BMJ Open

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based comparison between the Rio 2016 and Tokyo 2020 games

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-060937
Article Type:	Original research
Date Submitted by the Author:	12-Jan-2022

Complete List of Authors:	FUKUI, KAZUKI; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Maeda, Noriaki; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Sasadai, Junpei; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Shimizu, Reia; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Tsutsumi, Shogo; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Arima, Satoshi; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Tashiro, Tsubasa; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Kaneda, Kazuki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Yoshimi, Mitsuhiro; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Mizuta, Rami; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Abekura, Takeru; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Esaki, Hinata; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Terada, Tomoki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Komiya, Makoto; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Suzuki, Akira; Sports Medical Center, Japan Institute of Sports Sciences

	(JISS) Urabe, Yukio; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation
Keywords:	SPORTS MEDICINE, REHABILITATION MEDICINE, ORTHOPAEDIC & TRAUMA SURGERY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based comparison between the Rio 2016 and Tokyo 2020 games

Authors

Kazuki Fukui[1], Noriaki Maeda[1], Junpei Sasadai[2], Reia Shimizu[2], Shogo Tsutsumi[1], Satoshi Arima[1], Tsubasa Tashiro[1], Kazuki Kaneda[1], Mitsuhiro Yoshimi[1], Rami Mizuta[1], Takeru Abekura[1], Hinata Esaki[1], Tomoki Terada[1], Makoto Komiya[1], Akira Suzuki[2], Yukio Urabe[1]

Affiliations

[1]Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

[2]Sports Medical Center, Japan Institute of Sports Sciences (JISS), 3-15-1 Nishigaoka Kita-ku, Tokyo, 115-0056, Japan

Corresponding author

Yukio Urabe

Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

E-mail address: yurabe@hiroshima-u.ac.jp

Word count

3471 words

ABSTRACT

Objectives

To identify the fall characteristics of athletes in wheelchair rugby and wheelchair basketball during the Tokyo 2020 Paralympic Games and compare these with those of the Rio 2016 Paralympic Games.

Design

Cross-sectional analysis

Primary and secondary outcome measures

We obtained video footage from the International Paralympic Committee of the Tokyo 2020 Paralympic Games that included 8 teams from each of the 18 wheelchair rugby and 10 wheelchair basketball games (men and women). The data were analyzed to evaluate the number of falls, class difference (low or high pointer), time of play during the fall, phase of play, contact with other athletes, fall direction, fall location, and the body part that first contacted the floor during the fall. These data from the Rio 2016 and Tokyo 2020 games were compared.

Results

Overall, 430 falls (rugby, 104; men's basketball, 230; and women's basketball, 96) occurred (average per game: 5.8, 23.0, and 9.6, respectively). Significant differences were observed among the three sports regarding the class, direction, fall location, and body part point of contact. In wheelchair rugby, falls occurred mainly in high-pointers and tended to be more lateral due to contact. In wheelchair basketball, falls occurred more in female high-pointers and in male low-pointers, with more forward falls due to forward contact. Unlike in the Rio 2016 games, no difference between the events based on the presence or absence of contact was observed in the Tokyo 2020 games.

Conclusions

The number of falls increased in Tokyo 2020 compared to Rio 2016, with no significant difference in the characteristics of falls between the Rio 2016 and Tokyo 2020 games. Only in men's wheelchair basketball, the number of falls in low pointers significantly increased in the Tokyo 2020 games when compared to that in the Rio 2016 games.

Strengths and limitations of this study

- This is the first study to characterize the falls of athletes in wheelchair team sports using data from the Rio 2016 and Tokyo 2020 Games.
- Injuries caused by the wheelchair falls in the videos were not identified.
- To clarify the relationship between falls and injuries, further analysis of the factors that causes falls should be combined and compared with survey data on injuries.

INTRODUCTION

The Tokyo 2020 Paralympic Games featured 4403 athletes competing in 539 events in 22 sports, making it the largest Paralympic Games in history and drawing increasing attention to the Paralympic Games. Hence, with the increase in the number of athletes, the level of competition is expected to improve, and sports injuries are also expected to increase[1]. A total of 441 athletes sustained as many as 510 injuries during the 14 days of competition at the Rio 2016 Paralympics, with 61 athletes injured during their participation in wheelchair rugby (WR) and wheelchair basketball (WB); this translated to 14.9 and 12.8 injuries per 1000 athlete days, respectively [2]. Furthermore, contact team sports such as WR and WB have a higher incidence of acute injuries than fencing and tennis (61%, 65%, and 42%, 37%, respectively)[3]. In these two wheelchair team sports, many falls commonly occur. Regarding the incidence of falls at the Rio 2016 Paralympics, 359 falls occurred in three disciplines (WR, men's WB, and women's WB). The rate of falls was the highest for MWB, followed by WWB and WR[4]. However, no other study has clarified the characteristics of falls in each sport. Moreover, the relationship between sports injury characteristics and the occurrence of falls in wheelchair team sports has not yet been presented. In the case of wheelchair sports, falls can result in head impacts and emergencies such as concussions, and research in the area of concussions has received increasing attention[5,6]. Therefore, understanding the causes of falls during games is essential in considering the prevention of injury occurrence in these team sports, and more data needs to be collected. One way to analyze the occurrence of falls in wheelchair-related sports is to use video recordings of games.

By retrospectively analyzing the video recordings of the games, which is an effective method that has been used previously to interpret injury occurrence in healthy individuals,[7-9] the occurrence and characteristics of these wheelchair-related sport injuries can be identified. The analysis of anterior cruciate ligament injuries helped researchers to understand the change of dynamic alignment during injury and plan preventive measures,[7] which is why we used this method to investigate the incidence of falls in WR and WB games at the Rio 2016 Paralympic Games[4].

WR and WB players also include individuals with quadriplegia, paraplegia, and amputations. Overall, WR players have more severe functional impairments than WB players, especially those affecting the extremities, such as cervical spinal cord injury (tetraplegia), multiple amputations, polio, cerebral palsy, and other neurological diseases[10]. WR players are classified based on their hand, arm, shoulder, and trunk functions, with disability levels ranging from 0.5 (lowest physical function) to 3.5(highest physical function), and are placed into seven categories based on their level of disability[11]. WB players must

have a permanent physical disability with reduced function of the lower extremities, which includes paralysis of the lower extremities, musculoskeletal disorders, spina bifida, amputation, and childhood paralysis[11]. These athletes are classified from 1.0 (lowest physical function) to 4.5 (highest physical function)[12]. Performance and injury rates vary greatly by class[13,14], and fall rates are expected to vary as well. However, no analysis of fall incidence by class has been reported.

At the Rio 2016 Paralympics, the incidence of falls and the duration of competition, the presence of contact, the direction of the fall, and the initial site of contact had different characteristics in the three events[4]. Meanwhile, we have not been able to clarify the incidence of falls for each class. In addition, five years have passed since the Rio 2016 Paralympics, and the incidence of falls is expected to be different due to the improvement of athletic performance. Moreover, the Tokyo 2020 Paralympics was held under special circumstances, with the games being postponed for one year due to the COVID-19 pandemic. Therefore, new characteristics of fall occurrence different from those of the Rio 2016 Paralympics may emerge, and accumulation of data will be crucial for injury prevention. This study aimed to investigate the number of falls and the occurrence of falls among wheelchair athletes in team sports at the 2020 Tokyo Paralympic Games, to compare the results with those at the 2016 Rio Paralympic Games, and to clarify the characteristics of major falls among the three major wheelchair team sports (WR, MWB, and W WB).

METHODS

In this cross-sectional video analysis, we obtained the official match videos of the WR and WB wheelchair team competitions from the IPC's official website, and analyzed the match videos of all eight teams participating in the WR and eight teams each from the MWB and WWB that advanced to the quarterfinals of the Tokyo 2020 Paralympic Games (Fig. 1). The WR matches are played in four 8-minute periods, and the WB matches are played in four 10-minute periods. Three physiotherapists with expertise in para-sports systematically analyzed the videos for fall mechanism and play circumstances. The videos were repeated as needed and displayed at normal speed, slow speed, or in still images. To record the number of falls, duration of play at the time of the fall, phase of play (offense or defense), contact with another player, direction of the fall, location of the fall (backcourt, frontcourt, or key or paint area), and the body part that first made contact with the floor, we modified a standard form similar to the one used in previous video analyses[4,15]. In order to record all falls, contact with the floor was considered to be necessary. Additionally, the fall data obtained from the IPC official website of the Rio 2016 Paralympic Games and used in our previous study, from a total of 18 WR and 10 WB match videos of men (MWB) and women (WWB), including eight teams in one event, were also used in this analysis[4].

Data regarding player information (age, sex, and functional classification) were used from the IPC website (Table 1). Regarding disability classification, based on previous studies, for WR, ≥2.0 were classified as high pointer and ≤1.5 and below as low pointer[16]; for WB, ≥3.0 were classified as high pointer and ≤2.5 as low pointer[17].

Statistical analysis

For all categorical variables, results that were consistent with the ratings of two out of three observers were reported. A good agreement among the three observers for all variables was considered when two or more observers were in agreement for all categorical items and the kappa coefficient was >0.8. A one-way analysis of variance was used to compare the mean incidence of falls for each of the three wheelchair sports games. Follow-up analyses were conducted using Bonferroni's post hoc test, if necessary. For the comparison of categorical variables, Pearson's X^2 test or Fisher's exact test was used. The Fisher's exact test was used instead of the X^2 test when the expected number was <5. All statistical analyses were performed using IBM SPSS version 27.0 (IBM japan, Tokyo, Japan). A p-value <0.05 considered statistically significant.

Patient and public involvement

This study was conducted without patient involvement. Patients were not asked to comment on the study design, consulted to derive results relevant to them, or consulted to

interpret the results. Patients were also not consulted in the writing or editing of this document for readability or accuracy.

RESULTS

Overall, 430 falls were recorded, of which 104 (24.2%) occurred in WR, 230 (53.5%) in MWB, and 96 (22.3%) in WWB, with the average number of falls per game being 5.8, 23.0, and 9.6, respectively. A significant difference in the number of falls was observed among the three sports ($p<0.001$). Table 2 shows the characteristics of falls in the three sport groups, and significant differences in class difference ($p<0.001$), direction of fall ($p<0.001$), location of fall ($p=0.019$), and body part first impacted ($p<0.001$) were detected among the three sports. When comparing falls with and without foul play, significant differences were detected in class ($p=0.021$) and whether contact occurred ($p=0.007$) (Table 3).

Table 4 shows a comparison of the characteristics of falls during the Rio 2016 Paralympics and the Tokyo 2020 Paralympics. In Rio 2016, a significant difference in the tendency of falls was observed among the three groups with and without contact ($p=0.037$), while in Tokyo 2020, no difference was observed ($p=0.167$). In terms of the number of low pointer falls, a significant difference in the tendency of falls was observed among the three groups in both Rio 2016 and Tokyo 2020 Paralympic Games ($p=0.003$, $p<0.001$).

Table 1. Demographic characteristics of athletes who participated the matches

	Wheelchair rugby (n=92)	Men's wheelchair basketball (n=96)	Women's wheelchair basketball (n=95)
Age (years±SD)	34.0±6.4	30.5±6.1	28.9±6.6
Sex			
Male	88	96	-
Female	4	-	95
Classification (%)			
0.5	15(16)	-	-
1.0	17(18)	16(17)	15(16)
1.5	8(9)	11(11)	9(9)
2.0	18(20)	10(10)	9(9)
2.5	7(8)	14(15)	10(11)
3.0	18(20)	7(7)	19(20)
3.5	9(10)	5(5)	8(8)
4.0	-	15(16)	13(14)
4.5	-	17(18)	13(14)

Table 2. Fall characteristics of the three groups

	Wheelchair rugby (n=104)	Men's wheelchair basketball (n=230)	Women's wheelchair basketball (n=96)	*p* - value
Classification (%)				**<0.001**
Low pointer	16(15.4)	125(54.3)	43(44.8)	
High pointer	88(84.6)	105(45.7)	53(55.2)	
Playing time (%)				
First quarter	29(27.9)	46(20.0)	28(29.2)	0.389
Second quarter	24(23.1)	48(20.9)	21(21.9)	
Third quarter	25(24.0)	57(24.8)	22(22.9)	

Fourth quarter	26(25.0)	79(34.3)	25(26.0)	
Playing phase (%)				0.154
Offence	60(57.7)	147(63.9)	68(70.8)	
Defence	44(42.3)	83(36.1)	28(29.2)	
Unidentified	-	-	-	
Contact with another player (%)				0.167
Contact	99(95.2)	209(90.9)	90(93.8)	
Non-contact	5(4.8)	15(6.5)	3(3.1)	
Unidentified	-	6(2.6)	3(3.1)	
Direction of the fall (%)				**<0.001**
Left	32(30.8)	27(11.7)	18(18.8)	
Right	31(29.8)	38(16.5)	15(15.6)	
Forward	27(26.0)	106(46.1)	42(43.8)	
Backward	12(11.5)	53(23.0)	16(16.7)	
Unidentified	2(1.9)	6(2.6)	5(5.2)	
Location of the fall (%)				**0.019**
Back court	40(38.5)	62(27.0)	27(28.1)	
Front court	43(41.3)	79(34.3)	34(35.4)	
Paint/key area	21(20.2)	89(38.7)	35(36.5)	
Body part first in contact with the floor (%)				**<0.001**
Hand	60(57.7)	180(78.3)	81(84.4)	
Elbow	24(23.1)	16(7.0)	2(2.1)	
Shoulder	7(6.7)	5(2.2)	1(1.0)	
Back	6(5.8)	15(6.5)	5(5.2)	
Unidentified/combined	7(6.7)	14(6.1)	7(7.3)	

Table 3. Fall characteristics of classification, contact situation and foul judgment

	No foul (n=258)	Foul (n=172)	*p* - value
Classification (%)			**0.021**
Low pointer	122(47.3)	62(36.0)	
High pointer	136(52.7)	110(64.0)	
Contact with another player (%)			**0.007**
Contact	227(88.0)	171(99.4)	
Non-contact	23(8.9)	0(0.0)	
Unidentified	8(3.1)	1(0.6)	

Table 4. The difference of fall characteristics during Tokyo 2020 and Rio 2016

Variable	Olympic	Competition	Number of falls	*p* - value
Contact with another player	Rio	WR	78	
		MWB	152	**0.037**
		WWB	85	
		Total	**315**	
	Tokyo	WR	99	0.167

		MWB	209	
		WWB	90	
		Total	**398**	
Low pointer	Rio	WR	17	
		MWB	65	
				0.003
		WWB	30	
		Total	**112**	
	Tokyo	WR	16	
		MWB	125	
				<0.001
		WWB	43	
		Total	**184**	

DISCUSSION

The characteristics of the number of falls occurring during the Tokyo 2020 Games among the three sports were similar to those of Rio 2016, with WB having a higher likelihood of falling than WR, especially with MWB having the highest risk of falling. Furthermore, the number of falls ranged from 5.8 to 23.0 per game, which was more than in Rio 2016 (5.3 to 17.2 per game). However, in terms of the presence or absence of contact and competition time, which tended to differ among the three events in Rio 2016, no difference was observed among the three events in Tokyo 2020. Meanwhile, a new difference was noted in the tendency of falls by class. To the best of our knowledge, this is the first study to characterize falls in wheelchair athletes playing team sports at the Paralympic Games and to compare them between Rio 2016 and Tokyo 2020.

As a result of dividing the number of fallers in each category into high and low pointers, WR (84.6%) and WWB (55.2%) tended to have a high percentage of high pointers,

while MWB (54.3%) conversely tended to have a high percentage of low pointers. Low pointing includes severe trunk dysfunction in addition to upper limb dysfunction in WR and severe trunk dysfunction in WB[11,12]. Therefore, they were considered to have less dynamic movements and lower risk of falling than high pointers. Nevertheless, in the MWB, the low pointers fell more often than the high pointers. This could be due to the difference in the proportion of low pointers and high pointers in the competition. In a previous study comparing the performance of male and female WB players, it has been reported that female players performed similarly to male players with 1.5 class points lower[18]. Hence, it can be inferred that up to 2.0–2.5 of the low pointers in MWB were able to move nearly as much as the high pointers in WWB. Assuming that high pointers can move aggressively on the court and that the increased contact with the opponent and have an increased risk of falling, players >2.0 (72%) may be at risk of falling in MWB. If we assume that the athletes can move aggressively in the MWB and are at an increased risk of falling, we would expect that athletes with a ≥2.0 MWB (72%) would be at risk of falling. Meanwhile, 2.0–2.5 athletes, who are low pointers but can perform as well as female high pointers, may have fallen more frequently in the MWB because they have less residual function. In order to consider the risk of falling in MWB, it is necessary to focus on the 2.0–2.5 athletes who can perform as well as female high pointers and have less residual function among men, rather than using the general classification of low point and high point.

When the incidence of falls with and without foul play was compared, the low pointer had 66.3% of falls without foul play. Meanwhile, the high pointers showed a different trend from the low pointers, with 55.3% of falls without foul play and 44.7% of falls with foul play, showing little difference in the incidence of falls with and without foul play. Moreover, despite the overwhelming prevalence of contact-type falls, there were more falls without foul play (n=258) than with foul play (n=172). In Rio 2016, the incidence of contact falls in WR was lower than in WB, but this time there was no difference in the incidence of contact falls in the three disciplines. This result may be due to an increase in falls caused by tackles without foul play in WR. At the Tokyo 2020 Games, the Paralympics were postponed for one year due to the pandemic, during which time the number of external games themselves decreased [19,20]. Since no international competitions were held for about a year, it is possible that there was little experience of contact play in the games. In addition, due to the pandemic, there was a period when contact play itself was avoided, and it is possible that contact play was not satisfactory during practice. Therefore, it is expected that WRs who were allowed to make contact forward of the axle were less tolerant of contact during games, and that falls in contact increased. Since we did not observe the situation during practice, we can only speculate, but the environment of Tokyo 2020 is unique in many ways, and these factors may

have changed the situation in which falls occurred.

In terms of fall direction, the WR players tended to fall more to the left, right, and front while the WB players tended to fall more to the front. The proportion of elbows and shoulders in the WR players was higher than that in the WB players, and most of the WB players fell from their hands. In WR, tackling from behind is a foul, while tackling from in front of the axle is allowed. Since the impact at contact is large, the momentum of the contacting side leads directly to a fall, and it is expected that there are many falls to the left and right. In addition, the tackled player still has the momentum of forward propulsion and falls forward as it is, so the WR is expected to have more falls to the left and right and forward. On the other hand, for WBs, contact is allowed, but not as violent contact as tackling, so even if the player loses balance due to contact, he will fall while rotating forward, which is expected to result in more forward falls. Additionally, most WR players have out-of-place injuries in their upper limbs, and their remaining trunk function is less than that of the WB players[21]. In the case of a fall, WR players may not be able to put out their hands immediately and may contact the ground from the elbow or shoulder. When the incidence of falls was divided into the backcourt, frontcourt, and paint (key) area, the incidence of falls in the key area was lower in the WR players, while the WB players tended to have more falls in the paint area. This may be due to the competition characteristics of WR, where contact in the key area is prohibited, and WB, where many players gather in the paint area under the goal. Therefore, it is necessary to understand that the occurrence of falls and the site of physical contact at the time of falls are different between WR and WB, even in the same team sports event. The incidence of injuries in WR and WB team sport events in the Paralympics did not improve in the London and Rio Paralympics (2012 and 2016, respectively)[2,3]. Furthermore, a detailed analysis of the mechanisms of trauma and injury has not been reported. The fact that the trends of fall characteristics of WR and WB were similar in Rio 2016 and Tokyo 2020 should be very useful data for the prevention of injury occurrence in WR and WB in the future.

This study's most significant findingis that the number of MWB low pointer falls increased the most in Tokyo 2020 compared with Rio 2016. This may be due to the difference in team composition. In Rio 2016, MWB low pointers accounted for 47%[4], while in Tokyo 2020, they accounted for 53%. In particular, there was a 9% decrease in the number of 3.0–3.5 players and a 4% increase in the number of 2.0–2.5 players. Therefore, it is expected that the countries that remain in the MWB final tournament tend to have more opportunities for players with ≥2.0 points, who have some remaining trunk function. However, in the MWB, the players with less residual function may be required to exert more effort to keep up with the high pointers. Therefore, in order to prevent falls in the future, it will be important to

conduct research focusing on the details of falls (e.g., the situation at the time of the fall and the direction of the fall) in athletes with MWB between 2.0 and 2.5, as well as on measures to prevent falls during contact. It will then be important to link this research to the prevention of injury occurrence in wheelchair team sports.

Limitations

There are several limitations to this study. First, we analyzed only official IPC videos and Internet-based IPC reports, so it is unclear whether we were able to analyze all actual falls. Nevertheless, we were able to analyze most of the falls, including those that interrupted the video. Second, we analyzed the games of the top eight teams in MWB and WWB to unify the number of teams, players, and level of competition with WR. The analysis of the 53 qualifying games excluded in our study can be used to present the characteristics of future WB falls. Last, we have not identified any injuries that occurred during the games. Therefore, whether these falls resulted in injuries or not was unknown. However, comparing Rio 2016 and Tokyo 2020, it is expected that more attention and research focus will be given to Paralympic sports injuries in the three popular team sports events of the Paralympics to clarify the differences in fall injuries between WR and WB athletes. Further research is needed to determine the differences in fall injuries between WR and WB athletes.

CONCLUSION

As in Rio 2016, the incidence of falls was high in Tokyo 2020 with MWB having the highest number of falls, followed by WWB and WR. The direction of fall occurrence and the first site of body contact at the time of the fall in Tokyo 2020 were also similar to those in Rio 2016. However, the occurrence of falls with and without contact in Tokyo 2020 was different from that in Rio 2016. Moreover, a new finding was obtained when comparing the low and high pointers, that more falls occurred in the low pointers of MWB. Further research will be conducted to understand the mechanism of fall injuries in wheelchair athletes and to relate these results to injury research.

COMPETING INTERESTS: None declared.FUNDING: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

AUTHOR CONTRIBUTIONS: KF designed the study and wrote the paper; all authors provided editing and comments for revision; NM, JS, and RS contributed to the analysis and

interpretation of the data and assisted in the preparation of the manuscript; ST, SA, TT, KK, MY, RM, TA, HE, and TT performed the video analysis; MK provided advice and YU was the principal investigator. All authors have approved the final version of the manuscript and have agreed to be accountable for all aspects of the work to ensure that any questions related to the accuracy or completeness of any part of the work are properly investigated and resolved.

PATINT AND PUBLIC INVOLVEMENT: Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

PATIENT CONSENT FOR PUBLICATION: Not required.

ETHICS APPROVAL: This study protocol was approved by Hiroshima University's Institutional Review Board (Study protocol ID number: E-1459).

DATA AVAILABILITY STATEMENT: All data relevant to the study are included in the article or uploaded as supplementary information. All data generated or analysed during this study are included in this published article.

REFERENCES

1. Clifton DR, Hertel J, Onate JA, et al. The first decade of web-based sports injury surveillance: descriptive epidemiology of injuries in US high school Girls' basketball (2005–2006 through 2013–2014) and National Collegiate Athletic Association Women's basketball (2004–2005 through 2013–2014). *J Athl Train* 2018;53:1037–48.
2. Derman W, Runciman P, Schwellnus M, et al. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2018;52:24–31. https://doi.org/10.1136/bjsports-2017-098039.
3. Willick SE, Webborn N, Emery C, et al. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32. https://doi.org/10.1136/bjsports-2013-092374.
4. Sasadai J, Maeda N, Shimizu R, et al. Analysis of team-sport wheelchair falls during the Rio 2016 Summer Paralympic Games: a video-based cross-sectional observational study. *BMJ Open* 2020;10:e033088. https://doi.org/10.1136/bmjopen-2019-033088.

5. Weiler R, Blauwet C, Clarke D, et al. Concussion in para sport: the first position statement of the Concussion in Para Sport (CIPS) Group. *Br J Sports Med* 2021;55:1187-95. https://doi.org/10.1136/bjsports-2020-103696.
6. Moran RN, Broglio SP, Francioni KK, et al. Exploring Baseline Concussion-Assessment Performance in Adapted Wheelchair Sport Athletes. *J Athl Train* 2020;55(8):856–62. https://doi.org/10.4085/1062-6050-294-19.
7. Olsen OE, Myklebust G, Engebretsen L, et al. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med* 2004;32:1002–12. https://doi.org/10.1177/0363546503261724.
8. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *Br J Sports Med* 2015;49:547–51. https://doi.org/10.1136/bjsports-2013-092234.
9. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. *Br J Sports Med* 2015;49:552–5. https://doi.org/10.1136/bjsports-2013-092235.
10. Tweedy S, Diaper N. Introduction to wheelchair sport. In: Goosey-Tolfrey V, ed. Wheelchair sport. A complete guide for athletes, coaches and teachers. Illinois, USA: Human Kinetics 2010: 3–28.
11. International wheelchair rugby federation. 2021. https://worldwheelchair.rugby/the-game-classifications/ (accessed).
12. IWBF player classification manual. 2021. https://iwbf.org/downloads/ (accessed).
13. Haydon DS, Pinder RA, Grimshaw PN, et al. Overground-Propulsion Kinematics and Acceleration in Elite Wheelchair Rugby. *Int J Sports Physiol Perform* 2021 Feb;13(2):156–62. https://journals.humankinetics.com/view/journals/ijspp/13/2/article-p156.xml (accessed Nov 30, 2021).
14. Marszałek J, Kosmol A, Morgulec-Adamowicz N, et al. Laboratory and Non-laboratory Assessment of Anaerobic Performance of Elite Male Wheelchair Basketball Athletes. *Front Psychol* 2019;10:514. https://doi.org/10.3389/fpsyg.2019.00514.
15. Blauwet C, Webborn N, Kissick J, et al. When van Mechelen's sequence of injury prevention model requires pragmatic and accelerated action: the case of para alpine skiing in Pyeong Chang 2018. *Br J Sports Med* 2019;53:1390–1.
16. Sadate B, Thierry W, Marjolaine A, et al. Performance, asymmetry and biomechanical parameters in wheelchair rugby players. *Sports Biomech* 2021 Apr;1898670. www.doi.org/10.1080/14763141.2021.1898670 (accessed Nov 29, 2021).

17. Tachibana K, Mutsuzaki H, Shimizu Y, et al. Influence of functional classification on skill tests in elite female wheelchair basketball athletes. *Medicina* 2019;55:740. https://doi.org/10.3390/medicina55110740 (accessed).
18. Cavedon V, Zancanaro C, Milanese C. Anthropometry, Body Composition, and Performance in Sport-Specific Field Test in Female Wheelchair Basketball Players. *Front Physiol* 2018;30:568. https://doi.org/10.3389/fphys.2018.00568.
19. Dove J, Gage A, Kriz P, et al. COVID-19 and Review of Current Recommendations for Return to Athletic Play. *R I Med J* 2013;103:15–20.
20. Mann RH, Clift BC, Boykoff J, et al. Athletes as community; athletes in community: covid-19, sporting mega-events and athlete health protection. *Br J Sports Med* 2020;54:1071–2. https://doi.org/10.1136/bjsports-2020-102433.
21. van der Slikke RMA, Berger MAM, Bregman DJJ, et al. Wearable Wheelchair Mobility Performance Measurement in Basketball, Rugby, and Tennis: Lessons for Classification and Training. *Sensors (Basel)* 2020;20:3518. https://doi.org/10.3390/s20123518.

Figure legend

Figure 1. Inclusion and exclusion criteria of match videos.

*Because WR is a mixed sport, there were no women and men categories.

MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

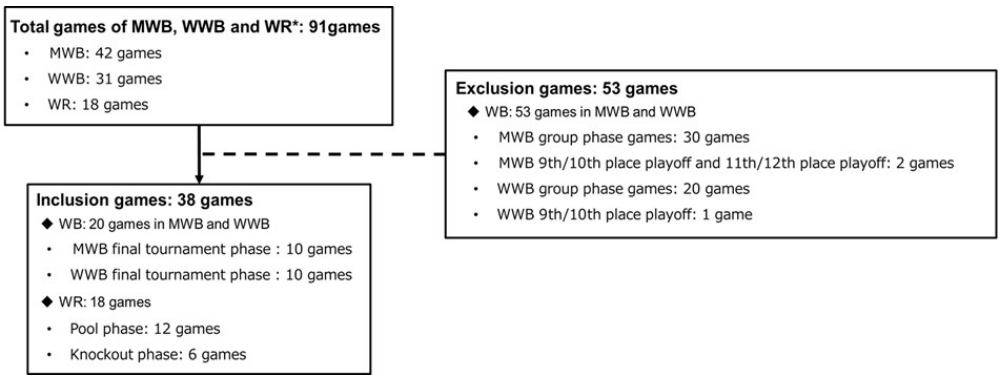

Figure 1. Inclusion and exclusion criteria of match videos. *Because WR is a mixed sport, there were no women and men categories. MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

161x59mm (150 x 150 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	Fig1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table1
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	Fig1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	-

		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based descriptive comparison between the Rio 2016 and Tokyo 2020 games

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-060937.R1
Article Type:	Original research
Date Submitted by the Author:	14-May-2022

Complete List of Authors:	FUKUI, KAZUKI; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Maeda, Noriaki; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Sasadai, Junpei; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Shimizu, Reia; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Tsutsumi, Shogo; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Arima, Satoshi; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Tashiro, Tsubasa; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Kaneda, Kazuki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Yoshimi, Mitsuhiro; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Mizuta, Rami; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Abekura, Takeru; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Esaki, Hinata; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Terada, Tomoki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Komiya, Makoto; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Suzuki, Akira; Sports Medical Center, Japan Institute of Sports Sciences

	(JISS) Urabe, Yukio; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Epidemiology, Sports and exercise medicine, Rehabilitation medicine
Keywords:	SPORTS MEDICINE, REHABILITATION MEDICINE, ORTHOPAEDIC & TRAUMA SURGERY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based descriptive comparison between the Rio 2016 and Tokyo 2020 games

Authors

Kazuki Fukui[1], Noriaki Maeda[1], Junpei Sasadai[2], Reia Shimizu[2], Shogo Tsutsumi[1], Satoshi Arima[1], Tsubasa Tashiro[1], Kazuki Kaneda[1], Mitsuhiro Yoshimi[1], Rami Mizuta[1], Takeru Abekura[1], Hinata Esaki[1], Tomoki Terada[1], Makoto Komiya[1], Akira Suzuki[2], Yukio Urabe[1]

Affiliations

[1]Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

[2]Sports Medical Center, Japan Institute of Sports Sciences (JISS), 3-15-1 Nishigaoka Kita-ku, Tokyo, 115-0056, Japan

Corresponding author

Yukio Urabe

Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

E-mail address: yurabe@hiroshima-u.ac.jp

Word count

3471 words

ABSTRACT

Objectives

To identify the fall characteristics of athletes in wheelchair rugby and wheelchair basketball during the Tokyo 2020 Paralympic Games and descriptively compare these with those of the Rio 2016 Paralympic Games.

Design

Cross-sectional analysis

Primary and secondary outcome measures

We obtained video footage from the International Paralympic Committee of the Tokyo 2020 Paralympic Games that included 8 teams from each of the 18 wheelchair rugby and 10 wheelchair basketball games (men and women). The data were analyzed to evaluate the number of falls, class difference (low or high pointer), time of play during the fall, phase of play, contact with other athletes, fall direction, fall location, and the body part that first contacted the floor during the fall. These data from the Rio 2016 and Tokyo 2020 games were compared.

Results

Overall, 430 falls (rugby, 104; men's basketball, 230; and women's basketball, 96) occurred (average per game: 5.8, 23.0, and 9.6, respectively). Significant differences were observed among the three sports regarding the class, direction, fall location, and body part point of contact. In wheelchair rugby, falls occurred mainly in high-pointers and tended to be more lateral due to contact. In wheelchair basketball, falls occurred more in female high-pointers and in male low-pointers, with more forward falls due to forward contact. Unlike in the Rio 2016 games, no difference between the events based on the presence or absence of contact was observed in the Tokyo 2020 games.

Conclusions

The number of falls increased in Tokyo 2020 compared to Rio 2016, with no significant difference in the characteristics of falls between the Rio 2016 and Tokyo 2020 games. Only in men's wheelchair basketball, the number of falls in low pointers significantly increased in the Tokyo 2020 games when compared to that in the Rio 2016 games.

Strengths and limitations of this study

- The analysis of wheelchair sport falls at the Tokyo 2020 Paralympic Games and the Rio 2016 Paralympic Games was conducted using official Paralympic videos available on the Internet.
- The characteristics of falls during wheelchair rugby and wheelchair basketball competitions were analyzed.

- The data from the Tokyo 2020 Paralympic Games and the Rio 2016 Paralympic Games were compared, and the characteristics of falls at the Tokyo Paralympic Games were analyzed.
- No injuries due to wheelchair falls were identified in the videos.
- The relationship between falls and injuries could not be explained.

INTRODUCTION

The Tokyo 2020 Paralympic Games featured 4403 athletes competing in 539 events in 22 sports, making it the largest Paralympic Games in history and drawing increasing attention to the Paralympic Games. Hence, with the increase in the number of athletes, the level of competition is expected to improve, and sports injuries are also expected to increase [1]. A total of 441 athletes sustained as many as 510 injuries during the 14 days of competition at the Rio 2016 Paralympics, with 61 athletes injured during their participation in wheelchair rugby (WR) and wheelchair basketball (WB); this translated to 14.9 and 12.8 injuries per 1000 athlete days, respectively [2]. Furthermore, contact team sports such as WR and WB have a higher incidence of acute injuries than fencing and tennis (61%, 65%, and 42%, 37%, respectively) [3]. In these two wheelchair team sports, many falls commonly occur. Regarding the incidence of falls at the Rio 2016 Paralympics, 359 falls occurred in three disciplines (WR, men's WB, and women's WB). The rate of falls was the highest for MWB, followed by WWB and WR [4]. However, no other study has clarified the characteristics of falls in each sport. Moreover, the relationship between sports injury characteristics and the occurrence of falls in wheelchair team sports has not yet been presented. In the case of wheelchair sports, falls can result in head impacts and emergencies such as concussions, and research in the area of concussions has received increasing attention [5, 6]. Therefore, understanding the causes of falls during games is essential in considering the prevention of injury occurrence in these team sports, and more data needs to be collected. One way to analyze the occurrence of falls in wheelchair-related sports is to use video recordings of games.

By retrospectively analyzing the video recordings of the games, which is an effective method that has been used previously to interpret injury occurrence in healthy individuals, [7-9] the occurrence and characteristics of these wheelchair-related sport injuries can be identified. The analysis of anterior cruciate ligament injuries helped researchers to understand the change of dynamic alignment during injury and plan preventive measures, [7] which is why we used this method in our previous study to investigate the incidence of falls in WR and WB games at the Rio 2016 Paralympic Games [4].

WR and WB players also include individuals with quadriplegia, paraplegia, and amputations. Overall, WR players have more severe functional impairments than WB players, especially those affecting the extremities, such as cervical spinal cord injury (tetraplegia), multiple amputations, polio, cerebral palsy, and other neurological diseases [10]. WR players are classified based on their hand, arm, shoulder, and trunk functions, with disability levels ranging from 0.5 (lowest physical function) to 3.5 (highest physical function),

and are placed into seven categories based on their level of disability [11]. WB players must have a permanent physical disability with reduced function of the lower extremities, which includes paralysis of the lower extremities, musculoskeletal disorders, spina bifida, amputation, and childhood paralysis [11]. These athletes are classified from 1.0 (lowest physical function) to 4.5 (highest physical function) [12]. Performance and injury rates vary greatly by class [13, 14], and fall rates are expected to vary as well. However, no analysis of fall incidence by class has been reported.

At the Rio 2016 Paralympics, the incidence of falls and the duration of competition, the presence of contact, the direction of the fall, and the initial site of contact had different characteristics in the three events [4]. Meanwhile, in our previous study we have not been able to clarify the incidence of falls for each class. In addition, five years have passed since the Rio 2016 Paralympics, and the incidence of falls is expected to be different due to the improvement of athletic performance. Moreover, the Tokyo 2020 Paralympics was held under special circumstances, with the games being postponed for one year due to the COVID-19 pandemic. Therefore, new characteristics of fall occurrence different from those of the Rio 2016 Paralympics may emerge, and accumulation of data will be crucial for injury prevention. This study aimed to investigate the number of falls and the occurrence of falls among wheelchair athletes in team sports at the 2020 Tokyo Paralympic Games, to compare the results with those at the 2016 Rio Paralympic Games, and to clarify the characteristics of major falls among the three major wheelchair team sports (WR, MWB, and W WB).

METHODS

In this cross-sectional video analysis, we obtained the official match videos of the WR and WB wheelchair team competitions from the International Paralympic Committee's (IPC) official website, and analyzed the match videos of all eight teams participating in the WR and eight teams each from the MWB and WWB that advanced to the quarterfinals of the Tokyo 2020 Paralympic Games (Fig. 1). The WR matches are played in four 8-minute periods, and the WB matches are played in four 10-minute periods. Three physiotherapists with expertise in para-sports systematically analyzed the videos for fall mechanism and play circumstances. The videos were repeated as needed and displayed at normal speed, slow speed, or in still images. To record the number of falls, duration of play at the time of the fall, phase of play (offense or defense), contact with another player, direction of the fall, location of the fall (backcourt, frontcourt, or key or paint area), and the body part that first made contact with the floor, we modified a standard form similar to the one used in previous video analyses [4, 15]. In order to record all falls, contact with the floor was considered to be necessary. Additionally, the fall data obtained from the IPC official website of the Rio 2016 Paralympic Games and used in our previous study, from a total of 18 WR and 10 WB match videos of men (MWB) and women (WWB), including eight teams in one event, were also used in this analysis [4]. Analysis of the Rio 2016 Paralympic Games data was also conducted using the same methods as for the present 2020 analysis.

Data regarding player information (age, sex, and functional classification) were used from the IPC website (Table 1). Regarding disability classification, based on previous studies, for WR, ≥2.0 were classified as high pointer and ≤1.5 and below as low pointer [16]; for WB, ≥3.0 were classified as high pointer and ≤2.5 as low pointer [17].

Statistical analysis

For all categorical variables, results that were consistent with the ratings of two out of three observers were reported. A good agreement among the three observers for all variables was considered when two or more observers were in agreement for all categorical items and the kappa coefficient was >0.8. A one-way analysis of variance was used to compare the mean incidence of falls for each of the three wheelchair sports games. Follow-up analyses were conducted using Bonferroni's post hoc test, if necessary. For the comparison of categorical variables, Pearson's X^2 test or Fisher's exact test was used. The Fisher's exact test was used instead of the X^2 test when the expected number was <5. Adjusted residuals were used for post hoc tests. Comparisons of the incidence of falls with and without foul contact were also conducted using Pearson's chi-square test. In order to compare the characteristics of falls at the Tokyo 2020 Paralympic Games with those at the Rio 2016

Paralympic Games, descriptive comparisons were also made between the results from the 2020 and 2016 Games regarding the presence of contact with other athletes, and the percentage of low pointer falls. All statistical analyses were performed using IBM SPSS version 27.0 (IBM japan, Tokyo, Japan). A p-value <0.05 considered statistically significant.

Patient and public involvement

This study was conducted without patient involvement. Patients were not asked to comment on the study design, consulted to derive results relevant to them, or consulted to interpret the results. Patients were also not consulted in the writing or editing of this document for readability or accuracy.

RESULTS

Overall, 430 falls were recorded, of which 104 (24.2%) occurred in WR, 230 (53.5%) in MWB, and 96 (22.3%) in WWB, with the average number of falls per game being 5.8, 23.0, and 9.6, respectively. There was a significant difference in the mean number of falls, occurring only between MWB and the other events (WR and WWB) ($p<0.001$). Table 2 shows the characteristics of falls in the three sport groups, and significant differences in class difference ($p<0.001$), direction of fall ($p<0.001$), location of fall ($p=0.019$), and body part first impacted ($p<0.001$) were detected among the three sports. When comparing falls with and without foul play, significant differences were detected in class ($p=0.021$) and whether contact occurred ($p=0.007$) (Table 3).

Table 4 shows a comparison of the characteristics of falls during the Rio 2016 Paralympics and the Tokyo 2020 Paralympics. In Rio 2016, a significant difference in the tendency of falls was observed among the three groups with and without contact ($p=0.037$), while in Tokyo 2020, no difference was observed ($p=0.167$). In terms of the number of low pointer falls, a significant difference in the tendency of falls was observed among the three groups in both Rio 2016 and Tokyo 2020 Paralympic Games ($p=0.003$, $p<0.001$).

196

Table 1. Demographic characteristics of athletes who participated the matches

	Wheelchair rugby (n=92)	Men's wheelchair basketball (n=96)	Women's wheelchair basketball (n=95)
Age (years±SD)	34.0±6.4	30.5±6.1	28.9±6.6
Sex			
Male	88	96	-
Female	4	-	95
Classification (%)			
0.5	15(16)	-	-
1.0	17(18)	16(17)	15(16)
1.5	8(9)	11(11)	9(9)
2.0	18(20)	10(10)	9(9)
2.5	7(8)	14(15)	10(11)
3.0	18(20)	7(7)	19(20)
3.5	9(10)	5(5)	8(8)
4.0	-	15(16)	13(14)
4.5	-	17(18)	13(14)

197

Table 2. Fall characteristics of the three groups

	Wheelchair rugby (n=104)	Men's wheelchair basketball (n=230)	Women's wheelchair basketball (n=96)	*p* - value
Classification (%)				**<0.001**
Low pointer	16(15.4)†	125(54.3)*	43(44.8)	
High pointer	88(84.6)*	105(45.7)†	53(55.2)	
Playing time (%)				
First quarter	29(27.9)	46(20.0)	28(29.2)	0.389
Second quarter	24(23.1)	48(20.9)	21(21.9)	
Third quarter	25(24.0)	57(24.8)	22(22.9)	
Fourth quarter	26(25.0)	79(34.3)	25(26.0)	

Playing phase (%)				0.154
Offence	60(57.7)	147(63.9)	68(70.8)	
Defence	44(42.3)	83(36.1)	28(29.2)	
Unidentified	-	-	-	
Contact with another player (%)				0.167
Contact	99(95.2)	209(90.9)	90(93.8)	
Non-contact	5(4.8)	15(6.5)	3(3.1)	
Unidentified	-	6(2.6)	3(3.1)	
Direction of the fall (%)				**<0.001**
Left	32(30.8)*	27(11.7)†	18(18.8)	
Right	31(29.8)*	38(16.5)	15(15.6)	
Forward	27(26.0)†	106(46.1)*	42(43.8)	
Backward	12(11.5)†	53(23.0)*	16(16.7)	
Unidentified	2(1.9)	6(2.6)	5(5.2)	
Location of the fall (%)				**0.019**
Back court	40(38.5)*	62(27.0)	27(28.1)	
Front court	43(41.3)	79(34.3)	34(35.4)	
Paint/key area	21(20.2)†	89(38.7)*	35(36.5)	
Body part first in contact with the floor (%)				**<0.001**
Hand	60(57.7)†	180(78.3)	81(84.4)*	
Elbow	24(23.1)*	16(7.0)†	2(2.1)†	
Shoulder	7(6.7)*	5(2.2)	1(1.0)	
Back	6(5.8)	15(6.5)	5(5.2)	
Unidentified/combined	7(6.7)	14(6.1)	7(7.3)	

198 • Values are expressed as the number of falls (% of total falls) for each group.

199 • * Significantly higher among the three events ($p<0.05$)

200 • †Significantly lower among the three events ($p<0.05$)

201

Table 3. Fall characteristics according to foul judgement

	No foul (n=258)	Foul (n=172)	*p* - value
Classification (%)			**0.021**
Low pointer	122(47.3)*	62(36.0)†	
High pointer	136(52.7)†	110(64.0)*	
Contact with another player (%)			**0.007**
Contact	227(88.0)†	171(99.4)*	
Non-contact	23(8.9)*	0(0.0)†	
Unidentified	8(3.1)	1(0.6)	

- Values are expressed as the number of falls (% of total falls) for each group.
- *Significantly higher in foul judgment (p<0.05)
- †Significantly lower in foul judgment (p<0.05)

Table 4. The difference of fall characteristics during Tokyo 2020 and Rio 2016

Variable	Paralympic	Competition	Number of falls	*p* - value
Contact with another player (%)	Rio	WR	78(24.8)†	
		MWB	152(48.3)	**0.037**
		WWB	85(27.0)	
		Total	**315**	
	Tokyo	WR	99(24.9)	
		MWB	209(52.5)	0.167
		WWB	90(22.6)	
		Total	**398**	
Low pointer (%)	Rio	WR	17(15.2)†	
		MWB	65(58.0)*	**0.003**
		WWB	30(26.8)	
		Total	**112**	

	Tokyo	WR	16(8.7)†	
		MWB	125(67.9)*	**<0.001**
		WWB	43(23.4)	
		Total	**184**	

- Values are expressed as the number of falls (% of total falls) for each Paralympic Games.
- * Significantly higher among the three events ($p<0.05$)
- †Significantly lower among the three events ($p<0.05$)

DISCUSSION

The characteristics of the number of falls occurring during the Tokyo 2020 Games among the three sports were similar to those of Rio 2016, with WB having a higher likelihood of falling than WR, especially with MWB having the highest risk of falling. Furthermore, the number of falls ranged from 5.8 to 23.0 per game, which was more than in Rio 2016 (5.3 to 17.2 per game). However, in terms of the presence or absence of contact and competition time, which tended to differ among the three events in Rio 2016, no difference was observed among the three events in Tokyo 2020. Meanwhile, a new difference was noted in the tendency of falls by class. To the best of our knowledge, this is the first study to characterize falls in wheelchair athletes playing team sports at the Paralympic Games and to descriptively compare them between Rio 2016 and Tokyo 2020.

As a result of dividing the number of fallers in each category into high and low pointers, WR (84.6%) and WWB (55.2%) tended to have a high percentage of falls among high pointers, while MWB (54.3%) conversely tended to have a high percentage of falls among low pointers. Low pointing includes severe trunk dysfunction in addition to upper limb dysfunction in WR and severe trunk dysfunction in WB [11, 12]. Therefore, less dynamic than high pointers, they avoided playing with the risk of falling, and as a result, estimated that the number of falls was lower. Nevertheless, in the MWB, the low pointers fell more often than the high pointers. This could be due to the difference in the proportion of low pointers and high pointers in the competition. In a previous study comparing the performance of male and female WB players, it has been reported that female players performed similarly to male players with 1.5 class points lower [18]. Hence, it can be inferred that up to 2.0–2.5 of the low pointers in MWB were able to move nearly as much as the high pointers in WWB. Assuming that high pointers can move aggressively on the court and that

the increased contact with the opponent and have an increased risk of falling, players >2.0 (72%) may be at risk of falling in MWB. If we assume that the athletes can move aggressively in the MWB and are at an increased risk of falling, we would expect that athletes with a ≥2.0 MWB (72%) would be at risk of falling. Meanwhile, 2.0–2.5 athletes, who are low pointers but can perform as well as female high pointers, may have fallen more frequently in the MWB because they have less residual function. In order to consider the risk of falling in MWB, it is necessary to focus on the 2.0–2.5 athletes who can perform as well as female high pointers and have less residual function among men, rather than using the general classification of low point and high point.

When the incidence of falls with and without foul play was compared, the low pointer had 66.3% of falls without foul play. Meanwhile, the high pointers showed a different trend from the low pointers, with 55.3% of falls without foul play and 44.7% of falls with foul play, showing little difference in the incidence of falls with and without foul play. Moreover, despite the overwhelming prevalence of contact-type falls, there were more falls without foul play (n=258) than with foul play (n=172). In Rio 2016, the incidence of contact falls in WR was lower than in WB, but this time there was no difference in the incidence of contact falls in the three disciplines. This result may be due to an increase in falls caused by tackles without foul play in WR. At the Tokyo 2020 Games, the Paralympics were postponed for one year due to the pandemic, during which time the number of external games themselves decreased [19, 20]. Since no international competitions were held for about a year, it is possible that there was little experience of contact play in the games. In addition, due to the pandemic, there was a period when contact play itself was avoided, and it is possible that contact play was not satisfactory during practice. Therefore, it is expected that WRs who were allowed to make contact forward of the axle were less tolerant of contact during games, and that falls in contact increased. Since we did not observe the situation during practice, we can only speculate, but the environment of Tokyo 2020 is unique in many ways, and these factors may have changed the situation in which falls occurred.

In terms of fall direction, the WR players tended to fall more to the left, right, and front while the WB players tended to fall more to the front. The proportion of elbows and shoulders in the WR players was higher than that in the WB players, and most of the WB players fell from their hands. In WR, tackling from behind is a foul, while tackling from in front of the axle is allowed. Since the impact at contact is large, the momentum of the contacting side leads directly to a fall, and it is expected that there are many falls to the left and right. In addition, the tackled player still has the momentum of forward propulsion and falls forward as it is, so the WR is expected to have more falls to the left and right and forward. On the other hand, for WBs, contact is allowed, but not as violent contact as tackling, so even

if the player loses balance due to contact, he will fall while rotating forward, which is expected to result in more forward falls. Additionally, most WR players have out-of-place injuries in their upper limbs, and their remaining trunk function is less than that of the WB players [21]. In the case of a fall, WR players may not be able to put out their hands immediately and may contact the ground from the elbow or shoulder. When the incidence of falls was divided into the backcourt, frontcourt, and paint (key) area, the incidence of falls in the key area was lower in the WR players, while the WB players tended to have more falls in the paint area. This may be due to the competition characteristics of WR, where contact in the key area is prohibited, and WB, where many players gather in the paint area under the goal. Therefore, it is necessary to understand that the occurrence of falls and the site of physical contact at the time of falls are different between WR and WB, even in the same team sports event. The incidence of injuries in WR and WB team sport events in the Paralympics did not improve in the London and Rio Paralympics (2012 and 2016, respectively) [2, 3]. Furthermore, a detailed analysis of the mechanisms of trauma and injury has not been reported. The fact that the trends of fall characteristics of WR and WB were similar in Rio 2016 and Tokyo 2020 should be very useful data for the prevention of injury occurrence in WR and WB in the future.

This study's most significant finding is that the number of MWB low pointer falls increased the most in Tokyo 2020 compared with Rio 2016. This may be due to the difference in team composition. In Rio 2016, MWB low pointers accounted for 47% [4], while in Tokyo 2020, they accounted for 53%. In particular, there was a 9% decrease in the number of 3.0–3.5 players and a 4% increase in the number of 2.0–2.5 players. Therefore, it is expected that the countries that remain in the MWB final tournament tend to have more opportunities for players with ≥2.0 points, who have some remaining trunk function. However, in the MWB, the players with less residual function may be required to exert more effort to keep up with the high pointers. Therefore, in order to prevent falls in the future, it will be important to conduct research focusing on the details of falls (e.g., the situation at the time of the fall and the direction of the fall) in athletes with MWB between 2.0 and 2.5, as well as on measures to prevent falls during contact. It will then be important to link this research to the prevention of injury occurrence in wheelchair team sports.

Limitations

There are several limitations to this study. First, we analyzed only official IPC videos and Internet-based IPC reports, so it is unclear whether we were able to analyze all actual falls. Nevertheless, we were able to analyze most of the falls, including those that interrupted the video. Second, we analyzed the games of the top eight teams in MWB and WWB to unify the number of teams, players, and level of competition with WR. The analysis

of the 53 qualifying games excluded in our study can be used to present the characteristics of future WB falls. Third, the players were not directly involved in this study, and the results were only obtained from the videos. A more detailed and accurate analysis could be conducted by directly surveying the players who fell. Lastly, we have not identified any injuries that occurred during the games. This is because the video and data used for this analysis did not provide data on whether an injury had occurred, whether the player was treated by a doctor, or whether the player left the game injured after the fall.Therefore, whether these falls resulted in injuries or not was unknown. However, comparing Rio 2016 and Tokyo 2020, it is expected that more attention and research focus will be given to Paralympic sports injuries in the three popular team sports events of the Paralympics to clarify the differences in fall injuries between WR and WB athletes. Further research is needed to determine the differences in fall injuries between WR and WB athletes.

CONCLUSION

As in Rio 2016, the incidence of falls was high in Tokyo 2020 with MWB having the highest number of falls, followed by WWB and WR. The direction of fall occurrence and the first site of body contact at the time of the fall in Tokyo 2020 were also similar to those in Rio 2016. However, the occurrence of falls with and without contact in Tokyo 2020 was different from that in Rio 2016. Moreover, a new finding was obtained when comparing the low and high pointers, that more falls occurred in the low pointers of MWB. Further research will be conducted to understand the mechanism of fall injuries in wheelchair athletes and to relate these results to injury research.

COMPETING INTERESTS: None declared.

FUNDING: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

AUTHOR CONTRIBUTIONS: KF designed the study and wrote the paper; all authors provided editing and comments for revision; NM, JS, and RS contributed to the analysis and interpretation of the data and assisted in the preparation of the manuscript; ST, SA, TT, KK, MY, RM, TA, HE, and TT performed the video analysis; MK and AS provided advice and YU was the principal investigator. All authors have approved the final version of the

manuscript and have agreed to be accountable for all aspects of the work to ensure that any questions related to the accuracy or completeness of any part of the work are properly investigated and resolved.

PATINT AND PUBLIC INVOLVEMENT: Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

PATIENT CONSENT FOR PUBLICATION: Not required.

ETHICS APPROVAL: This study protocol was approved by Hiroshima University's Institutional Review Board (Study protocol ID number: E-1459). The same Review Board waived the need for obtaining informed consent from the athletes.

DATA AVAILABILITY STATEMENT: All data relevant to the study are included in the article or uploaded as supplementary information. All data generated or analysed during this study are included in this published article.

REFERENCES

1. Clifton DR, Hertel J, Onate JA, et al. The first decade of web-based sports injury surveillance: descriptive epidemiology of injuries in US high school Girls' basketball (2005–2006 through 2013–2014) and National Collegiate Athletic Association Women's basketball (2004–2005 through 2013–2014). *J Athl Train* 2018;53:1037–48.
2. Derman W, Runciman P, Schwellnus M, et al. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2018;52:24–31. https://doi.org/10.1136/bjsports-2017-098039.
3. Willick SE, Webborn N, Emery C, et al. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32. https://doi.org/10.1136/bjsports-2013-092374.
4. Sasadai J, Maeda N, Shimizu R, et al. Analysis of team-sport wheelchair falls during the Rio 2016 Summer Paralympic Games: a video-based cross-sectional observational study. *BMJ Open* 2020;10:e033088. https://doi.org/10.1136/bmjopen-2019-033088.
5. Weiler R, Blauwet C, Clarke D, et al. Concussion in para sport: the first position statement of the Concussion in Para Sport (CIPS) Group. *Br J Sports Med* 2021;55:1187-95. https://doi.org/10.1136/bjsports-2020-103696.

6. Moran RN, Broglio SP, Francioni KK, et al. Exploring Baseline Concussion-Assessment Performance in Adapted Wheelchair Sport Athletes. *J Athl Train* 2020;55(8):856–62. https://doi.org/10.4085/1062-6050-294-19.
7. Olsen OE, Myklebust G, Engebretsen L, et al. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med* 2004;32:1002–12. https://doi.org/10.1177/0363546503261724.
8. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *Br J Sports Med* 2015;49:547–51. https://doi.org/10.1136/bjsports-2013-092234.
9. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. *Br J Sports Med* 2015;49:552–5. https://doi.org/10.1136/bjsports-2013-092235.
10. Tweedy S, Diaper N. Introduction to wheelchair sport. In: Goosey-Tolfrey V, ed. Wheelchair sport. A complete guide for athletes, coaches and teachers. Illinois, USA: Human Kinetics 2010: 3–28.
11. International wheelchair rugby federation. 2021. https://worldwheelchair.rugby/the-game-classifications/ (accessed).
12. IWBF player classification manual. 2021. https://iwbf.org/downloads/ (accessed).
13. Haydon DS, Pinder RA, Grimshaw PN, et al. Overground-Propulsion Kinematics and Acceleration in Elite Wheelchair Rugby. *Int J Sports Physiol Perform* 2021 Feb;13(2):156–62. https://journals.humankinetics.com/view/journals/ijspp/13/2/article-p156.xml (accessed Nov 30, 2021).
14. Marszałek J, Kosmol A, Morgulec-Adamowicz N, et al. Laboratory and Non-laboratory Assessment of Anaerobic Performance of Elite Male Wheelchair Basketball Athletes. *Front Psychol* 2019;10:514. https://doi.org/10.3389/fpsyg.2019.00514.
15. Blauwet C, Webborn N, Kissick J, et al. When van Mechelen's sequence of injury prevention model requires pragmatic and accelerated action: the case of para alpine skiing in Pyeong Chang 2018. *Br J Sports Med* 2019;53:1390–1.
16. Sadate B, Thierry W, Marjolaine A, et al. Performance, asymmetry and biomechanical parameters in wheelchair rugby players. *Sports Biomech* 2021 Apr;1898670. www.doi.org/10.1080/14763141.2021.1898670 (accessed Nov 29, 2021).
17. Tachibana K, Mutsuzaki H, Shimizu Y, et al. Influence of functional classification on skill tests in elite female wheelchair basketball athletes. *Medicina* 2019;55:740. https://doi.org/10.3390/medicina55110740 (accessed).

18. Cavedon V, Zancanaro C, Milanese C. Anthropometry, Body Composition, and Performance in Sport-Specific Field Test in Female Wheelchair Basketball Players. *Front Physiol* 2018;30:568. https://doi.org/10.3389/fphys.2018.00568.
19. Dove J, Gage A, Kriz P, et al. COVID-19 and Review of Current Recommendations for Return to Athletic Play. *R I Med J* 2013;103:15–20.
20. Mann RH, Clift BC, Boykoff J, et al. Athletes as community; athletes in community: covid-19, sporting mega-events and athlete health protection. *Br J Sports Med* 2020;54:1071–2. https://doi.org/10.1136/bjsports-2020-102433.
21. van der Slikke RMA, Berger MAM, Bregman DJJ, et al. Wearable Wheelchair Mobility Performance Measurement in Basketball, Rugby, and Tennis: Lessons for Classification and Training. *Sensors (Basel)* 2020;20:3518. https://doi.org/10.3390/s20123518.

Figure legend

Figure 1. Inclusion and exclusion criteria of match videos.
*Because WR is a mixed sport, there were no women and men categories.
MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

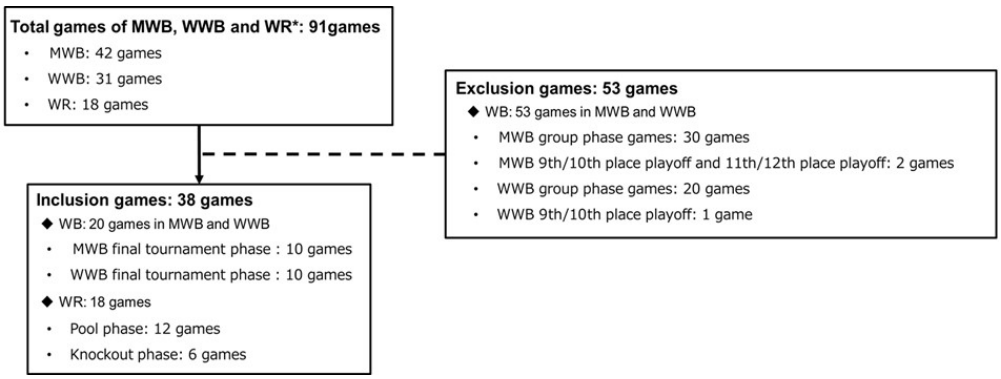

Figure 1. Inclusion and exclusion criteria of match videos. *Because WR is a mixed sport, there were no women and men categories. MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

161x59mm (150 x 150 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	Fig1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table1
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	Fig1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	-

		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based descriptive comparison between the Rio 2016 and Tokyo 2020 games

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-060937.R2
Article Type:	Original research
Date Submitted by the Author:	07-Jul-2022
Complete List of Authors:	Fukui, Kazuki; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing Maeda, Noriaki; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Sasadai, Junpei; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Shimizu, Reia; Sports Medical Center, Japan Institute of Sports Sciences (JISS) Tsutsumi, Shogo; Hiroshima University Graduate School of Biomedical and Health Sciences Faculty of Medicine Institute of Health Sciences Department of Nursing, Department of Sports Rehabilitation Arima, Satoshi; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Tashiro, Tsubasa; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Kaneda, Kazuki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Yoshimi, Mitsuhiro; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Mizuta, Rami; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Abekura, Takeru; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Esaki, Hinata; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Terada, Tomoki; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Komiya, Makoto; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation Suzuki, Akira; Sports Medical Center, Japan Institute of Sports Sciences

	(JISS) Urabe, Yukio; Hiroshima University Faculty of Medicine Graduate School of Biomedical and Health Sciences, Department of Sports Rehabilitation
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Epidemiology, Sports and exercise medicine, Rehabilitation medicine
Keywords:	SPORTS MEDICINE, REHABILITATION MEDICINE, ORTHOPAEDIC & TRAUMA SURGERY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title

Analysis of wheelchair falls in team sports at the Paralympic Games: Video-based descriptive comparison between the Rio 2016 and Tokyo 2020 games

Authors

Kazuki Fukui[1], Noriaki Maeda[1], Junpei Sasadai[2], Reia Shimizu[2], Shogo Tsutsumi[1], Satoshi Arima[1], Tsubasa Tashiro[1], Kazuki Kaneda[1], Mitsuhiro Yoshimi[1], Rami Mizuta[1], Takeru Abekura[1], Hinata Esaki[1], Tomoki Terada[1], Makoto Komiya[1], Akira Suzuki[2], Yukio Urabe[1]

Affiliations

[1]Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

[2]Sports Medical Center, Japan Institute of Sports Sciences (JISS), 3-15-1 Nishigaoka Kita-ku, Tokyo, 115-0056, Japan

Corresponding author

Yukio Urabe

Graduate School of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima, 734-8553, Japan

E-mail address: yurabe@hiroshima-u.ac.jp

Word count

3298 words

ABSTRACT

Objectives

To identify the fall characteristics of athletes in wheelchair rugby and wheelchair basketball during the Tokyo 2020 Paralympic Games and descriptively compare these with those of the Rio 2016 Paralympic Games.

Design

Cross-sectional analysis

Primary and secondary outcome measures

We obtained video footage from the International Paralympic Committee of the Tokyo 2020 Paralympic Games that included 8 teams from each of the 18 wheelchair rugby and 10 wheelchair basketball games (men and women). The data were analyzed to evaluate the number of falls, class difference (low or high pointer), time of play during the fall, phase of play, contact with other athletes, fall direction, fall location, and the body part that first contacted the floor during the fall. These data from the Rio 2016 and Tokyo 2020 games were compared.

Results

Overall, 430 falls (rugby, 104; men's basketball, 230; and women's basketball, 96) occurred (average per game ± standard deviation: 5.8±3.1, 23.0±5.4, and 9.6±5.0, respectively). Significant differences in class, direction, fall location, and body part point of contact between the three sports were observed. In wheelchair rugby, falls occurred mainly in high-pointers and tended to be more lateral due to contact. In wheelchair basketball, falls occurred more in female high-pointers and in male low-pointers, with more forward falls due to forward contact. Unlike in the Rio 2016 games, no difference between the events based on the presence or absence of contact was observed in the Tokyo 2020 games.

Conclusions

The number of falls increased in Tokyo 2020 compared to Rio 2016, with no significant difference in the characteristics of falls between the Rio 2016 and Tokyo 2020 games. Only in men's wheelchair basketball, the number of falls in low pointers significantly increased in the Tokyo 2020 games when compared to that in the Rio 2016 games.

Strengths and limitations of this study

- The analysis of wheelchair sport falls at the Tokyo 2020 Paralympic Games and the Rio 2016 Paralympic Games was conducted using official Paralympic videos available on the Internet.
- The characteristics of falls during wheelchair rugby and wheelchair basketball competitions were analyzed by three physiotherapists to ensure consistency.

- Data from the Tokyo 2020 Paralympic Games and Rio 2016 Paralympic Games were analyzed using video-based descriptive comparisons.
- To match the number of teams in wheelchair rugby and wheelchair basketball, it was not possible to include data of the 53 wheelchair basketball qualifying games in the analysis.
- This video analysis cannot explain the relationship between falls and injuries.

INTRODUCTION

The Tokyo 2020 Paralympic Games featured 4403 athletes competing in 539 events in 22 sports, making it the largest Paralympic Games in history and drawing increasing attention to the Paralympic Games. Hence, with the increase in the number of athletes, the level of competition is expected to improve, and sports injuries are also expected to increase [1]. A total of 441 athletes sustained as many as 510 injuries during the 14 days of competition at the Rio 2016 Paralympics, with 61 athletes injured during their participation in wheelchair rugby (WR) and wheelchair basketball (WB); this translated to 14.9 and 12.8 injuries per 1000 athlete days, respectively [2]. Furthermore, contact team sports such as WR and WB have a higher incidence of acute injuries than fencing and tennis (61% 65%, 42%, and 37%, respectively) [3]. In these two wheelchair team sports, many falls are common. Regarding the incidence of falls at the Rio 2016 Paralympics, 359 falls occurred in three disciplines (WR, men's WB [MWB], and women's WB [WWB]). The rate of falls was the highest for MWB, followed by WWB and WR [4]. However, no other study has clarified the characteristics of falls in each sport. Moreover, the relationship between sports injury characteristics and the occurrence of falls in wheelchair team sports has not yet been presented. In the case of wheelchair sports, falls can result in head impacts and emergencies such as concussions, and research in the area of concussions has received increasing attention [5, 6]. Therefore, understanding the causes of falls during games is essential in considering the prevention of injury occurrence in these team sports, and more data needs to be collected. One way to analyze the occurrence of falls in wheelchair-related sports is to use video recordings of games.

By retrospectively analyzing the video recordings of the games, which is an effective method that has been used previously to interpret injury occurrence in healthy individuals, [7-9] the occurrence and characteristics of these wheelchair-related sport injuries can be identified. The analysis of anterior cruciate ligament injuries helped researchers to understand the change of dynamic alignment during injury and plan preventive measures, [7] which is why we used this method in our previous study to investigate the incidence of falls in WR and WB games at the Rio 2016 Paralympic Games [4].

WR and WB players also include individuals with quadriplegia, paraplegia, and amputations. Overall, WR players have more severe functional impairments than WB players, especially those affecting the extremities, such as cervical spinal cord injury (tetraplegia), multiple amputations, polio, cerebral palsy, and other neurological diseases [10]. WR players are classified based on their hand, arm, shoulder, and trunk functions, with disability levels ranging from 0.5 (lowest physical function) to 3.5 (highest physical function) and are placed into seven categories based on their level of disability [11]. WB players must

have a permanent physical disability with reduced function of the lower extremities, which includes paralysis of the lower extremities, musculoskeletal disorders, spina bifida, amputation, and childhood paralysis [11]. These athletes are classified from 1.0 (lowest physical function) to 4.5 (highest physical function) [12]. Performance and injury rates vary greatly by class [13, 14], and fall rates are expected to vary as well. However, no analysis of fall incidence by class has been reported.

At the Rio 2016 Paralympics, the incidence of falls and the duration of competition, the presence of contact, the direction of the fall, and the initial site of contact had different characteristics in the three events [4]. Meanwhile, in our previous study we have not been able to clarify the incidence of falls for each class. In addition, five years have passed since the Rio 2016 Paralympics, and the incidence of falls is expected to be different due to the improvement of athletic performance. Moreover, the Tokyo 2020 Paralympics was held under special circumstances, with the games being postponed for one year due to the coronavirus disease 2019 pandemic. Therefore, new characteristics of fall occurrence different from those of the Rio 2016 Paralympics may emerge, and accumulation of data will be crucial for injury prevention. This study aimed to investigate the number of falls and the occurrence of falls among wheelchair athletes in team sports at the 2020 Tokyo Paralympic Games, to compare the results with those at the 2016 Rio Paralympic Games, and to clarify the characteristics of major falls among the three major wheelchair team sports (WR, MWB, and WWB).

METHODS

In this cross-sectional video analysis, we obtained the official match videos of the WR and WB wheelchair team competitions from the International Paralympic Committee's (IPC) official website, and analyzed the match videos of all eight teams participating in the WR and eight teams each from the MWB and WWB that advanced to the quarterfinals of the Tokyo 2020 Paralympic Games (Fig. 1). The WR matches are played in four 8-minute periods, and the WB matches are played in four 10-minute periods. Three physiotherapists with expertise in para-sports systematically analyzed the videos for fall mechanism and play circumstances. The videos were repeated as needed and displayed at normal speed, slow speed, or in still images. To record the number of falls, duration of play at the time of the fall, phase of play (offense or defense), contact with another player, direction of the fall, location of the fall (backcourt, frontcourt, or key or paint area), and the body part that first made contact with the floor, we modified a standard form similar to the one used in previous video analyses [4, 15]. In order to record all falls, contact with the floor was considered to be necessary. Additionally, the fall data obtained from the IPC official website of the Rio 2016 Paralympic Games and used in our previous study from a total of 18 WR and 10 WB match videos of men (MWB) and women (WWB), including eight teams in one event, were also used in this analysis [4]. Analysis of the Rio 2016 Paralympic Games data was also conducted using the same methods in this present 2020 analysis.

Data regarding player information (age, sex, and functional classification) were used from the IPC website (Table 1). Regarding disability classification, based on previous studies, for WR, ≥2.0 was classified as high pointer and ≤1.5 as low pointer [16]; for WB, ≥3.0 were classified as high pointer and ≤2.5 as low pointer [17].

Statistical analysis

For all categorical variables, results that were consistent with the ratings of two out of three observers were reported. A good agreement among the three observers for all variables was considered when two or more observers were in agreement for all categorical items and the kappa coefficient was >0.8. A one-way analysis of variance was used to compare the mean incidence of falls for each of the three wheelchair sports games. Follow-up analyses were conducted using Bonferroni's post hoc test, if necessary. For the comparison of categorical variables, Pearson's X^2 test or Fisher's exact test was used. Fisher's exact test was used instead of the X^2 test when the expected number was <5. Adjusted residuals were used for post hoc tests. Comparisons of the incidence of falls with and without foul contact were also conducted using Pearson's chi-square test. In order to compare the characteristics of falls at the Tokyo 2020 Paralympic Games with those at the Rio 2016

Paralympic Games, descriptive comparisons were also made between the results from the 2020 and 2016 Games regarding the presence of contact with other athletes, and the percentage of low pointer falls. All statistical analyses were performed using IBM SPSS version 27.0 (IBM Japan, Tokyo, Japan). A p-value <0.05 was considered statistically significant.

Patient and public involvement

This study was conducted without patient involvement. Patients were not asked to comment on the study design, consulted to derive results relevant to them, or consulted to interpret the results. Patients were also not consulted in the writing or editing of this document for readability or accuracy.

RESULTS

Overall, 430 falls were recorded, of which 104 (24.2%) occurred in WR, 230 (53.5%) in MWB, and 96 (22.3%) in WWB, with an average number of falls per game of 5.8±3.1, 23.0±5.4, and 9.6±5.0, respectively. There was a significant difference in the mean number of falls between only MWB and the other events (WR and WWB) ($p<0.001$). Table 2 shows the characteristics of falls in the three sport groups. Significant differences in class difference ($p<0.001$), direction of fall ($p<0.001$), location of fall ($p=0.019$), and body part first impacted ($p<0.001$) were detected among the three sports. When comparing falls with and without foul play, significant differences were detected in class ($p=0.021$) and whether contact occurred ($p=0.007$) (Table 3).

Table 4 shows a comparison of the characteristics of falls during the Rio 2016 Paralympics and the Tokyo 2020 Paralympics. In Rio 2016, a significant difference in the tendency of falls was observed among the three groups with and without contact ($p=0.037$), while in Tokyo 2020, no difference was observed ($p=0.167$). In terms of the number of low pointer falls, a significant difference in the tendency of falls was observed among the three groups in both Rio 2016 and Tokyo 2020 Paralympic Games ($p=0.003$, $p<0.001$).

Table 1. Demographic characteristics of athletes who participated in the matches

	Wheelchair rugby (n=92)	Men's wheelchair basketball (n=96)	Women's wheelchair basketball (n=95)
Age (years±SD)	34.0±6.4	30.5±6.1	28.9±6.6
Sex			
Male	88	96	-
Female	4	-	95
Classification (%)			
0.5	15 (16)	-	-
1.0	17 (18)	16 (17)	15 (16)
1.5	8 (9)	11 (11)	9 (9)
2.0	18 (20)	10 (10)	9 (9)
2.5	7 (8)	14 (15)	10 (11)
3.0	18 (20)	7 (7)	19 (20)
3.5	9 (10)	5 (5)	8 (8)
4.0	-	15 (16)	13 (14)
4.5	-	17 (18)	13 (14)

Table 2. Fall characteristics of the three groups

	Wheelchair rugby (n=104)	Men's wheelchair basketball (n=230)	Women's wheelchair basketball (n=96)	*p* - value
Classification (%)				**<0.001**
Low pointer	16 (15.4)†	125 (54.3)*	43 (44.8)	
High pointer	88 (84.6)*	105 (45.7)†	53 (55.2)	
Playing time (%)				
First quarter	29 (27.9)	46 (20.0)	28 (29.2)	0.389
Second quarter	24 (23.1)	48 (20.9)	21 (21.9)	
Third quarter	25 (24.0)	57 (24.8)	22 (22.9)	
Fourth quarter	26 (25.0)	79 (34.3)	25 (26.0)	

10

Playing phase (%)				0.154
Offence	60 (57.7)	147 (63.9)	68 (70.8)	
Defence	44 (42.3)	83 (36.1)	28 (29.2)	
Unidentified	-	-	-	
Contact with another player (%)				0.167
Contact	99 (95.2)	209 (90.9)	90 (93.8)	
Non-contact	5 (4.8)	15 (6.5)	3 (3.1)	
Unidentified	-	6 (2.6)	3 (3.1)	
Direction of the fall (%)				**<0.001**
Left	32 (30.8)*	27 (11.7)†	18 (18.8)	
Right	31 (29.8)*	38 (16.5)	15 (15.6)	
Forward	27 (26.0)†	106 (46.1)*	42 (43.8)	
Backward	12 (11.5)†	53 (23.0)*	16 (16.7)	
Unidentified	2 (1.9)	6 (2.6)	5 (5.2)	
Location of the fall (%)				**0.019**
Back court	40 (38.5)*	62 (27.0)	27 (28.1)	
Front court	43 (41.3)	79 (34.3)	34 (35.4)	
Paint/key area	21 (20.2)†	89 (38.7)*	35 (36.5)	
Body part first in contact with the floor (%)				**<0.001**
Hand	60 (57.7)†	180 (78.3)	81 (84.4)*	
Elbow	24 (23.1)*	16 (7.0)†	2 (2.1)†	
Shoulder	7 (6.7)*	5 (2.2)	1 (1.0)	
Back	6 (5.8)	15 (6.5)	5 (5.2)	
Unidentified/combined	7 (6.7)	14 (6.1)	7 (7.3)	

201 • Values are expressed as the number of falls (% of total falls) for each group.

202 • * Significantly higher among the three events ($p<0.05$)

203 • †Significantly lower among the three events ($p<0.05$)

204

Table 3. Fall characteristics according to foul judgement

	No foul (n=258)	Foul (n=172)	*p* - value
Classification (%)			**0.021**
Low pointer	122 (47.3)*	62 (36.0)†	
High pointer	136 (52.7)†	110 (64.0)*	
Contact with another player (%)			**0.007**
Contact	227 (88.0)†	171 (99.4)*	
Non-contact	23 (8.9)*	0 (0.0)†	
Unidentified	8 (3.1)	1 (0.6)	

- Values are expressed as the number of falls (% of total falls) for each group.
- *Significantly higher in foul judgment (p<0.05)
- †Significantly lower in foul judgment (p<0.05)

Table 4. The difference of fall characteristics during Tokyo 2020 and Rio 2016

Variable	Olympic	WR	MWB	WWB	*p* - value
Contact with another player (%)	Rio (total=315)	78 (24.8)†	152 (48.3)	85 (27.0)	**0.037**
	Tokyo (total=398)	99 (24.9)	209 (52.5)	90 (22.6)	0.167
Low pointer (%)	Rio (total=112)	17 (15.2)†	65 (58.0)*	30 (26.8)	**0.003**
	Tokyo (total=184)	16 (8.7)†	125 (67.9)*	43 (23.4)	**<0.001**

- Values are expressed as the number of falls (% of total falls) for each Paralympic Games.
- * Significantly higher rate among the three events (p<0.05)
- † Significantly lower rate among the three events (p<0.05)

DISCUSSION

The characteristics of the number of falls occurring during the Tokyo 2020 Games among the three sports were similar to those of Rio 2016, with WB having a higher likelihood

of falling than WR; MWB had the highest risk of falling. Furthermore, the number of falls ranged from 5.8 to 23.0 per game, which was more than in Rio 2016 (5.3 to 17.2 per game). However, in terms of the presence or absence of contact and competition time, which tended to differ among the three events in Rio 2016, no difference was observed among the three events in Tokyo 2020. Meanwhile, a new difference was noted in the tendency of falls by class. To the best of our knowledge, this is the first study to characterize falls in wheelchair athletes playing team sports at the Paralympic Games and to descriptively compare them between Rio 2016 and Tokyo 2020.

As a result of dividing the number of fallers in each category into high and low pointers, WR (84.6%) and WWB (55.2%) tended to have a high percentage of falls among high pointers, while MWB (54.3%) conversely tended to have a high percentage of falls among low pointers. Low pointing includes severe trunk dysfunction in addition to upper limb dysfunction in WR and severe trunk dysfunction in WB [11, 12]. Therefore, less dynamic than high pointers, they avoided playing with the risk of falling, and as a result, estimated that the number of falls was lower. Nevertheless, in the MWB, the low pointers fell more often than the high pointers. This could be due to the difference in the proportion of low pointers and high pointers in the competition. In a previous study comparing the performance of male and female WB players, it has been reported that female players performed similarly to male players with a point ≥1.5 [18]. Hence, it can be inferred that up to 2.0–2.5 of the low pointers in MWB were able to move nearly as much as the high pointers in WWB. Assuming that high pointers can move aggressively on the court and that the increased contact with the opponent increases the risk of falling, players with a point >2.0 (72%) may be at risk of falling in MWB. If we assume that the athletes can move aggressively in the MWB and are at an increased risk of falling, we would expect that athletes with a point ≥2.0 would be at risk of falling in MWB (72%). Meanwhile, athletes with 2.0–2.5 points (low pointers) who can perform as well as female high pointers may have fallen more frequently in the MWB because they have less residual function. In order to consider the risk of falling in MWB, it is necessary to focus on the athletes with 2.0–2.5 points who can perform as well as female high pointers and have a less residual function among men, rather than using the general classification of low pointer and high pointer.

When the incidence of falls with and without foul play was compared, the low pointers had 66.3% of falls without foul play. Meanwhile, the high pointers showed a different trend from the low pointers, with 55.3% of falls without foul play and 44.7% of falls with foul play, showing little difference in the incidence of falls with and without foul play. Moreover, despite the overwhelming prevalence of contact-type falls, there were more falls without foul play (n=258) than with foul play (n=172). In Rio 2016, the incidence of contact

falls in WR was lower than in WB, but this time there was no difference in the incidence of contact falls in the three disciplines. This result may be due to an increase in falls caused by tackles without foul play in WR. At the Tokyo 2020 Games, the Paralympics were postponed for one year due to the pandemic, during which time the number of external games themselves decreased [19, 20]. Since no international competitions were held for about a year, it is possible that there was little experience of contact play in the games. In addition, due to the pandemic, there was a period when contact play itself was avoided, and it is possible that contact play was not satisfactory during practice. Therefore, it is expected that WRs who were allowed to make contact forward of the axle were less tolerant of contact during games, and that falls in contact increased. Since we did not observe the situation during practice, we can only speculate, but the environment of Tokyo 2020 is unique in many ways, and these factors may have changed the situation in which falls occurred.

In terms of fall direction, the WR players tended to fall more to the left, right, and front while the WB players tended to fall more to the front. The proportion of elbows and shoulders in the WR players was higher than that in the WB players, and most of the WB players fell from their hands. In WR, tackling from behind is a foul, while tackling from in front of the axle is allowed. Since the impact at contact is large, the momentum of the contacting side leads directly to a fall, and it is expected that there are many falls to the left and right. In addition, the tackled player still has the momentum of forward propulsion and falls forward as it is, so the WR is expected to have more falls to the left and right and forward. On the other hand, for WBs, contact is allowed, but not as violent contact as tackling; therefore, even if the player loses balance due to contact, he will fall while rotating forward, which is expected to result in more forward falls. Additionally, most WR players have out-of-place injuries in their upper limbs, and their remaining trunk function is less than that of the WB players [21]. In the case of a fall, WR players may not be able to put out their hands immediately and may contact the ground from the elbow or shoulder. When the incidence of falls was divided into the backcourt, frontcourt, and paint (key) area, the incidence of falls in the key area was lower in the WR players, while the WB players tended to have more falls in the paint area. This may be due to the competition characteristics of WR, where contact in the key area is prohibited, and WB, where many players gather in the paint area under the goal. Therefore, it is necessary to understand that the occurrence of falls and the site of physical contact at the time of falls are different between WR and WB, even in the same team sports event. The incidence of injuries in WR and WB team sport events in the Paralympics did not improve in the London and Rio Paralympics (2012 and 2016, respectively) [2, 3]. Furthermore, a detailed analysis of the mechanisms of trauma and injury has not been reported. The fact that the trends of fall characteristics of WR and WB were similar in Rio

2016 and Tokyo 2020 should be very useful data for the prevention of injury occurrence in WR and WB in the future.

This study's most significant finding is that the number of MWB low pointer falls increased more in Tokyo 2020 compared with Rio 2016. This may be due to the difference in team composition. In Rio 2016, MWB low pointers accounted for 47% [4], while in Tokyo 2020, they accounted for 53%. In particular, there was a 9% decrease in the number of players with a with 3.0–3.5 points and a 4% increase in the number of players with 2.0–2.5 points. Therefore, it is expected that the countries that remain in the MWB final tournament tend to have more opportunities for players with ≥2.0 points, who have some remaining trunk function. However, in the MWB, the players with less residual function may be required to exert more effort to keep up with the high pointers. Therefore, in order to prevent falls in the future, it will be important to conduct research focusing on the details of falls (e.g., the situation at the time of the fall and the direction of the fall) in athletes with MWB between 2.0 and 2.5, as well as on measures to prevent falls during contact. It will then be important to link this research to the prevention of injury occurrence in wheelchair team sports.

Limitations

There are several limitations to this study. First, we analyzed only official IPC videos and Internet-based IPC reports, so it is unclear whether we were able to analyze all actual falls. Nevertheless, we were able to analyze most of the falls, including those that interrupted the video. Second, we analyzed the games of the top eight teams in MWB and WWB to unify the number of teams, players, and level of competition with WR. The analysis of the 53 qualifying games excluded in our study can be used to present the characteristics of future WB falls. Third, the players were not directly involved in this study, and the results were only obtained from the videos. A more detailed and accurate analysis could be conducted by directly surveying the players who fell. Lastly, we did not identify any injuries that occurred during the games. This is because the video and data used for this analysis did not provide data on whether an injury had occurred, whether the player was treated by a doctor, or whether the player left the game injured after the fall. Therefore, whether these falls resulted in injuries or not was unknown. However, comparing Rio 2016 and Tokyo 2020, it is expected that more attention and research focus will be given to Paralympic sports injuries in the three popular team sports events of the Paralympics to clarify the differences in fall injuries between WR and WB athletes. Further research is needed to determine the differences in fall injuries between WR and WB athletes.

CONCLUSION

As in Rio 2016, the incidence of falls in Tokyo 2020 was high, with MWB having the

highest number of falls, followed by WWB and WR. The direction of fall occurrence and the first site of body contact at the time of the fall in Tokyo 2020 were also similar to those in Rio 2016. However, the occurrence of falls with and without contact in Tokyo 2020 was different from that in Rio 2016. Moreover, a new finding was obtained when comparing the low and high pointers: more falls occurred in the low pointers of MWB. Further research will be conducted to understand the mechanism of fall injuries in wheelchair athletes and to relate these results to injury research.

ACKNOWLEDGMENTS:

COMPETING INTERESTS: None declared.

FUNDING: This research received no specific grant from any funding agency in the public, commercial. or not-for-profit sectors.

AUTHOR CONTRIBUTIONS: KF designed the study and wrote the paper; all authors revised the manuscript; NM, JS, and RS contributed to the analysis and interpretation of the data and assisted in the preparation of the manuscript; ST, SA, TT, KK, MY, RM, TA, HE, and TT performed the video analysis; MK and AS provided advice, and YU was the principal investigator. All authors have approved the final version of the manuscript and have agreed to be accountable for all aspects of the work to ensure that any questions related to the accuracy or completeness of any part of the work are properly investigated and resolved.

PATINT AND PUBLIC INVOLVEMENT: Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

PATIENT CONSENT FOR PUBLICATION: Not required.

ETHICS APPROVAL: This study protocol was approved by Hiroshima University's Institutional Review Board (Study protocol ID number: E-1459). The same Review Board waived the need for obtaining informed consent from the athletes.

DATA AVAILABILITY STATEMENT: All data relevant to the study are included in the article or uploaded as supplementary information. All data generated or analyzed during this study are included in this published article.

REFERENCES

1. Clifton DR, Hertel J, Onate JA, et al. The first decade of web-based sports injury surveillance: descriptive epidemiology of injuries in US high school Girls' basketball (2005–2006 through 2013–2014) and National Collegiate Athletic Association Women's basketball (2004–2005 through 2013–2014). *J Athl Train* 2018;53:1037–48.
2. Derman W, Runciman P, Schwellnus M, et al. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2018;52:24–31. https://doi.org/10.1136/bjsports-2017-098039.
3. Willick SE, Webborn N, Emery C, et al. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32. https://doi.org/10.1136/bjsports-2013-092374.
4. Sasadai J, Maeda N, Shimizu R, et al. Analysis of team-sport wheelchair falls during the Rio 2016 Summer Paralympic Games: a video-based cross-sectional observational study. *BMJ Open* 2020;10:e033088. https://doi.org/10.1136/bmjopen-2019-033088.
5. Weiler R, Blauwet C, Clarke D, et al. Concussion in para sport: the first position statement of the Concussion in Para Sport (CIPS) Group. *Br J Sports Med* 2021;55:1187-95. https://doi.org/10.1136/bjsports-2020-103696.
6. Moran RN, Broglio SP, Francioni KK, et al. Exploring Baseline Concussion-Assessment Performance in Adapted Wheelchair Sport Athletes. *J Athl Train* 2020;55(8):856–62. https://doi.org/10.4085/1062-6050-294-19.
7. Olsen OE, Myklebust G, Engebretsen L, et al. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med* 2004;32:1002–12. https://doi.org/10.1177/0363546503261724.
8. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *Br J Sports Med* 2015;49:547–51. https://doi.org/10.1136/bjsports-2013-092234.
9. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. *Br J Sports Med* 2015;49:552–5. https://doi.org/10.1136/bjsports-2013-092235.

10. Tweedy S, Diaper N. Introduction to wheelchair sport. In: Goosey-Tolfrey V, ed. Wheelchair sport. A complete guide for athletes, coaches and teachers. Illinois, USA: Human Kinetics 2010: 3–28.
11. International wheelchair rugby federation. 2021. https://worldwheelchair.rugby/the-game-classifications/ (accessed).
12. IWBF player classification manual. 2021. https://iwbf.org/downloads/ (accessed).
13. Haydon DS, Pinder RA, Grimshaw PN, et al. Overground-Propulsion Kinematics and Acceleration in Elite Wheelchair Rugby. *Int J Sports Physiol Perform* 2021 Feb;13(2):156–62. https://journals.humankinetics.com/view/journals/ijspp/13/2/article-p156.xml (accessed Nov 30, 2021).
14. Marszałek J, Kosmol A, Morgulec-Adamowicz N, et al. Laboratory and Non-laboratory Assessment of Anaerobic Performance of Elite Male Wheelchair Basketball Athletes. *Front Psychol* 2019;10:514. https://doi.org/10.3389/fpsyg.2019.00514.
15. Blauwet C, Webborn N, Kissick J, et al. When van Mechelen's sequence of injury prevention model requires pragmatic and accelerated action: the case of para alpine skiing in Pyeong Chang 2018. *Br J Sports Med* 2019;53:1390–1.
16. Sadate B, Thierry W, Marjolaine A, et al. Performance, asymmetry and biomechanical parameters in wheelchair rugby players. *Sports Biomech* 2021 Apr;1898670. www.doi.org/10.1080/14763141.2021.1898670 (accessed Nov 29, 2021).
17. Tachibana K, Mutsuzaki H, Shimizu Y, et al. Influence of functional classification on skill tests in elite female wheelchair basketball athletes. *Medicina* 2019;55:740. https://doi.org/10.3390/medicina55110740 (accessed).
18. Cavedon V, Zancanaro C, Milanese C. Anthropometry, Body Composition, and Performance in Sport-Specific Field Test in Female Wheelchair Basketball Players. *Front Physiol* 2018;30:568. https://doi.org/10.3389/fphys.2018.00568.
19. Dove J, Gage A, Kriz P, et al. COVID-19 and Review of Current Recommendations for Return to Athletic Play. *R I Med J* 2013;103:15–20.
20. Mann RH, Clift BC, Boykoff J, et al. Athletes as community; athletes in community: covid-19, sporting mega-events and athlete health protection. *Br J Sports Med* 2020;54:1071–2. https://doi.org/10.1136/bjsports-2020-102433.
21. van der Slikke RMA, Berger MAM, Bregman DJJ, et al. Wearable Wheelchair Mobility Performance Measurement in Basketball, Rugby, and Tennis: Lessons for Classification and Training. *Sensors (Basel)* 2020;20:3518. https://doi.org/10.3390/s20123518.

Figure legend

Figure 1. Inclusion and exclusion criteria of match videos.

*Because WR is a mixed sport, there were no women and men categories.

MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

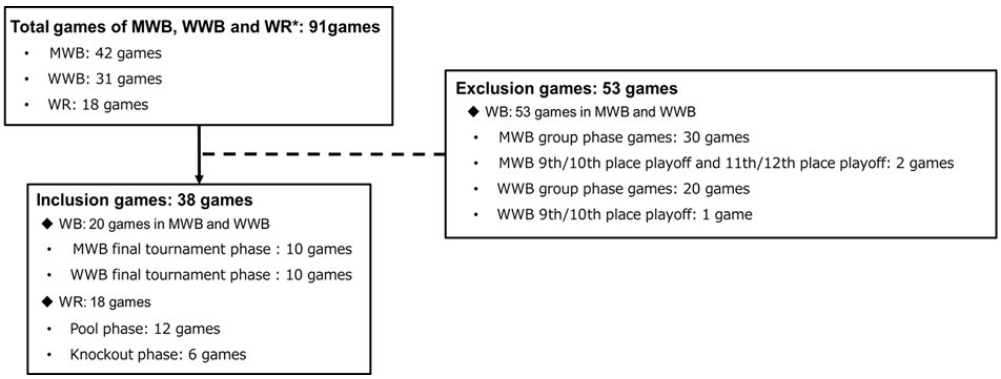

Figure 1. Inclusion and exclusion criteria of match videos. *Because WR is a mixed sport, there were no women and men categories. MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

161x59mm (150 x 150 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	Fig1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table1
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	Fig1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	-

		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.