys and girls. Ankle injuries were the most common in boys and girls, followed by face injuries and hand and finger injuries for boys, followed by knee injuries and hand and finger injuries for girls.

Sprains were the most common injuries in boys and girls, followed by contusions in boys and fractures in girls. In addition, heat illness was common in both boys and girls.

Regarding the situations of injury, injuries caused by body contact were the highest during games for both boys and girls, with injuries caused by non-contact being the highest for girls. A future task is to reduce the game IRs for boys and girls in high school basketball during the season.

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Conflicts of interest - There is no conflict of interest.

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