




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

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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 analysed 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 \pm SD: 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 with 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 with that in the Rio 2016 games.

INTRODUCTION

The Tokyo 2020 Paralympic Games featured 4403 athletes competing in 539 events in 22 sports, making it the largest Paralympic

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 analysed by three physiotherapists to ensure consistency.
- ⇒ Data from the Tokyo 2020 Paralympic Games and Rio 2016 Paralympic Games were analysed 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.

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 analyse the occurrence of falls in wheelchair-related sports is to use video recordings of games.

By retrospectively analysing 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, 5 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 1 year due to 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 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 analysed 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 (figure 1). The WR matches are played in four 8 min periods, and the WB matches are played in four 10 min periods. Three

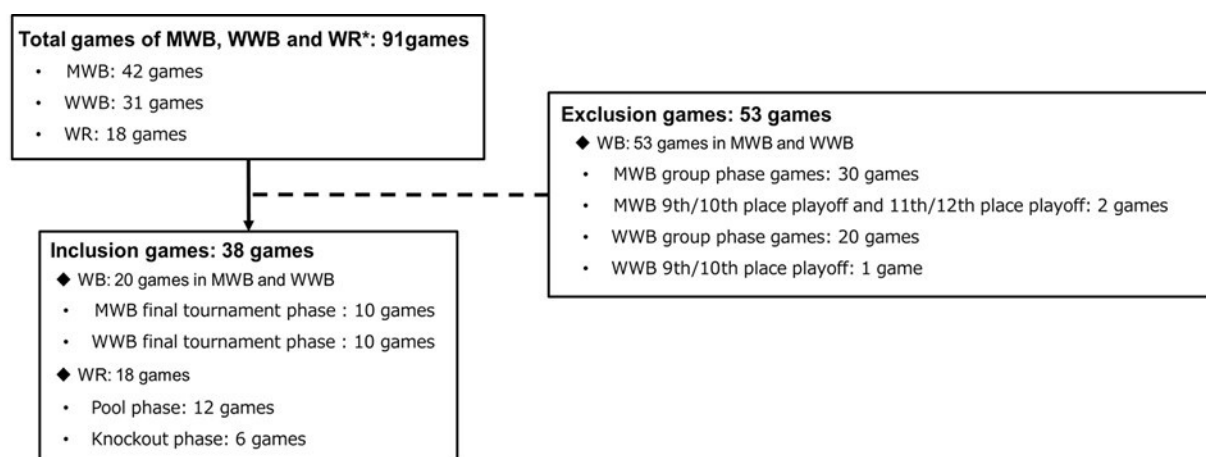


Figure 1 Inclusion and exclusion criteria of match videos. *Because WR is a mixed sport, there were no women and men categories. MWB, WB game videos for men; WB, wheelchair basketball; WR, wheelchair rugby; WWB, WB game videos for women.

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) |

physiotherapists with expertise in para-sports systematically analysed 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 (offence or defence), 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 10WB 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 pointer¹⁶; 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 χ^2 test or Fisher's exact test was used. Fisher's exact test was used instead of the χ^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 χ^2 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 V.27.0 (IBM). A $p<0.05$ 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 ($p=0.003$, $p<0.001$).

DISCUSSION

The characteristics of the number of falls occurring during the Tokyo 2020 Games among the three sports

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 (%) | | | | 0.389 |
| First quarter | 29 (27.9) | 46 (20.0) | 28 (29.2) | |
| 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) | |

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

p values < 0.05 are considered significant (indicated with **emboldened** font)

*Significantly lower among the three events (p<0.05).

†Significantly higher among the three events (p<0.05).

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 (5.3–17.2 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 characterise 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

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.
p values < 0.05 are considered significant (indicated with **emboldened** font)
*Significantly higher in foul judgement (p<0.05).
†Significantly lower in foul judgement (p<0.05).

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 1 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

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.
p values < 0.05 are considered significant (indicated with **emboldened** font)
*Significantly lower rate among the three events (p<0.05).
†Significantly higher rate among the three events (p<0.05).
MWB, men's wheelchair basketball; WR, wheelchair rugby; WWB, women's WB.

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 (eg, 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 analysed only official IPC videos and Internet-based IPC reports, so it is unclear whether we were able to analyse

all actual falls. Nevertheless, we were able to analyse most of the falls, including those that interrupted the video. Second, we analysed 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.

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study are included in the article or uploaded as online supplemental information. All data generated or analysed during this study are included in this published article.

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