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Original Research

History of chronic disease is a novel intrinsic risk factor associated with gradual onset injuries in recreational road cyclists: A cross-sectional study in 21,824 cyclists - SAFER XIV

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ABSTRACT

Objectives: Risk factors related to Gradual onset injuries (GOIs) in cyclists need to be identified to enable effective injury prevention strategies. We aim to determine risk factors related to GOIs in cyclists participating in mass community-based events.
Design: Cross-sectional study.
Setting: Cape Town Cycle Tour.
Participants: Race entrants (n = 35,914)
Main outcome measures: Completion of pre-race medical questionnaires. 21,824 consenting cyclists (60.8%) were studied. 617 cyclists reported GOIs. Selected risk factors associated with GOIs: demographics, training/racing history, chronic disease history, and medication use, were explored using multi-variate analyses.
Results: Prevalence ratio (PR) of GOIs was similar in males and females, but higher in older age categories [>50 yrs vs. categories: ≤30yrs (PR = 1.6); 31 to ≤40yrs (PR = 1.5); 41 to <50yrs (PR = 1.4)] ($p < 0.0001$). Intrinsic risk factors associated with GOIs (adjusted for gender and age) were: 1) increased weekly training/racing frequency (PR = 1.1, $p = 0.0003$), 2) chronic disease history [cardiovascular disease symptoms (PR = 2.3, $p = 0.0026$), respiratory disease (PR = 1.6, $p < 0.0001$), nervous system/psychiatric disease (PR = 1.5, $p = 0.0082$)], and 3) history of analgesic/anti-inflammatory medication (AAIM) used before/during racing (PR = 5.1, $p < 0.0001$).
Conclusion: Increased training frequency, chronic disease and AAIM use are risk factors associated with GOIs in cyclists. A novel finding is that in recreational cyclists, chronic disease history could be considered when managing GOIs and implementing prevention programs.

1. Introduction

Cycling is a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages (Dahlquist et al., 2015; De Bernardo et al., 2012; Kotler et al., 2016). However, there is also a risk of acute traumatic and gradual onset injuries (GOIs) in both amateur and professional cyclists (Barrios et al., 2015; Decalzi et al., 2013; Roi & Tinti, 2014).

GOIs are defined as injuries without a specific, identifiable acute event responsible for their occurrence (Clarsen et al., 2013). We showed that about 3% of recreational cyclists report GOIs that are severe enough to interfere with cycling or require treatment or seek medical advice from a health professional (du Toit et al., 2020). These GOIs in cyclists affect mostly the knee, lower back and

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shoulder and >37% of injuries are severe enough to affect training and competition (du Toit et al., 2020). Of concern is that almost 50% of cyclists with GOIs report a symptom duration >12 months (du Toit et al., 2020). The principles of preventing GOIs rely on identifying the underlying intrinsic (related to the cyclist) and extrinsic (related to the bicycle and environment) risk factors associated with GOIs (Clarsen et al., 2010). Risk factors associated with GOIs in cyclists need to be identified so that effective injury prevention programs can be designed and implemented.

There are limited studies on the risk factors associated with GOIs in cyclists, and most studies have only focussed on biomechanical risk factors, utilising a case-control study design (Baskins et al., 2016; Bini et al., 2014; Streisfeld et al., 2017). Intrinsic risk factors that have been associated with GOIs in cyclists include older age, female gender, training load, anatomical malalignment and muscle inflexibility of the lower limb (Dahlquist et al., 2015; Dettori & Norvell, 2006; Kotler et al., 2016). Extrinsic risk factors associated with GOIs in cyclists include training errors, cycling surfaces, incorrect bicycle fitting, and adult or peer pressure (Bini et al., 2014; Dettori & Norvell, 2006; Kotler et al., 2016). However, in the majority of these studies, the identification of intrinsic and extrinsic risk factors was limited to studies in professional cyclists, utilising relatively small sample sizes, and limiting the analyses to a univariate exploration for risk factors associated with GOIs.

In a few studies (Dahlquist et al., 2015; Dannenberg et al., 1996; Van der Walt et al., 2014; Weiss, 1985; Wilber et al., 1995) where the relationship between multiple risk factors associated with GOIs in cyclists is reported, comparisons are difficult because of methodological differences that include: differences in the definition of gradual onset injury (Dahlquist et al., 2015; Dannenberg et al., 1996; Van der Walt et al., 2014; Wilber et al., 1995), reporting the exposure (Dannenberg et al., 1996; Weiss, 1985), small sample sizes not allowing for multivariate analysis (Dahlquist et al., 2015; Weiss, 1985; Wilber et al., 1995), low-response rates with possible selection bias (Van der Walt et al., 2014; Wilber et al., 1995), and the use of self-reported data with differences in timing and content of questionnaire administration (Dahlquist et al., 2015; Dannenberg et al., 1996; Van der Walt et al., 2014; Weiss, 1985; Wilber et al., 1995). Multivariate analysis to identify intrinsic risk factors was only performed in two studies (Dahlquist et al., 2015; Wilber et al., 1995).

The aim of this study was to determine selected intrinsic risk factors associated with GOIs in recreational cyclists participating in a 109 km, single-day, mass community-based cycling event. The objectives were to explore the following specific risk factors associated with GOIs in a large sample of recreational cyclists using a multi-variate analysis: cyclist demographics (age group and gender), cycling training/racing history, a history of existing chronic disease, and medication usage.

2. Methods

A cross-sectional study design was used. Prior to the onset of the study, the Research Ethics Committee of the Faculty of Health Sciences approved the study (REC numbers **431/2015** and **213/2017**). This study is part of a series of ongoing SAFER (**S**trategies to reduce **A**dverse medical events **F**or the **E**xercise**R**) studies, for which data collection is ongoing (Schwellnus & Derman, 2014).

The Cape Town Cycle Tour (CTCT) is an annual single-day road cycle race hosted in Cape Town, South Africa, usually 109 km long. A total of 35,914 cyclists entered the 2016 CTCT, and 21,902 gave written informed consent for their data to be used for research purposes. Seventy-eight cyclists had missing or incomplete injury data leaving a final study population of 21,824 (60.8% of all race entrants).

The response rate was acceptable, but we conducted a post-hoc analysis to determine if the participants in this study were indeed representative of all the cycle race entrants.

(du Toit et al., 2020) All cycle race entrants from the 2016 CTCT were required to complete an online medical screening questionnaire at the time of registration. The online medical screening tool consisted of a series of questions that were based on the guidelines for cardiovascular evaluation of middle-aged/senior individuals engaged in leisure-time sport activities (Position stand from the European Association of Cardiovascular Prevention and Rehabilitation) (Borjesson et al., 2011), and our previous studies in distance runners (Rotunno et al., 2018; Schwabe et al., 2018; Schwellnus et al., 2019). We adapted the online screening tool for runners to include questions specifically related to common medical complications encountered during cycling. The final screening questions included the following: cycling training/racing history and medical history which included history of acute traumatic and GOIs (current, or recent – last 12 months), chronic cardiovascular disease (CVD), risk factors for CVD, symptoms of CVD, respiratory disease, metabolic or hormonal disease, GIT disease, nervous system disease, renal or bladder disease, haematological or immune system disease, cancer, allergies, general medication usage for chronic disease, and medication usage before and during racing.

In keeping with a recent IOC consensus paper (Bahr, Clarsen, Derman, & al, 2020), we recognise that cycling injuries result from a transfer of kinetic energy (agent) that damages tissue and that this transfer of energy may result from: 1) a near-instantaneous exchange of large quantities of kinetic energy (e.g. cycling accident), 2) from the gradual accumulation of low-energy transfer over time (as in the development of patellofemoral pain), or 3) from a combination of both mechanisms (repetitive training regime resulting in discal lower back pain that then manifests itself acutely following a minor cycling accident) (Bahr, Clarsen, Derman, & al, 2020). However, in our medical screening tool, which was designed prior to the recent IOC consensus statement (Bahr, Clarsen, Derman, & al, 2020), cyclists were specifically asked the following question related to injuries: *"Do you or did you suffer from any symptoms of a CHRONIC (no accident) cycling injury (muscles tendons bones ligaments or joints) IN YOUR CYCLING CAREER?"*. We therefore included only injuries where there was no self -reported history of a near-instantaneous exchange of large quantities of kinetic energy (e.g. cycling accident), and we report these as GOIs. The severity of a GOI was defined as: *"An injury that is/was severe enough to interfere with cycling or require treatment e.g. use medication or require you to seek medical advice from a health professional"*. In response to a "yes" answer to this question, cyclists were grouped as having a gradual onset injury (GOI group = 617). Cyclists who reported no history of a GOI acted as controls (n = 21,207).

In this descriptive cross-sectional study, various categories of selected intrinsic risk factors associated with a past history of GOIs in cyclists were explored:

- Demographic variables: Age groups (≤30 years, 31 to ≤40 years, 41 to ≤50 years, >50 years) and gender (male, female)
- Cycling training/racing history variables: years of recreational cycling, years of participation in distance cycling events of >2 h, average number of training sessions per week in the last 12 months, average weekly distance in the last 12 months, and average racing speed category.
- History of chronic disease: a history of existing CVD, risk factors for CVD, symptoms of CVD, respiratory disease, endocrine disease, GIT disease, nervous system or psychiatric disease, kidney or bladder disease, haematological system disease or immune system disease, cancer, and allergies.

- Medication usage: chronic disease prescription medication usage, and use of analgesic anti-inflammatory medication (AAIM) (week before racing, during racing).

Analyses were conducted using SAS statistical software (version 9.4, Cary NC). The binary-scaled dependent variable in the model was the response to the question related to GOIs. Cyclists were coded as having a gradual onset cycling injury if they reported (1) a chronic injury in the past 12 months or (2) a current chronic injury or (3) a past chronic injury. Cyclists could report more than one GOI, e.g. reporting both a neck and a shoulder injury. To qualify for coding of an injury entry for (1) how long ago the injury started, (2) which side of the body the injury was, and (3) the anatomical area was coded. For 78 records, there were discrepancies in the coding of the relevant injury variables and these records were deleted from the data. Since some modelling situations arose with convergence problems, PROC GENMOD with the Poisson distribution with a log link option were used and p values for Type 3 GEE (generalized estimating equations) analysis were reported. The repeated statement was included to allow for the correlated data as more than one injury could be reported by the same cyclist (exchangeable correlation structure). Prevalence ratios (PR) were calculated as the measure of association. The statistical significance level was 5%, unless specified otherwise. Univariate unadjusted prevalences (% and 95%CIs) and prevalence ratios were reported for age and gender, cycling training/racing history, history of chronic disease, history of medication usage. The demographic, chronic disease, history of medication variables were entered into the model as categorical variables. The training and racing speed variables were entered into the model as numeric variables and the prevalence of GOIs (% and 95%CIs) were reported at the 1st quartile, median and 3rd quartile for these variables. The multiple regression initially included all the univariate significant risk factors and indicated the intrinsic risk factors for GOIs in cyclists and the final model contained only the significant risk factors. The multiple regression model was extended by adding the variable 'average racing speed' and was based on 18,703 consenting cycle race entrants, i.e. this question had 14% missing responses and it was therefore decided to not include the variable in the first multiple model. In the final model, all interactions with age group and gender were explored. In the multivariate model, the level of significance was established at $p < 0.01$.

3. Results

The demographics of all cyclists entering the 2016 CTCT, compared with the consenting cycle race entrants, that were participants in this study, is outlined in Table 1.

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of GOIs by age group, and gender is depicted in Table 2.

Gender was not associated with a higher PR of GOIs in cyclists (PR = 1.2, p = 0.0610), while older age (>50 years) was associated with a higher PR of GOIs in cyclists compared with all other age groups ($p < 0.0001$).

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of GOIs by cycling training/racing history is depicted in Table 3.

The crude unadjusted analysis results show that a number of training variables are associated with an increased prevalence ratio of GOIs in cyclists. The highest PR of GOIs in cyclists was associated with increased years of participation in distance cycling events >2 h (PR = 1.13; $p < 0.0001$), increased average weekly training/racing frequency in the last 12 months (times per week) (PR = 1.12, $p < 0.0001$), increased average weekly cycling distance in the last 12 months (PR = 1.08; $p < 0.0001$), increased years of recreational cycling (years) (PR = 1.08; $p < 0.0001$), and increased average racing speed category (PR = 1.06, $p < 0.0001$).

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of GOIs by history of main categories of chronic disease is depicted in Table 4.

The main observation is that a history of chronic disease is associated with a higher PR of GOIs in cyclists. Specifically, the crude unadjusted analysis showed that the highest PR of GOIs in cyclists is associated with a history of any symptoms of CVD (PR = 4.0; $p < 0.0001$), followed by a history of any nervous system/psychiatric disease (PR = 2.8; $p < 0.0001$), and any GIT disease (PR = 2.3; $p < 0.0001$). In addition, history of any respiratory disease (PR = 2.2; $p < 0.0001$), any kidney or bladder disease (PR = 2.1; p = 0.0009), any endocrine disease (PR = 1.8; p = 0.0050), any allergies (PR = 1.7; $p < 0.0001$), any history of CVD (PR = 1.7; p = 0.0130), and any risk factor for CVD (PR = 1.5; $p < 0.0001$) were also associated with a higher risk of GOIs in cyclists.

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of GOIs by regular use of any prescription medications, and AAIM medication usage during training and racing is depicted in Table 4.

The use of both regular prescribed medication for chronic disease (PR = 1.7, p = 0.0001) and use of any AAIM use in the week before or during racing (PR = 6.3, p = 0.0001) were associated with a higher PR of GOIs in cyclists.

The multiple regression included all the significant risk factors from the univariate analysis to determine intrinsic risk factors associated with GOIs in cyclists. The frequency (%) and adjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of GOIs by main categories of training load, history of chronic disease or medications use, and injuries is depicted in Table 5.

In the multiple regression model, the training-related factor

Table 1
Characteristics of all cycle race entrants and cycle race entrants consenting as study participants (consenting cycle race entrants) (du Toit, 2020 – in review).

Characteristics		All cycle race entrants (n = 35,914)		Cycle race entrants consenting as study participants (n = 21,824)		p-value
		n	%[a]	n	%[a]	
Gender	Males	28,311	78.8	17,282	79.2	0.0390
	Females	7603	21.2	4542	20.8	
Age groups (years)	≤30	6453	18.0	3333	15.3	<0.0001
	31 to ≤40	7814	21.8	4447	20.4	
	41 to ≤50	10,583	29.4	6382	29.2	
	>50	11,064	30.8	7662	35.1	

Study participants were significantly more likely to be in the >50-year age group ($p < 0.0001$), and to be male compared with all cycle race entrants (p = 0.0390).
[a] % out of total.

Table 2
The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR) (with 95%CI) of cyclists with a history of gradual onset injuries (GOIs) by gender and age group (univariate analysis).

Characteristics		Consenting cycle race entrants (n = 21,824)	Cycle race entrants with gradual onset injuries (GOIs) (n = 617)		PR (95% CI)	p-value
		N	n	% (95% CI)		
Gender	Males	17,282	469	2.7 (2.5–3.0)		0.0610
	Females	4542	148	3.3 (2.8–3.8)	1.2 (1.0–1.4)	
Age groups (years)	≤30	3333	74	2.2 (1.8–2.8)	1.6 (1.2–2.1)[b]	<0.0001[a]
	31 to ≤40	4447	106	2.4 (2.0–2.9)	1.5 (1.2–1.9)[c]	
	41 to ≤50	6382	164	2.6 (2.2–3.0)	1.4 (1.1–1.7)[d]	
	>50	7662	273	3.6 (3.2–4.0)		

PR: Prevalence Ratio.
[a] Significantly different between age groups.
[b] >50 vs ≤ 30 years, p = 0.0003.
[c] >50 vs 31 to ≤40 years, p = 0.0004.
[d] >50 vs 41 to ≤50 years, p = 0.0008.

Table 3
The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of gradual onset injuries (GOIs) by cycling training/racing history (n = 21,727) (univariate analysis).

Cycling training/racing history (n = 21,727)	Points in the continuous variable[a]	Predicted frequency of cyclists with gradual onset injuries (GOIs) at specific points in the continuous variable % (95% CI)	PR (95% CI)	p-value
Years of recreational cycling (yrs)	4yrs	2.5 (2.2–2.8)		<0.0001
	10yrs	2.7 (2.5–3.0)		
	18yrs	3.1 (2.8–3.3)	1.08 (1.04–1.12)[c]	
Years of participation in distance cycling events >2 h (yrs)	3yrs	2.4 (2.2–2.6)		<0.0001
	6yrs	2.6 (2.3–2.8)		
	15yrs	3.2 (2.9–3.5)	1.13 (1.08–1.17)[c]	
Average weekly training/racing frequency in the last 12 months (times per week)	2/week	2.6 (2.4–2.8)		<0.0001
	3/week	2.9 (2.7–3.1)		
	4/week	3.2 (2.9–3.5)	1.12 (1.07–1.16)[d]	
Average weekly cycling distance in the last 12 months (km/week)	40 km	2.5 (2.3–2.8)		<0.0001
	80 km	2.7 (2.5–3.0)		
	130 km	3.0 (2.8–3.2)	1.08 (1.05–1.11)[e]	
Average racing speed category (km/h) n = 18,703[b]	21.1 km/h	2.5 (2.2–2.8)		<0.0001
	24.8 km/h	2.8 (2.5–3.0)		
	29.2 km/h	3.2 (2.9–3.5)	1.06 (1.03–1.09)[f]	

PR: Prevalence Ratio.
[a] Points on the continuous variables are the 1st quartile, median and 3rd quartile for each training variable.
[b] Variable has 14% missing responses.
[c] Average increase in risk for a 5-year increase.
[d] Average increase in risk for 1 more training session per week.
[e] Average increase in risk for 40 km more training per week.
[f] Average increase in risk for 2 km/h increase in speed.

associated with a higher PR of GOIs in cyclists was increased average weekly training/racing frequency in the last 12 months (times per week) (PR = 1.1, p = 0.0003). Secondly, GOIs in cyclists were associated with a history of chronic disease as follows: any symptoms of CVD (PR = 2.3, p = 0.0026), any respiratory disease (PR = 1.6, p < 0.0001), and any nervous system/psychiatric disease (PR = 1.5, p = 0.0082). Finally, a history of any AAIM used in the week before or during racing was associated with a higher PR of GOIs in cyclists (PR = 5.1, p < 0.0001).

Further modelling showed that the interaction for age group (≤50; >51 years) and respiratory disease was significant (p = 0.008). The results showed that the respiratory disease PR for older athletes was 1.2 (95%CI: 0.9–1.6, respiratory disease positive = 12.5% and negative = 10.6%) and for younger athletes the PR was 2.0 (95%CI: 1.5–2.5, respiratory disease positive = 15.4% and negative = 7.9%) indicating that respiratory disease was a predictor of GOIs in cyclists for younger cyclists, but not for older athletes.

4. Discussion

The main finding of this study is that a history of certain chronic diseases (any symptoms of CVD, any respiratory disease, and any nervous system/psychiatric disease) are intrinsic risk factors associated with GOIs in cyclists. An increased average weekly training/racing frequency was also associated with GOCIs. We also show that a history of any AAIM use in the week before or during racing is associated with GOCIs. The prevalence risk of GOIs in cyclists was not significantly different between genders, but was higher in the >50 years, compared to other age groups.

As far as we are aware, this is the first study to report an association between a variety of underlying chronic diseases and GOIs in recreational cyclists. The prevalence of chronic disease in

Table 4
The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR) of cyclists with a history of gradual onset injuries (GOIs) by history of main category of chronic disease and by history of regular use of any medications, and use of medication during training and racing (univariate analysis).

		Consenting cycle race entrants (n = 21,824)	Cycle race entrants with gradual onset injuries (GOIs) (n = 617)		PR (95% CI)	p-value
		N	n	% (95% CI)		
History of chronic disease						
Any risk factor for CVD	yes	4525	178	3.9 (3.4–4.5)	1.5 (1.3–1.8)	<0.0001
	no	17,089	439	2.6 (2.3–2.8)		
	missing data	210	0			
Any history of CVD	yes	817	38	4.7 (3.4–6.3)	1.7 (1.2–2.3)	0.0130
	no	20,797	579	2.8 (2.6–3.0)		
	missing data	210	0			
Any symptoms of CVD	yes	233	26	11.2 (7.8–16.0)	4.0 (2.8–5.8)	<0.0001
	no	21,381	591	2.8 (2.6–3.0)		
	missing data	210	0			
Any endocrine disease	yes	835	41	4.9 (3.6–6.6)	1.8 (1.3–2.4)	0.0050
	no	20,784	573	2.8 (2.5–3.0)		
	missing data	205	3			
Any respiratory disease	yes	2482	135	5.4 (4.6–6.4)	2.2 (1.8–2.6)	<0.0001
	no	19,157	482	2.5 (2.3–2.7)		
	missing data	185	0			
Any GIT disease	yes	1169	70	6.0 (4.8–7.5)	2.3 (1.8–2.9)	<0.0001
	no	20,456	543	2.7 (2.4–2.9)		
	missing data	199	4			
Any nervous system/psychiatric disease	yes	767	58	7.6 (5.9–9.7)	2.8 (2.2–3.7)	<0.0001
	no	20,864	557	2.7 (2.5–2.9)		
	missing data	193	2			
Any kidney or bladder disease	yes	645	38	5.9 (4.3–8.0)	2.1 (1.6–2.9)	0.0009
	no	20,990	578	2.8 (2.5–3.0)		
	missing data	189	1			
Any haematological or immune disease	yes	293	15	5.1 (3.1–8.4)	1.8 (1.1–3.0)	0.0760
	no	21,325	600	2.8 (2.6–3.0)		
	missing data	206	2			
Any cancer	yes	701	28	4.0 (2.8–5.7)	1.4 (1.0–2.1)	0.1130
	no	20,926	587	2.8 (2.6–3.0)		
	missing data	197	2			
Any allergies	yes	2968	133	4.5 (3.8–5.3)	1.7 (1.4–2.1)	<0.0001
	no	18,659	482	2.6 (2.4–2.8)		
	missing data	197	2			
History of medication usage						
Any regular prescribed medication usage for chronic disease	yes	5505	229	4.2 (3.7–4.7)	1.7 (1.5–2.0)	0.0001
	no	16,126	388	2.4 (2.2–2.7)		
	missing data	193	0			
Any AAIM use in the week before or during racing	yes	1892	231	12.2 (10.8–13.8)	6.3 (5.4–7.3)	0.0001
	no	19,658	383	1.9 (1.8–2.2)		
	missing data	274	3			

CVD: Cardiovascular disease.
GIT: Gastrointestinal disease.
n: number of cyclists in the study.
PR: Prevalence ratio.
AAIM: analgesic/anti-inflammatory medication.

recreational cyclists varies between 10 and 16% (Weiss, 1985; Wilber et al., 1995), and this is likely to increase as the age of participants in recreational cycling increases. The potential mechanism/s to explain the relationship between chronic disease and risk of GOIs in recreational cyclists requires further study, but there is some evidence that chronic diseases may be related to increased risk of GOIs (Abate et al., 2013; Abboud & Kim, 2010; Applegate et al., 2017; Daga et al., 2018; Graat-Verboom et al., 2009; Lin et al., 2015; Mammen, 2016; Marie et al., 2008). More specifically, chronic disease in a number of organ systems or medication that is used to treat chronic disease, are related to tendinopathies (Abate et al., 2013; Applegate et al., 2017; Lin et al., 2015; Marie et al., 2008), ligament injuries (Abate et al., 2013; Applegate et al., 2017) and bone stress injuries.[30-31.] For example, hypercholesterolaemia, diabetes mellitus and the metabolic syndrome are chronic diseases that are associated with chronic tendinopathy (Abboud & Kim, 2010; Applegate et al., 2017; Lin et al., 2015). Prescription medications for chronic diseases such as statins, increase the risk of skeletal muscle myopathy (Mammen, 2016; Marie et al., 2008), while proton pump inhibitors and corticosteroids may increase the risk of osteopenia (Daga et al., 2018; Diehl & Johnson, 2016). Finally, there may also be a relationship between chronic disease and chronic pain in athletes. (Ramanathan et al., 2018). However, it is important to note that, due to our cross-sectional design, we cannot establish a cause-effect relationship between chronic disease and GOIs in cyclists. We do suggest that this relationship be explored in future research studies. (Ramanathan et al., 2018) Nevertheless, we recommend that clinicians take note of the possible association between gradual onset injuries and certain chronic diseases, particularly when managing patients or introducing injury prevention programs. This is important, because cyclists with a history of chronic disease will benefit greatly from the

Table 5
The adjusted[$*] frequency (%; with 95%CI) and prevalence ratio (PR; with 95%CI) of cyclists with gradual onset injuries (GOIs) by combined main categories of risk factors (cycling training/racing history, history of chronic disease and history of medication usage) (multiple regression model).

			Cyclists with gradual onset injuries (GOIs) % (95% CI)	PR (95% CI)	p-value
Cycling training/racing history	Average weekly training/racing frequency in the last 12 months (times per week)	2/ week	8.1 (5.5–11.8)	1.1 (1.0 –1.1)[a]	0.0003
		3/ week	8.8 (6.0–12.9)		
		4/ week	9.6 (6.5–14.2)		
History of chronic disease	Any symptoms of CVD	Yes	16.9 (11.6–24.5)	2.3 (1.6 –3.3)	0.0026
		No	7.5 (6.4–8.7)		
	Any respiratory disease	Yes	14.1 (11.1–18.0)	1.6 (1.3 –1.9)	<0.0001
		no	8.9 (7.1–11.3)		
	Any nervous system/psychiatric disease	yes	13.9 (10.4–18.6)	1.5 (1.2 –2.0)	0.0082
		no	9.1 (7.3–11.2)		
History of medication usage	Any AAIM use in the week before or during racing	yes	25.3 (20.4–31.5)	5.1 (4.3 –6.0)	<0.0001
		no	5.0 (3.9–6.4)		

AAIM: analgesic/anti-inflammatory medication.
CVD: Cardiovascular disease.
PR: Prevalence ratio.
[$*]: Adjusted for gender and age group.
[a] Average increase in risk for 1 more training session per week.

health benefits of regular physical activity, including cycling (American College of Sports et al., 2018).

There is some evidence that increased weekly training and increased racing frequency is associated with the development of GOIs in cyclists (Wilber et al., 1995). In one cross-sectional study, participants were 2.3–4 times more likely to be treated for an gradual onset injury during the Cycle Across Maryland tour if they usually cycled less than 26 miles (41.8 km) per week in preparation for the tour (Dannenberg et al., 1996). We show that increased average weekly training/racing frequency is a risk factor for GOIs in recreational cyclists. Others suggested that cyclists with less years of cycling experience had more buttock and groin complaints (Weiss, 1985; Wilber et al., 1995), but there was no relationship between long distance riding experience and any other GOIs in cyclists (Weiss, 1985).

We show that a history of AAIM medication usage in the week before or during racing is strongly associated with GOIs in recreational cyclists. The association between AAIM medication usage and GOIs in recreational cyclists has not been explored in previous studies. Again, because of the limitation of our cross-sectional study design, cause-effect cannot be determined. We speculate that this finding is likely to be related to the use of AAIM to treat the symptoms of a GOI before and during cycling races and therefore is likely to be an effect of the GOI, rather than a cause. However, there are data to show that anti-inflammatory medication use can also negatively affect soft tissue and bony healing (Duchesne et al., 2017; Hainline et al., 2017). This means that regular anti-inflammatory medication used to treat gradual onset injuries may also potentially contribute to a failure of the healing response. Again, this requires further study, but we recommend that clinicians take note of the association between AAIM use and gradual onset injuries when managing cyclists with GOIs. We suggest that further studies are conducted to determine the prevalence of AAIM use in cyclists, as well as the risk of medical complications associated with AAIM during cycling.

We show that gender was not associated with a higher PR of GOIs in cyclists, but other studies have shown that female cyclists have an increased risk for developing GOIs, particularly in the neck (1.5 times), shoulder (2.2 times), and the medial knee (3.1 times) (Van der Walt et al., 2014; Weiss, 1985; Wilber et al., 1995). However, in two studies, no significant differences in injury risk at various anatomical sites was found between male and female cyclists (Weiss, 1985; Wilber et al., 1995). The relationship between gender and risk of GOIs in cyclists requires further study.

Finally, in our study age category >50 years was associated with a higher prevalence ratio (PR) of GOIs in cyclists, compared to other age categories, but we did not explore age as a risk factor for GOIs at specific anatomical sites in cyclists. In two other studies it has been suggested that younger age is a risk for medial knee pain, back, buttocks, and upper leg complaints in cyclists (Dannenberg et al., 1996; Weiss, 1985). In another study, no significant association between age and cycling injury was found (Van der Walt et al., 2014). In one prospective observational study where multivariate analysis was conducted, pain level (at enrolment) and older age were associated with injuries in cyclists (Dahlquist et al., 2015). To extrapolate these findings to our study on GOIs in cyclists is not possible, because of the differences in the definition of injury. In particular, no distinction was made between traumatic injuries and GOIs in cyclists in this study (Dahlquist et al., 2015).

The main strengths of this study are the large sample size, an acceptable overall response rate (60%) with a post-hoc analysis that our study population was, with some limitations, generalizable to all cycle race entrants. A further significant strength of our study was that we were able to conduct multiple regression analyses. This is also the first study, to our knowledge, that shows underlying chronic disease, medication usage and a history of a GOIs in cyclists as intrinsic risk factors associated with GOIs in recreational cycling.

Specific limitations of our study were that our data are self-reported, with a potential for recall bias. We also acknowledge that our observations may not be compared to findings in other studies because of differences in the definition of GOIs. Also, from our results, we cannot infer cause-effect as this was a cross-sectional study design. We suggest that further research be aimed at determining the causal relationship between specific GOIs in different age groups of cyclists and specific chronic diseases or medication usage in a larger sample size. We also acknowledge that we did not explore all possible risk factors, specifically other intrinsic risk factors related to biomechanical abnormalities and extrinsic risk factors related to bicycle set-up, that may be associated with GOIs in cyclists in specific anatomical sites.

5. Conclusion

Risk factors associated with GOIs in recreational cyclists have not been well-studied. We identified novel intrinsic risk factors associated with a history of GOIs in recreational cyclists, using a multivariate model on a large sample of recreational cyclists entering for a one-day road cycling event. Average weekly training/racing frequency in the last 12 months (times per week)], a history of chronic disease [any symptoms of CVD, any respiratory disease, and any nervous system/psychiatric disease], and a history of AAIM usage in the week before or during racing were intrinsic risk factors associated with GOIs in cyclists. These findings are important for clinicians who may consider that GOIs in cyclists are not associated with a single aetiology, but rather a more complex interaction of a variety of intrinsic and extrinsic factors requiring careful and systematic clinical assessment. Finally, we acknowledge that future research is required to determine the cause-effect relationship between GOIs in cyclists and the factors we identified, and also explore possible pathophysiological mechanisms that may link GOIs in cyclists to underlying chronic disease and medication usage.

Contributorship

François du Toit (FDT): study concept, study planning, data cleaning, data interpretation, manuscript (first draft), manuscript editing.

Martin Schwellnus (MS): responsible for the overall content as guarantor, study concept, study planning, data cleaning, data interpretation, manuscript (first draft), manuscript editing, facilitating funding.

Paola Wood (PW): study concept, study planning, data interpretation, manuscript (first draft), manuscript editing.

Sonja Swanevelder (SS): study planning, data cleaning, data interpretation, manuscript editing.

Jannelene Killops (JK): study planning, data collection, data interpretation, manuscript editing.

Esme Jordaan (EJ): study planning, data analysis including statistical analysis, data interpretation, manuscript editing.

Data sharing statement

No additional data are available.

Funding statement

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South African Medical Research Council (partial funding, statistical analysis)

Ethical statment

A cross-sectional study design was used. Prior to the onset of the study, the Research Ethics Committee of the Faculty of Health Sciences approved the study (REC numbers **431/2015** and **213/2017**). This study is part of a series of ongoing SAFER (**S**trategies to reduce **A**dverse medical events **F**or the **E**xercise**R**) studies, for which data collection is ongoing.

Findings

- Increased average weekly training/racing frequency is a training-related risk factor associated with gradual onset injuries (GOIs) in recreational cyclists.
- GOIs are also associated with a history of chronic disease (any symptoms of CVD, any respiratory disease, and any nervous system/psychiatric disease) and a history of any analgesic anti-inflammatory drugs use in the week before or during racing.

Implications

- Clinicians could consider that GOIs are not associated with a single aetiology, but rather that a variety of intrinsic and extrinsic factors influence GOIs requiring careful and systematic clinical assessment.
- This study shows that clinicians could explore the possibility that GOIs may, in some cases, be associated with underlying chronic disease.

Caution

- Specific limitations of our study were that our data are self-reported, with a potential for recall bias.
- As this was a cross-sectional study design, we acknowledge that, from our results, we cannot infer cause-effect.

Declaration of competing interest

The authors declare that there are no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2020.08.008.

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