RESEARCH ARTICLE

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Foot Pain and Cycling: a survey of frequency, type, location, associations and amelioration of foot pain

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Abstract

The foot – pedal interface is the primary site for energy transfer from the cyclist to the bicycle, with anecdotal evidence that foot injuries from cycling are common. However, there is little research regarding the prevalence, aetiology and/or management of such injuries. 1) What is the distribution of age, gender, foot/pedal interface use and distances cycled amongst cyclists who experience foot pain? 2) What type of pain and what region of the foot do cyclists experience pain? 3) What amelioration techniques are used for this cycling foot pain? 4) Are there key groups of cyclists at greater risk of foot pain than others?. Cyclists over 18 years of age riding a non-stationary, upright bicycle at least once a week (minimum of one hour) were invited to participate in an electronic questionnaire. The electronic link to the survey was distributed through three large databases Bike SA, (the peak representative body for South Australian cyclists), Mega Bike (a large bicycle shop in Adelaide) and staff and students of the School of Health Sciences at the University of South Australia. The survey asked about cycling participation, pedal interface and foot pain. The survey was returned by 397 participants (93.9% responses eligible for analysis). Foot pain was reported by 53.9% respondents. The forefoot, inclusive of the toenails, toes and ball of the foot, was the highest reported region of foot pain (61%). The pain was described as 'burning' and 'numbness'. 'Stopping' for a period of time during the cycle and 'removing their shoes', 'walking around', 'massaging' and 'stretching' the foot was the most commonly reported amelioration technique. The group of cyclists at greatest risk of experiencing foot pain are those who ride with an attached (cleated-in, strap, cage) foot-pedal interface.

This paper found a high frequency of foot pain in cyclists (53.9% of cohort). The pain was overwhelmingly described as 'burning' and 'numbness' with the forefoot region most implicated. 'Stopping' for a period of time during the cycle and 'removing their shoes', 'walking around', 'massaging' and 'stretching' the foot was the most commonly reported amelioration technique. The group of cyclists who are at the greatest risk of experiencing foot pain are those who ride with an attached foot-pedal interface (2.6 odds ratio); followed by the combination of those who use an attached foot-pedal interface and who are 26 years of age or older (2.2 odds ratio). Our study highlights the importance of addressing the current knowledge gap regarding foot pain and cycling and the need to investigate effective interventions for this problem.

Keywords: foot pain, cyclist, bicycle, injury

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Introduction

Bicycling is increasing in popularity in Australia (Sikic et al 2009; Cycling Promotion Fund Annual Report, 2009). Austroads and the Australian Bicycle Council reported in their National Cycling Participation Report in 2011 that 4 million Australians participated in cycling, with 18% of Australians cycling in any typical week (Australian Bicycle Council 2010). Cycling is currently the fourth most popular sport for adults in Australia, with a higher participation rate than running (11.6% vs. 9.9%) (Cycling Promotion Fund Annual Report, 2009). Bicycle sales have annually outsold car sales in Australia since the year 2000, with 2,000,000 more bicycles sold than cars over this period (Australian Bicycle Council 2010). Whilst the health, environmental, community and financial benefits of cycling are well acknowledged (Cycling Promotion Fund Annual Report, 2009; Bauman and Rissel 2009) the injuries associated with this activity are far less reported. For these reasons, and perhaps associated with the 'hype' of Adelaide playing host each year to the only world tour cycling event to be held in the southern hemisphere (The Tour Down Under), it appears that recreational cycling participation is steadily increasing in South Australia, as it is indeed increasing Australia wide.

Cycling injury research can be broadly collated into two categories, trauma-related (as a result of a collision or fall) and non-trauma related (over-use type injuries). Non-traumatic cycling injury literature is primarily focused on the neck, arms, buttock, perineum and knees, with very little published data on foot injuries in cycling (Callaghan 2005; Mellion 1991). The foot injuries that are reported in the literature are descriptions of foot numbness, metatarsalgia, achilles tendonitis and plantar fasciitis (Mellion 1991; Gregor and Wheeler 1994; Sanner and O'Halloran 2000). Dettori and Novell (2006) reported on the prevalence and incidence of lower leg/foot cycling injuries collated from four separate studies within their review of non-traumatic bicycling injuries (Dannenberg et al 1996; Kulund and Brubaker 1978; Weiss 1985; Wilber et al 1995). The data were presented as self-reported levels of pain collected from cyclists participating in tour rides, ranging from the shortest distance of 545km over a six day event to the longest distance of 7242km over an 80 day event. The prevalence of lower leg/foot injuries was reported to be 7%, 13% and 22% respectively, and an incidence rate of 24% (Dettori and Novell 2006). However this data considered both the lower leg and the foot to be one unit rather than separate anatomical regions. Therefore the data cannot be extrapolated and used as meaningful foot pain data for the wider cycling population.

The foot – pedal interface is the only direct site for energy transfer from the cyclist to the bicycle. In a 'cleated-in' pedal-interface, all of the body's force to make the bicycle move forward are transferred to the pedal at a small contact area of around 60mm2, and there is consistent anecdotal evidence that forefoot pain at this point of energy transfer is common (Callaghan 2005; Gregor and Wheeler 1994; Jarobe and Quesada 2003). However, there is very little research regarding the frequency, aetiology and/or management of foot pain in cycling available to guide the clinician. The small amount of available literature is descriptive non-systematic literature reviews or opinion. Where data is reported, participants have not been sampled robustly and moreover the literature focuses overwhelmingly on elite cyclists.

We therefore undertook a study to address the lack of information about foot pain in cycling. Primarily we aimed to describe the frequency of foot pain amongst cyclists in Adelaide, South Australia.

Materials and methods

Ethics approval was provided by the University of South Australia. An electronic survey was used to collect information from cyclists within South Australia, during December 2010. Cyclists were invited to take part in our research and complete the survey if they were riding a non-stationary, upright bicycle at least once per week for a minimum of one continuous hour, and were at least 18 years of age. At the time the study was conducted, there was no formal register of cyclists in South Australia, as cyclists are not required to register this mode of transport with the government. We thus debated the best approach to recruiting a strong sample of cyclists which would reflect the general population of bike riders in South Australia. A pragmatic approach was chosen.

The electronic link to the survey was distributed through three large databases; Bike SA (the peak representative body for South Australian cyclists, providing among many other services, personal accident and public liability insurance to their members), Mega Bike (a large bicycle shop in Adelaide) and staff and students of the School of Health Sciences at the University of South Australia. For the first two sources of cyclists, the survey link was distributed to members through the organisations' electronic newsletter. For the last source of cyclists, a direct email was sent with a link to the survey through the university general email list. It is of note that the survey was directed towards regular cyclists based in South Australia. We did not know how many individuals had access to email at the time of survey dissemination (and therefore received the survey link), or how many people who received the survey, fitted the inclusion criteria. No details were collected on how survey respondents received the survey.

The most appropriate and cost-efficient method of data collection for this research was an electronic survey (www.surveymonkey.com). No validated surveys are available for foot pain in cycling, thus the survey was designed by two authors (HU & SJ) (both cyclists). The questions were designed to collect as much relevant information as possible and yet still be easy to complete, focusing on establishing the basic demographic of the respondents (assumed to reflect Adelaide's cycling community), with presence or absence of foot pain being the main outcome of interest. The survey was distributed for feedback to researchers with experience in survey design and cycling. The survey items and order were modified iteratively from the feedback. No pilot study was conducted to test validity or reliability. The survey instrument contained ten questions and took approximately four minutes to complete, please refer to appendix A – Survey).

Data were then downloaded into an MSExcel file. Descriptive statistics were used: percentages for question responses, with differences between responses tested by chi-square analysis. Responses to the question 'Please describe this pain that you have experienced (eg: type of pain, what makes it worse?, what makes it better?)' were sorted into categories using emergent coding, to understand the nature of cycling-related foot pain for future analysis.

Putative risk factors for cycling-related foot pain were considered in categorical form for analysis, using logistic regression models. Where variables could be divided into more than two categories, divisions were based on similar data frequencies in categories, and/or logical data groupings.

- Gender - (comparison level female)
- Age - (comparison level 18-25 year olds); 26-35 years; 36 – 50 years; 51 – 70+ years

- Kilometres ridden per week (comparison level 1-25 km); 26 – 50 km; 51 – 80 km; 81 – 100 km; 100 km+
- Attached foot – pedal interface (comparison No attachment)
- Reason for cycling - (comparison Transport); exercise; both exercise and transport.

Univariate strength of associations between foot pain and putative independent predictors were described by Odds Ratios (95% CI) derived initially from logistic regression models using SAS Version 9.3 in the manner described by Bagley, White and Golomb (2001). The univariate predictors were then considered for the biological potential for interaction. A priori, age, using an attached foot-pedal interface and longer distances ridden potentially interacted. Older-aged cyclists may suffer foot pain the longer distance they ride because of the potential for aging joints and muscles to be stressed by the lengthy repetitive action of cycling (Fukuchi and Duarte 2008). Using a pedal interface and riding longer distances may stress structures of the foot because of sustained localised pressure on the ball of the foot (Sanderson, Henning and Black 2000; Henning and Sanderson 1995; Jarobe and Quesada 2003). A multivariate stepwise logistic regression model was then developed which included the strongest univariate predictors, and any significant interaction terms.

Research questions: Primarily we aimed to describe the frequency of foot pain amongst cyclists; as a result four research questions were posed: 1) What is the distribution of age, gender, foot/pedal interface use and distances cycled amongst cyclists who experience foot pain? 2) What type of pain and what region of the foot do cyclists experience pain? 3) What amelioration techniques are used for this cycling foot pain? 4) Are there key groups of cyclists at greater risk of foot pain than others?

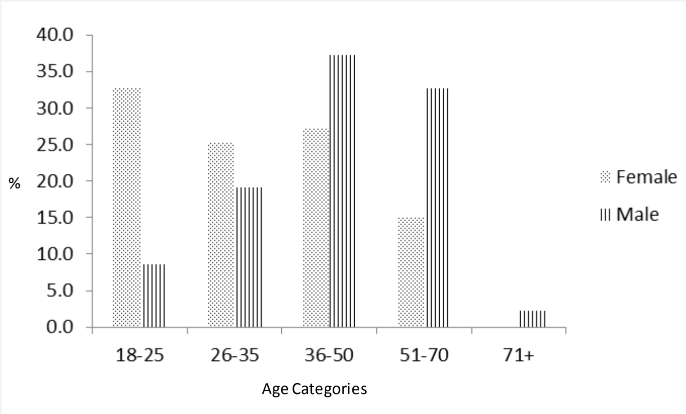

Figure 1. Percentage of males and females within each age category.

Results

Research question 1 - Demographic of participants

A total of 397 surveys were returned with 373 surveys (93.9%) complete and eligible for analysis (24 surveys were incomplete and hence excluded). There were more males than female respondents (265 males, 107 females; 71.3% v 28.7%). The frequency of gender representation within each age category can be seen in figure 1.

Over half of the cohort (n=201) reported experiencing foot pain whilst cycling (53.9%), figure 2. Of these 201 participants, nine reported cycling for transport only, 90 for exercise only and 102 for both transport and exercise. The response of 'other' reported by participants as to why they cycle was predominantly answered, 'for pleasure' and 'for competition'.

Of the cyclists who did experience foot pain the greatest sufferers were participants aged 26-35 years (60.3%) and 36-50 years (60.2%). People who rode 51-80 km per week and 100km+ represented the largest group of foot pain sufferers with 60.3% and 61.2% respectively. Whilst foot pain was reported by 71.4% of people who used an attached foot-pedal interface (cleated-in, strap, cage).

Research question 2 - Location and description of foot pain

Location of foot pain was reported by 197 participants (294 pain locations). The majority of foot pain was reported to occur at the ball of the foot (109 reports), followed by the toes and arch of the foot (59 reports each). There was a smaller representation of ankle (17 reports), toenails (13 reports) and heel (7 reports) pain. The choice of 'Other' (30 reports) did not elicit any new foot regions that weren't already offered. The forefoot, inclusive of the toenails, toes and ball of the foot, was the highest reported region of foot pain

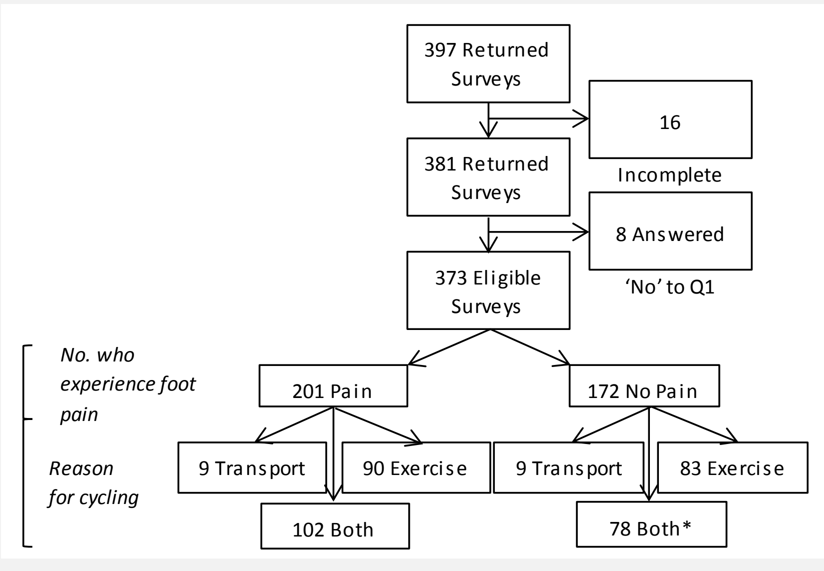

Figure 2. Flow diagram of study sample.

*2 participants answered 'other' only.

Table 1. Strength of association of independent predictors with foot pain

Predictors of Pain	Default Comparator	% of ppl with pain	Odds Ratio Estimate	95% CI
Gender	Female	50.5	0.8	(0.5 – 1.3)
Age	18 – 25 yr olds	32.8	-	-
- 26 – 35		60.3	3.1	(1.5 – 6.3)*
- 36 – 50		60.2	3.1	(1.6 – 5.8)*
- 51 – 70+		53.2	2.3	(1.2 – 4.5)*
Km's ridden	1 – 25km	17.9	-	-
- 26 – 50 km		40.9	3.1	(1.0 – 9.9)*
- 51 – 80 km		60.3	6.9	(2.3 – 20.8)*
- 81 – 100 km		52.9	5.2	(1.8 – 15.2)*
- 100 km +		61.2	7.2	(2.6 – 20.0)*
Attached foot – pedal interface	No attachment	28.6	3.6	(2.0 – 6.5)*
Reason for cycling	Transport	0.0	-	-
- Exercise		52.0	1.3	(0.5 – 3.3)
- Both		56.7	1.6	(0.6 – 4.0)

* = Significant

(61%). Followed by the midfoot region, inclusive of the arch of the foot (20%) and the rearfoot region, consisting of the heel and ankle (8.2%) (Note: 'Other' 10.2%).

A total of 161 descriptions of the foot pain were reported. Descriptors of pain were resoundingly similar, the respondents used one or a combination of the following descriptors; 'numbness', 'hot foot', 'pins and needles', 'cramp', 'dull ache', 'tingling', 'burning', 'swelling' and 'pressure'.

Table 2. Results of univariate modelling using recombined categories of independent predictors

Predictors of Pain	Default Comparator	Odds Ratio Estimate	95% CI
Km's ridden	1 – 25km	-	-
- 26 – 50 km		3.2	(1.0 – 9.9)*
- 51 km +		6.6	(2.5 – 17.9)*
For binary form analysis			
- ≥51 km		3.1	(1.8 – 5.3) *
Foot – pedal interface	No attachment	-	-
- 'Cleated-in'		4.4	(2.3 – 8.4)*
- Cage + Strap		2.2	(0.9 – 5.5)
For binary form analysis			
- All attachments		3.6	(1.9 – 6.5) *
Age	18 – 25 yrs olds	-	-
For binary form analysis			
- 26 yrs +		2.8	(1.6 – 5.1)*

* = Significant

Research question 3 – Amelioration techniques

There were 77 responses of amelioration for the foot pain. The resounding majority suggested that 'stopping' for a period of time during the ride helped to relieve the pain. Stopping was mostly combined with 'removing shoes', 'walking around', 'massage' and 'stretching'. There were a large number of responses that also suggested 'wiggling my toes', 'concentrating on pulling-up' (the pull-up phase of the pedal stroke), 'loosening shoes', 'changing shoes', 'changing cleats' and 'using orthotics and insoles'.

A total of 261 responses to question ten; what happens as a result of the pain? were recorded. The majority of responses (155) responded with 'allow you to keep riding, although it does annoy you'. Sixty-two responded with 'reduce your performance', whilst 'stop

Table 3. Multivariate stepwise regression analysis

Modelling steps	Variable1	Variable 2	Variable 3	OR (95%CI)	Likelihood ratio	df	p value
1	interface			3.6 (2.0-6.5)	19.8	1	<0.05
	interface			2.6 (1.4-4.9)	26.5	2	<0.05
		distance		2.2 (1.2-3.9)			
	interface			4.5 (1.4-13.3)	28	3	<0.05
		distance		4.0 (1.2-12.7)			
			interface*distance	0.4 (0.1-1.7)			
2	interface			3.1 (1.7-5.7)	26.7	2	<0.05
		age		2.2 (1.204.1)			
	interface			2.6 (1.4-4.9)	30.4	3	<0.05
		age		1.3 (0.5-2.9)			
			interface* age	1.9 (1.0-3.9)			
3	interface			2.6 (1.3-4.9)	30.2	3	<0.05
		distance		1 (0.8-1.3)			
			interface* age	2.2 (1.1-4.2)			
4	interface			2.3 (1.1-4.8)	23.9	2	<0.05
		interface*distance*age		1.7 (1.0-3.1)			

you from riding' and 'not bother you at all' was reported 13 times respectively. There were 18 responses of 'other' which highlighted the following significant themes; 'becomes a mental problem to block the pain out', 'continually shift my position in the saddle', 'continually concentrate on wiggling my toes', 'stop for periods of time during the ride' and 'buy new shoes'.

Research question 4 - Are there key groups of cyclists at greater risk of foot pain than others?

Table 1 reports the univariate association between each putative cause of foot pain and foot pain occurrence. Of note, all factors excluding gender and reason for cycling were significantly associated with foot pain.

The significant associates; age, kilometres ridden and use of an attached foot-pedal interface, were then reclassified into fewer categories for further testing, again using univariate models. This was undertaken by combining categories with similar associations. The re-grouping of these variables and the findings of the second round of univariate models are reported in Table 2.

Testing indicated that being aged 26 years or older, regularly cycling greater than 51 km and using an attached-pedal interface were significantly associated with foot pain.

The three strongest predictors of cycling induced foot pain; foot-pedal interface (all attachments), distance (>51km) and age (26 yrs +) were entered into a multivariate stepwise regression analysis, refer to table 3. Model three provides the strongest prediction of foot pain as it takes account for all three important variables and explains significantly more variance than distance and interface alone, or interface and age alone.

Using an attached foot-pedal interface is the strongest predictor of experiencing foot pain whilst cycling, increasing a cyclists chance by 2.6 times. The second strongest predictor of foot pain is in a model which considers the interaction of an attached foot-pedal interface and being 26 years of age or older, this interaction increasing a cyclists risk by 2.2 times.

Discussion

This paper is the first known study to describe and report on the frequency of foot pain in cyclists in Australia. Over half the cohort reported foot pain whilst cycling with forefoot pain being the highest reported region of pain. The pain was overwhelmingly described as 'burning' and 'numbness'. 'Stopping' for a period of time during the cycle and 'removing their shoes', 'walking around', and 'massaging' and 'stretching' the foot were the most commonly reported amelioration techniques. The group of cyclists at greatest risk of experiencing foot pain were cyclists using an attached foot-pedal interface. This study highlights the importance of considering the foot-pedal interface as a mechanism of producing pain, particularly when spending regular or lengthy periods on a bicycle.

The foot-pedal interface has not been well addressed within cycling literature despite its importance for energy transfer from the cyclist to the bicycle. Jarobe and Quesada concluded from their study that the plantar pressures recorded during seated cycling were within the range recorded for normal walking, despite cycling being considered a lower form of impact (Jarobe and Quesada 2003). Hence, the plantar pressures in cycling should not be dismissed as the possible cause of foot problems amongst cyclists. This is especially true for competitive cyclists who will potentially 'push' 39 million pedal cycles during their career (Jarobe and Quesada 2003). Whilst competitive and elite cyclists usually have ready access to medical services for their injuries, most recreational cyclists do not have the same high level of medical resources at their disposal. This could be a significant issue for recreational cyclists, as over half of the recreational cyclists in this study did in fact experience foot pain whilst cycling.

The 'clipless' interface has been shown to localise plantar pressure to the hallux and first metatarsophalangeal joint (Sanderson, Henning and Black 2000; Henning and Sanderson 1995). Foot pain whilst cycling can perhaps in part be attributed to this localisation of plantar pressure whilst performing a highly repetitive task. The foot injuries reported in the literature to date describe foot numbness, metatarsalgia, achillies tendonitis and plantar fasciitis (Mellion 1991; Gregor and Wheeler 1994; Sanner and O'Halloran 2000). The data from our study seems to support the reports of foot numbness and metatarsalgia previously reported in the literature. These authors postulate that the repetitive activity of cycling which localises plantar pressures ('cleated-in' interface) may be more likely to contribute to conditions of neurovascular compromise. Symptoms of neurovascular compromise would include complaints of numbness, burning, tingling and cramping. The authors suggest that 'time spent riding' and 'pressures' of the different pedal-foot interfaces be further researched to explain the outcomes of this initial data.

Although this paper concentrates specifically on the foot-pedal interface, many other factors not explored within this research could be attributed to the presence of foot pain whilst cycling. These could include bicycle set-up (saddle height, saddle distance, cleat position), type of cycling shoe (type of cleat, material of sole), shoe fit (too tight, too narrow, attached too tightly), foot type (pes planus, pes cavus), presence of any lower limb biomechanical or structural deformities (genu varum, forefoot supinatus, ankle joint equinus), differences in body mass, cycling in hills or on flat terrain, use of low or high gear and experience and fitness of the cyclist. None of these factors can be confirmed or refuted with the data from this research. This data does however provide support for these factors to be explored. The amelioration techniques described by respondents which centred specifically on the foot-pedal interface, for example; changing their shoes, moving their cleats, removing or loosening their shoes, concentrating on the 'pull up phase' and wriggling their toes, would support a review of the fit of the bicycle and the cyclist and the shoe wear worn.

Pain should not occur regularly as a result of participation in any sporting activity. As over half our cohort reported experiencing foot pain whilst cycling it appears to be an important issue requiring further investigation. Foot pain from cycling may have a negative impact on cycling participation, including reluctance to cycle at all. A community with large numbers of recreational cyclists experiences many benefits inclusive of environmental, health and financial benefits (Cycling Promotion Fund Annual Report 2009; Bauman 2009). Experiencing pain whilst cycling would seem to be particularly important for those cyclists who reported cycling for both transport and exercise (102 of the 201 surveyed participants; 50.7%) as the impact of their foot pain would potentially have larger ramifications on individual and community health. With increasing participation in recreational cycling in Australia, and the health benefits from it, there would appear to be a need to understand any problems experienced in order to maintain interest.

Limitations of the study and implications for future research: Primarily a limitation of the study is the cross sectional research design which does not allow for cause and effect relationships to be established. Secondly the limitations to our study relate in part to our sampling frame and the lack of a known denominator of cyclists to whom to distribute the survey. Four studies were identified amongst the literature that assessed non-traumatic bicycling injuries. Three of these studies sampled their cohort by surveying cyclists participating in tour events (Dannenburg et al 1996; Kulund and Brubaker 1978; Weiss 1985). Whilst Wilber and colleagues (1995) randomly sampled recreational cyclists with a mail-out questionnaire, no details were provided regarding how these cyclists were identified or as to how randomisation occurred.

In the absence of a formal register of cyclists in South Australia, external generalisability of our findings cannot be assumed, as we could not select participants randomly from a known reference population. Our sample reflects cyclists from only one State (South Australia). What is not known is how this sample represents the rest of the cycling population in South Australia, or of other Australian cycling populations. We attempted to recruit our sample using a pragmatic approach with broad circulation of the survey instrument through the cycling community, using common mechanisms of information exchange (emails, electronic newsletters). It is also possible that by using an internet based medium we would have also excluded potential participants whom did not have access to a computer at the time of the study, this potentially may have led to an underrepresentation of older adults within our sample.

Implications of the study: Despite the limitations of the study, particularly in relation to sampling and the unknown size of the likely reference group, a moderate sample size was achieved (n= 373). This sample provides useful pilot data which can be used to inform future research; with the results being applicable to both researchers and clinicians.

Future research needs to further investigate and describe more robustly the ‘cycling population’. In light of the definitional ambiguity surrounding the concept of ‘Recreation and Elite cyclists’ more research is required to define these populations. Within these populations, given the frequency of foot pain reported, investigations into causation and management of foot pain is warranted, which may involve an investigation of cycling shoe wear and/or the foot-pedal interface.

Conclusions

This paper found a high frequency of foot pain in cyclists (53.9% of cohort). The pain was overwhelmingly described as ‘burning’ and ‘numbness’ with the forefoot region (inclusive of the toenails, toes and ball of the foot) most implicated. ‘Stopping’ for a period of time during the cycle and ‘removing their shoes’, ‘walking around’, ‘massaging’ and ‘stretching’ the foot was the most commonly reported amelioration technique. The group of cyclists who are at the greatest risk of experiencing foot pain are those who ride with an attached foot-pedal interface (2.6 odds ratio); followed by the combination of cyclists who are 26 years of age or older and use an attached foot-pedal interface (2.2 odds ratio). Our study highlights the importance of addressing the current knowledge gap regarding foot pain and cycling and the need to investigate effective interventions for this problem.

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