Women, older age, faster cycling speed and increased wind speeds are independent risk factors for acute injury-related medical encounters during a 109 km mass community-based participation cycling event: a 3-year study in 102251 race starters—SAFER XII

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ABSTRACTt

Background: There are limited data on acute injury-related medical encounters (injuries) in endurance cycling events.

Objective: To determine the risk factors for injuries during a mass community-based endurance cycling event.

Design: Retrospective, cross-sectional study.

Setting: Cape Town Cycle Tour (109 km), South Africa.

Participants: 102 251 race starters.

Methods: All injuries for 3 years were recorded by race medical doctors and nurses. Injuries were grouped into main anatomical area of injury, and a Poisson regression model was used to determine the risk factors associated with injuries.

Results: The four injury risk factors associated with all injuries during an endurance cycling event were sex (women vs men, $p<0.0001$), older age ($p=0.0005$), faster cycling speed ($p<0.0001$) and higher average individualised Wind Speed (aiWindSpeed, $p<0.0001$). The only risk factor for serious/life-threatening injuries was women ($p=0.0413$). For specific main anatomical areas: head/neck (women), upper limb (women, older age, faster cyclists), trunk (women, higher aiWindSpeed), and lower limb (higher aiWindSpeed).

Conclusion: Women, older age, faster cycling speed and higher aiWindSpeed were all risk factors for acute injuries during a mass community-based endurance cycling event. These risk factors should help inform race organisers and medical teams on race day to ensure the best medical care is given, and effective acute injury prevention programmes are disseminated.

INTRODUCTION

Physical exercise has increased in popularity in recent years, mostly owing to the increase in knowledge regarding its health benefits.[1 2] Cycling, in particular, is a popular form of recreational exercise, and participation in mass community-based endurance cycling events has increased.[3 4] However, cycling is also well known for its high incidence of injuries (both acute and gradual onset injuries).[5 6]

Injury-related medical encounters during cycling events have not been well documented, and only a few studies have investigated acute injury-related medical encounters (from here on referred to as 'injuries'; also referred to as traumatic injuries) during these events.[4 7–13] Furthermore, the definitions are not standardised in previous papers, and this makes comparisons difficult. In single-day cycling events, the incidence rate (IR) of acute traumatic injuries varies from 3.7 to 5 per 1000 participants.[7 8 13] In one other study, during a multiday cycling event, a medical encounter rate of 199 per 1000 participants was reported.[10] However, this included all medical encounters (both injuries and illnesses) of all severity, illustrating how difficult it can be to make comparisons between studies. In order to address this problem, a consensus statement was recently published to standardise definitions and methods of data recording and reporting of medical encounters at mass community-based endurance sports events.[14] We recently reported an IR of 3.2 injuries per 1000 race starters during a 109 km community-based mass participation cycling event,[15] using the definitions and methods described in the 2019 consensus document.[14] We also reported that the upper limb (IR=1.9) was the anatomical area that was most commonly injured, followed by the lower limb (IR=1.0) and head/neck (IR=0.8) regions.[15]

Determining the IR of injuries is the first important step in injury prevention,[16] and this must be followed by investigations to identify risk factors associated with these injuries.[16] Risk factors associated with acute injuries in mass community-based endurance cycling events have not been thoroughly investigated. Women were found to have an increased risk of acute injuries compared with men in two studies,[7 8] and in another study, women were also found to be at a higher risk for serious acute injuries.[13] In two studies in multiday cycling events, the lack of previous tour experience was associated with an increased risk of acute/traumatic injury[17] or any injury/illness.[12] In another study, racing history was associated with an increased risk of injury, [17] but another study showed inexperienced cyclists were more likely to sustain an injury.[13] Age of participants for acute injuries[8] and all medical encounters in cyclists has been explored but with mixed results.[12] Risk factors for acute injuries in specific anatomical areas have not been explored, with only one study reporting an association between women and an increased risk for eye problems.[7]

The study aimed to determine the independent risk factors that were associated with injuries during a mass community-based participation endurance cycling event (the Cape Town Cycle Tour) over 3 years (2012–2014). We also wanted to identify the risk factors associated with the specific main anatomical areas of injuries in endurance cyclists. We hypothesise that race day factors as well as age and sex will be risk factors for injuries.

METHODS

Study design

This is a cross-sectional study with a retrospective analysis of data collected over 3 years from 2012 to 2014.

Participants and demographics

This study is part of a series of studies known as the *S*trategies to reduce *A*dverse medical events *F*or the *E*xercise*R* studies.[18] This study is a component of the retrospective study at the Cape Town Cycle Tour that was conducted on all race starters from 2012 to 2014 and the details of the study methodology have been fully described.[15]

The Cape Town Cycle Tour is held annually in Cape Town and is approximately 109 km.[19] During the 3-year study period, 128 350 cyclists registered for the races with 102 251 cyclists starting the races (race starters=79.7% of registrations). Only race starters were included in this study. Participants are required to be 13 years or older to enter the race, while there is no upper age limit.

Medical data collection

Details of the medical data collection procedure and specific definitions have been reported and are in accordance with the consensus statement for reporting in mass community-based endurance sports events.[14 15] In summary, each injury was accurately recorded by race medical doctors and nurses on each race day using an electronic platform during the 3-year study period in a standardised format. All injuries were reviewed and classified by the race medical director as moderate or serious life-threatening injuries, according to the criteria as defined in the 2019 international consensus of reporting medical encounters[14] (JK). Injuries were subclassified by main anatomical area of injury affected as follows: head and neck, upper limb, trunk (combination of chest, abdomen, lumbar spine, hip/pelvis) and lower limb.

Environmental conditions on race days for each year

On race day, hourly weather data were collected from five automated weather stations from the South African Weather Services along the route. Using these data, and the individual race participant's start time and average speed into account, we could calculate an average individual weather exposure value (average individual Wind Speed exposure, aiWindSpeed, and average individual Wet-Bulb Globe Temperature, aiWBGT) for each individual cyclist (further details regarding this calculation in supplementary material A). Both variables were included in the analyses of all risk factors.

Patient and public involvement (PPI)

We did not directly include PPI in this study, but the database used in the study was developed and is updated by a group that includes patient advisory representatives, including race organisers and medical directors.

Primary outcome

The primary outcome of interest was all injuries occurring during the Cape Town Cycle Tour over 3 years. Secondary outcomes were (1) serious/life-threatening injuries and (2) the following main anatomical areas of injury: head and neck, upper limb, trunk and lower limb.

Statistical analysis of data

All cyclist's entry data were entered into a database and analysed using SAS statistical software (V.9.4). One primary outcome variable and five secondary outcome variables were modelled; the primary outcome of interest was all injuries and the secondary outcome variables were (1) serious/life-threatening injuries and (2) the four main anatomical areas of injury: head and neck, upper limb, trunk and lower limb. Separate regression models were done with the six outcomes, including sex, age groups, average cycling speed and average individualised windspeed on race day as independent variables.

When including the independent variables in the regression model, some of the categories had small frequencies and thus some of the log-binomial regression models encountered convergence problems. Therefore, a modified Poisson regression with robust standard errors (sandwich estimator) was used to overcome this limitation of the log-binomial model.

As the same cyclist could have entered the race up to three times during the study period, the correlated structure of the data was accounted for by specifying an exchangeable correlation structure type.

For the main outcome, all injuries, results for one multiple regression model including all the independent variables were reported. For the secondary outcomes, due to the small numbers of injuries, results for separate univariate regression models were reported for each independent variable and no multiple model results were reported.

For all outcome variables the numbers overall, the numbers in each category of the independent variable, and the IRs per 1000 race starters (IR and 95% CI) were reported. The IRRs (95% CI) were also reported to indicate the relative measure of the effect.

The statistical significance level was 5%, unless otherwise specified.

RESULTS

Demographics of participants

Our cohort (race starters) consisted of 80 354 men and 21 897 women (table 1). Of the 102 251 starters, only 97 335 finished the race and this consisted of 77 074 men and 20 261 women.

Table 1. Demographics of all race starters (by sex, age group and year)

Sex	Age groups	2012 n (%)	2013 n (%)	2014 n (%)	All years n (%)
All		43 578 (100)	42 229 (100)	42 543 (100)	102 251 (100)
Males	≤30 years	5794 (17.0)	5793 (16.9)	5422 (15.9)	17 009 (16.6)
	31–40 years	6575 (19.3)	6457 (18.9)	6427 (18.9)	19 459 (19.0)
	41–50 years	7498 (22.1)	7592 (22.2)	7618 (22.4)	22 708 (22.2)
	>50 years	6804 (20.0)	6998 (20.5)	7376 (21.7)	21 178 (20.7)
	All	26 671 (78.5)	26 840 (78.4)	26 843 (78.8)	80 354 (78.6)
Females	≤30 years	2163 (6.4)	2183 (6.4)	2001 (5.9)	6347 (6.2)
	31–40 years	1963 (5.8)	1976 (5.8)	1891 (5.5)	5830 (5.7)
	41–50 years	2107 (6.2)	2110 (6.2)	2087 (6.1)	6304 (6.2)
	>50 years	1081 (3.2)	1110 (3.2)	1225 (3.6)	3416 (3.4)
	All	7314 (21.5)	7379 (21.6)	7204 (21.2)	21 897 (21.4)

Age, sex, cycling speed and aiWindSpeed as risk factors associated with injuries

The IR of all injuries for sex, age group, cycling speed and aiWindSpeed using a multiple regression model is depicted in table 2 (resulting in independent risk factors). Overall IR of all injuries was 3.2 (2.9 to 3.6).

For all injuries, women were at a higher risk than men ($p<0.0001$), older age ($p=0.0005$), faster cycling speed ($p<0.0001$) and higher aiWindSpeed ($p<0.0001$).

Table 2. The incidence rate (IR: per 1000 cyclists starting the race: 95% CI) of all injuries in the 3-year study period (multiple regression analysis)

Variable	Category	n	IR (95% CI)	Incidence ratio (95% CI)	P value*
All injuries (n=330)					
Sex	Female	106	5.4 (4.3 to 6.7)	2.2 (1.7 to 2.9)	<0.0001
	Male	224	2.4 (2.1 to 2.8)		
Age groups (years)	<50	233	2.8 (2.4 to 3.3)		0.0005
	>50	97	4.7 (3.8 to 5.8)	1.7 (1.3 to 2.1)	
Average cycling speed (km/hour)†	20	293	2.6 (2.2 to 3.2)	1 unit increase 1.1 (1.0 to 1.1)	<0.0001
	25		3.7 (3.2 to 4.3)		
aiWindSpeed‡	5.0	317	2.1 (1.6 to 2.6)	2 unit increase 2.2 (1.7 to 2.8)	<0.0001
	5.6		2.6 (2.2 to 3.2)		
	6.7		4.0 (3.4 to 4.8)		

- *P value for the variable in the model.
- †Continuous variable represents two specific points.
- ‡Continuous variable represents the first quartile, median, third quartile. Numbers of participants therefore not available.
- n, number of participants with injury.

The results of the main anatomical areas and serious life-threatening injury and deaths using a univariate analysis are presented in table 3. Overall IR of serious life-threatening injury and deaths was 0.2 (0.1 to 0.3) per 1000 starters, head and neck was 0.7 (0.5 to 0.9), upper limb was 1.8 (1.5 to 2.1) per 1000 starters, trunk was 0.6 (0.5 to 0.8) per 1000 starters and lower limb was 0.9 (0.8 to 1.1) per 1000 starters.

For serious life-threatening injury/deaths, women (p=0.0413) were at a marginally higher risk. For head and neck injuries, only women (p=0.0057) were significantly associated. For upper limb injuries, women (p=0.0014), older age (p=0.0194) and faster cycling speed (p=0.0089) were significantly associated. For trunk injuries, women (p=0.0303) had a marginally higher risk and higher aiWindSpeed (p=0.0041) was associated. Finally, for lower limb injuries, higher aiWindSpeed (p=0.0005) was a significant risk factor.

Table 3. The incidence rate (IR: per 1000 cyclists starting the race: 95% CI) of serious life-threatening injury and deaths, head/neck injuries, upper limb, trunk and lower limb in the 3-year study period (univariate analysis)

Variable	Category	n	IR (95% CI)	Incidence ratio (95% CI)	P value*
Serious life-threatening injury and deaths (n=22)					
Sex	Female	10	0.5 (0.2 to 0.8)	3.1 (1.3 to 7.1)	0.0413
	Male	12	0.1 (0.1 to 0.3)		
Age groups (years)	≤50	13	0.2 (0.1 to 0.3)		0.1281
	>50	9	0.4 (0.2 to 0.7)	2.2 (0.9 to 5.1)	
Average cycling speed (km/hour)†	20	22	0.2 (0.1 to 0.4)	1 unit increase 1.0 (0.9 to 1.1)	0.9943
	25		0.2 (0.1 to 0.3)		
aiWindSpeed‡	5.0	22	0.2 (0.1 to 0.4)	2 unit increase 1.1 (0.5 to 2.6)	0.8369
	5.6		0.2 (0.1 to 0.3)		
	6.7		0.2 (0.1 to 0.4)		
Head/neck (n=69)					
Sex	Female	27	1.5 (1.0 to 2.2)	2.5 (1.5 to 4.2)	0.0057
	Male	42	0.6 (0.4 to 0.8)		
Age groups (years)	≤50	45	0.6 (0.5 to 0.9)		0.0599
	>50	24	1.2 (0.8 to 1.8)	1.8 (1.1 to 3.1)	
Average cycling speed (km/hour)†	20	69	0.7 (0.5 to 1.0)	1 unit increase 1.0 (1.0 to 1.0)	0.8298
	25		0.7 (0.5 to 0.9)		
aiWindSpeed‡	5.0	69	0.9 (0.6 to 1.2)	2 unit increase 0.8 (0.3 to 1.8)	0.5134
	5.6		0.8 (0.6 to 1.0)		
	6.7		0.7 (0.4 to 1.2)		

Upper limb (n=183)					
Sex	Female	60	2.7 (2.1 to 3.5)	1.8 (1.3 to 2.4)	0.0014
	Male	123	1.5 (1.3 to 1.8)		
Age groups (years)	≤50	124	1.6 (1.3 to 1.9)		0.0194
	>50	59	2.4 (1.9 to 3.1)	1.5 (1.1 to 2.0)	
Average cycling speed (km/hour)†	20	183	1.3 (1.1 to 1.6)	1 unit increase 1.0 (1.0 to 1.1)	0.0089
	25		1.6 (1.4 to 1.9)		
aiWindSpeed‡	5.0	183	1.8 (1.4 to 2.3)	2 unit increase 1.0 (0.6 to 1.5)	0.8579
	5.6		1.8 (1.5 to 2.1)		
	6.7		1.8 (1.3 to 2.3)		
Trunk (n=63)					
Sex	Female	22	1.0 (0.7 to 1.5)	2.0 (1.2 to 3.3)	0.0303
	Male	41	0.5 (0.4 to 0.7)		
Age groups (years)	≤50	44	0.6 (0.4 to 0.8)		0.2950
	>50	19	0.8 (0.5 to 1.2)	1.4 (0.8 to 2.3)	
Average cycling speed (km/hour)†	20	63	0.6 (0.4 to 0.8)	1 unit increase 1.0 (1.0 to 1.1)	0.5828
	25		0.6 (0.5 to 0.8)		
aiWindSpeed‡	5.0	63	0.4 (0.3 to 0.6)	2 unit increase 2.2 (1.4 to 3.5)	0.0041
	5.6		0.5 (0.4 to 0.7)		
	6.7		0.8 (0.6 to 1.1)		

Lower limb (n=95)					
Sex	Female	25	1.1 (0.8 to 1.7)	1.3 (0.8 to 2.1)	0.2806
	Male	70	0.9 (0.7 to 1.1)		
Age groups (years)	≤50	66	0.9 (0.7 to 1.1)		0.1739
	>50	29	1.2 (0.8 to 1.7)	1.4 (0.9 to 2.1)	
Average cycling speed (km/hour)†	20	95	0.8 (0.6 to 1.1)	1 unit increase 1.0 (1.0 to 1.0)	0.7610
	25		0.9 (0.7 to 1.1)		
aiWindSpeed‡	5.0	95	0.6 (0.4 to 0.8)	2 unit increase 2.5 (1.6 to 3.8)	0.0005
	5.6		0.8 (0.6 to 1.0)		
	6.7		1.3 (1.0 to 1.6)		

- **Multiple injuries for the same cyclist have not been included in the analysis.**
- **Upper limb injuries constitute 55% of all injuries.**
- **There were no injury-related deaths during this period.**
- ***P value for the variable in the model.**
- **†Continuous variable represents two specific points.**
- **‡Continuous variable represents the first quartile, median, third quartile. Numbers of participants therefore not available.**
- **aiWindSpeed, average individualised Wind Speed; n, number of participants with injury.**

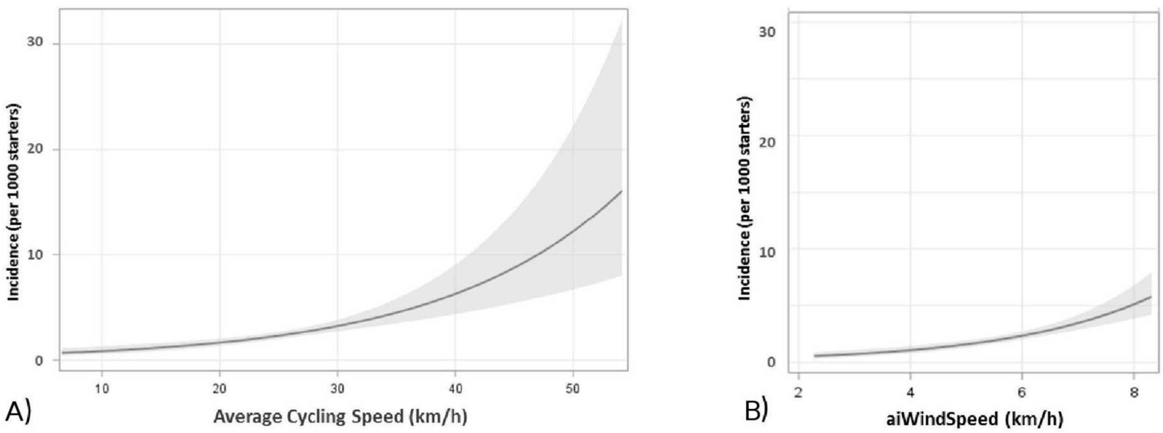

Figure 1. (A) All injury incidence for average cycling speed during the Cape Town Cycle Tour (p<0.0001). (B) All injury incidence for aiWindSpeed during the Cape Town Cycle Tour (p<0.0001). Cycling speed: modelled for participants aged 40.88 years (average age), cycling at aiWindSpeed 5.76 units (average). aiWindSpeed: average individual Wind Speed exposure, modelled for participants aged 40.88 years (average age), cycling at 23.79 km/hour (average). Wide CIs are indicative of the small sample size at that speed graphs are presented for men.

Cycling speed and wind speed as risk factors associated with all injuries

The relationship between IR of all injuries for average cycling speed and aiWindSpeed is depicted in figure 1A,B respectively.

For all injuries, faster cycling speed and aiWindSpeed were significantly associated with injuries.

Cycling speed and wind speed as risk factors associated with serious life-threatening injuries and death and main anatomical regions

The relationship between IR of upper limb injuries and average cycling speed is depicted in figure 2.

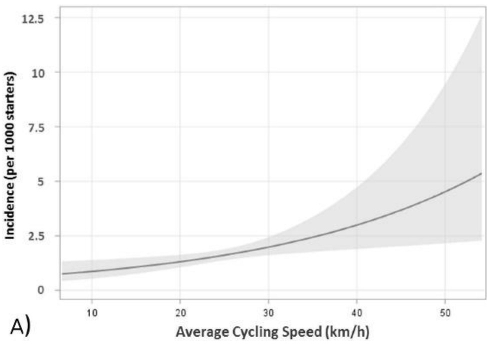

Figure 2. Upper limb injury incidence for average cycling speed (p=0.0089). Model for participants aged 40.88 years (average age), cycling at average individual Wind Speed exposure 5.76 units (average). Wide CIs are indicative of the small sample size at that speed.

Only upper limb injuries were significantly associated with faster cycling speed.

The relationship between IR of trunk and lower limb injuries for aiWindSpeed is depicted in figure 3A,B respectively.

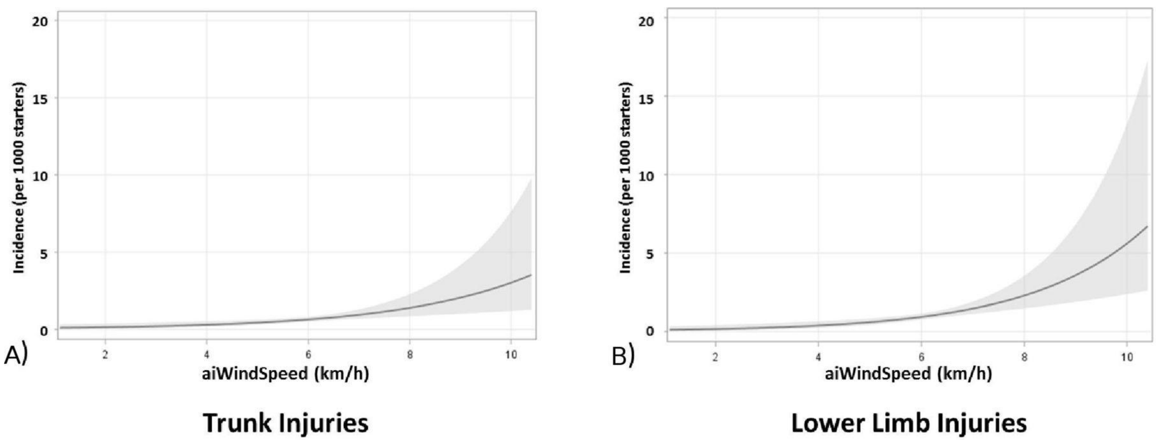

Figure 3. (A) Trunk injury incidence for aiWindSpeed (p=0.0041). (B) Lower limb injury incidence for aiWindSpeed (p=0.0005). aiWindSpeed, average individual Wind Speed exposure. Model for participants aged 40.88 years (average age), cycling at 23.79 km/hour (average speed). Wide CIs are indicative of the small sample size at that speed.

Higher aiWindSpeed was significantly associated with a higher risk of trunk injuries and lower limb injuries.

DISCUSSION

The main finding in this study was that we could identify four risk factors that are associated with acute traumatic injuries in cyclists as follows: (1) female sex (all injuries, serious life-threatening injuries, and head/neck, upper limb and injuries to the trunk), (2) older age (>50 years; all injuries, and upper limb injuries), (3) faster average cycling speed (all injuries, upper limb), and (4) higher aiWindSpeed (all injuries, trunk and injuries to the lower limb).

Our first finding that female sex was associated with an increased risk of injury including serious injuries and injuries to most anatomical areas is in keeping with previous studies in 1 day cycling events investigating traumatic injuries[7 8] and also in running studies.[20] In one study, women were 1.3 times more likely to get injured compared with men during a 1 day cycling event for recreational cyclists.[8] Serious life-threatening injuries and injuries to the head and neck are particularly important to investigate as they usually are severe and consist largely of concussions,[15] where the long-term effects are still unknown.[21] Our study was not designed to explore the possible reasons why female cyclists are at higher risk for injuries, and this would require further investigation.

Our second main finding is that older age (>50 years) is associated with an increased risk of all injuries, and injuries to the upper limbs. Older age as a risk factor for acute injury has not been well documented in previous literature and different methodologies (single-day events vs multiday events) and definitions (severity of an injury) have been used, making comparisons difficult. We are aware of only two studies where the association between age and acute cycling injuries was investigated. In one study, cyclists under the age of <35 years were 1.4 times more likely to get injured (this was not a multiple regression model, therefore not an independent risk factor).[8] In a multiday cycle tour cohort study, cyclists >50 years were at higher risk for acute injuries.[12] While the multiday cycle tour also used a multiple regression model, their sample size was very small (4000 participants) compared with our study. The association between age and acute injury risk on cycling also requires further study, and possible reasons for this finding need to be investigated. Risk factors for injuries in specific anatomical areas require further investigation.

We show that faster cycling speed was associated with an increased risk of all injuries and injuries in specific anatomical areas. To our knowledge, this association has not been reported in any previous studies. This finding is very plausible, because it makes sense that the faster the cycling speed, the higher the chances would be of the collision/crash resulting in an injury (of at least moderate severity). We do note that the relationship between cycling speed and injury risk is not linear and that in general, there appears to be an infliction point at an average cycling speed of about 40 km/hour, where the risk of injuries increases almost exponentially. We also take note that this increased risk appears to be greater in female cyclists.

Finally, we also show that a higher aiWindSpeed is associated with an increased risk of injuries and specific anatomical areas. Furthermore, the wind speed was individualised to each participant as they progressed throughout the race. In events such as the Cape Town Cycle Tour, participants can be exposed to very different environmental conditions, owing to the staggered start and the long duration of the event (up to 7 hours). This novel variable of aiWindSpeed takes into account the specific environmental conditions during an event that a participant is exposed to. To our knowledge, this is the first time wind speed has been investigated as a possible risk factor for acute injuries in cyclists. Again, this makes sense as higher wind speeds, particularly in potential areas on the course where the wind direction is a cross wind, can reduce the ability of cyclists to control the bicycle, and thereby increase the risk for cycling crashes resulting in injuries. Higher wind speeds, combined with faster cycling speeds, would logically be associated with higher risk of acute injuries in cyclists. We also note that the relationship between wind speed and injury risk is not linear, and that in general, there appears to be an infliction point at wind speeds >6 km/hour, where the risk of all injuries and injuries by anatomical areas appears to increase. These risk factors, both demographic, performance and environmental, could help to assist race organisers in preparation and identifying areas of high risk (eg, high speed and high wind areas).

The strengths of this study are that to our knowledge this is the largest study performed investigating the risk factors associated with acute injuries in recreational cyclists during a single-day event. The severity of the injuries was collected, allowing identification of risk factors for serious life-threatening injuries, which are novel data. Importantly, these data were reported and analysed according to the 2019 consensus statement for mass community-based endurance sports events,[14] allowing for future comparisons to be made. All injury data were collected by medical doctors and the race entry and day data were accurately recorded for all injuries. Furthermore, the environmental data were individualised to each participant, according to their start and finish time, allowing for the modelling of a novel individual environmental exposure variable (aiWindSpeed) data. We were also able to identify risk factors associated with serious life-threatening injuries (novel data), acknowledging that for this analysis, the sample size was smaller. In future, we hope to further explore risk factors for more serious injuries in a larger sample. We also acknowledge that this study was a retrospective analysis of data collected over a 3-year period and that some of the subgroups of injuries contained small numbers, resulting in wide CIs. These data should be interpreted with some caution, and this research programme will continue prospectively.

SUMMARY AND CONCLUSIONS

To our knowledge, this is the largest study to investigate risk factors associated with acute injury-related medical encounters in a mass community-based endurance cycling event. During a single-day cycling event over 3 years, we identified four risk factors that are associated with acute injury-related medical encounters during a mass community-based endurance cycling event as follows: women, older age (>50 years), faster cycling speed and higher wind speed. The identification of these risk factors is important to guide race organisers and medical teams on race day to prepare for injury-related medical encounters based on the profile of cyclists, as well as design and implement injury prevention programmes for cycling events. Our novel data on wind speed may guide decision-making by race organisers to mitigate risk of acute injuries when adverse weather conditions are forecast at future cycling events.

What is already known on the subject

- Cycling has a high incidence of acute onset injuries, due to falls/collisions
- During mass community-based participation cycling events, upper limb injuries were the most common acute injury-related medical encounters

- Female sex, older age (>50 years) faster cycling speed and higher wind speeds are risk factors associated with a higher incidence of acute injury-related medical encounters in a mass community-based endurance cycling event.

What this study adds

- Women, older age (>50 years) faster cycling speed and higher wind speeds are risk factors associated with a higher incidence of acute injury-related medical encounters in a mass community-based endurance cycling event.
- This study adds valuable insight into the risk factors for acute injury-related medical encounters in a mass community-based endurance cycling event.
- The data regarding the risk factors may help race organisers and medical directors prepare better for the injuries on race day.
- Preventative programmes can be better designed using this knowledge of risk factors tailored to the high-risk groups, and even further targeted for specific injuries based on the anatomical area of injury.

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