Title: A longitudinal exploration of pain tolerance and participation in contact sports

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Abstract

Background/aims: Athletes who choose to engage in contact sports do so with the knowledge that participation will bring pain in the form of contact with others, injury, and from exertion. Whilst athletes who play contact sports have been shown to have higher pain tolerance than those who do not, it is unclear whether this is a result of habituation over time, or as a result of individual differences at the outset. The aim was to compare pain responses over an athletic season in athletes who participated in contact sport and those who disengaged from it.

Methods: One hundred and two new contact athletes completed measures of cold and ischemic pain tolerance, perceived pain intensity, pain bothersomeness, pain coping styles and attendance at the start, middle (4 months) and end (8 months) of their season. The athletes were drawn from martial arts, rugby and American football. Cluster analysis placed 47 athletes into a participating category and 55 into a non-participating cluster.

Results: Participating athletes had higher ischemic pain tolerance at the start ($r = 0.27$, $p = 0.05$), middle ($r = 0.41$, $p < 0.0001$) and end of the season ($r = 0.57$, $p < 0.0001$) compared to non-participating athletes. In addition participating athletes were more tolerant to cold pain at the end of the season ($r = 0.39$, $p < 0.0001$), compared to non-participating athletes. Participating athletes also exhibited higher direct coping, catastrophized less about injury pain and also found contact pain to be less bothersome physically and psychologically compared to non-participating athletes. Participating athletes were more tolerant of ischemic pain at the end of the season compared to the start ($r = 0.28$, $p = 0.04$). Conversely non-participating athletes became significantly less tolerant to both pain stimuli by the end of the season (cold pressor; $r = 0.54$, $p <0.0001$; ischemia; $r = 0.43$, $p = 0.006$). Pain intensity as measured by a visual analog scale did not change over the season for both groups.

Conclusions: Those who cease participation in contact sports become less pain tolerant of experimental pain, possibly a result of catastrophizing. The results suggest that athletes who commit to contact sports find pain less bothersome over time, possibly as a result of experience and learning to cope with pain. Athletes who continue to participate in contact sports have a higher pain tolerance, report less bothersomeness and have higher direct coping than those who drop out. In addition, tolerance to ischemic pain increased over the season for participating athletes.

Implications: Having a low pain tolerance should not prevent athletes from taking part in contact sports, as pain becomes less bothersome in athletes who adhere to such activities. Participating in contact sports may result in maintained cold pain tolerance, increased ischemic pain tolerance, reduced catastrophizing and better coping skills. Coaches can therefore work with athletes to develop pain coping strategies to aid adherence to contact sports.

Key words: tolerance; learning; adherence; bothersomeness; pain

1. Introduction

There is evidence that athletes and non-athletes differ in their responses to pain [1,2]. A meta-analysis of 15 studies found that athletes have a higher pain tolerance than non-athletes [3]. Athletes who participate in high contact sports have higher pain tolerance and report less pain intensity than athletes who play non-contact or low contact sports [4,5,6]; Athletes who engage in endurance sports also exhibit higher pain tolerance than others [7], and highly trained swimmers have higher pain tolerance than recreational athletes [8].

There are many plausible reasons for these differences, including alterations to endogenous inhibitory processes [3], individual differences such as personality [9], or learning to cope with pain [10]. It has been postulated that engaging in regular, vigorous physical activity may alter pain perception and tolerance, [3,11,7]. Such activity may improve or alter endogenous inhibitory processes, thereby reducing pain. Thus, endurance athletes may perceive and process pain differently to non-athletes as a result of repeated exposure to exhausting training [7]. Further studies have suggested that participation in high intensity training along with personality traits and perceptions regarding pain control may mediate pain responses [12]. It has also been postulated that individuals learn to tolerate pain through the use of coping strategies [12], or through habituation [13], resilience [14] or experience [5]. In laboratory studies repeated exposure to pain has resulted in task interference habituation, indicating that in controlled environments, the recurrent experience of pain may reduce its intensity and its detrimental effects on performance [13]. It has also been suggested that pain intensity may decrease as a result of experience, as illustrated in studies of battlefield pain [15] and labour pain [16]. There is evidence however that exposure to pain may result in sensitisation due to pain-related anxiety [17].

There has been little exploration of adherence to painful contact sports; however injury rehabilitation research has shown that individuals with high pain tolerance adhere better to treatment programmes [18]. Exercise adherence literature suggests that approximately 50% of people who begin an exercise programme drop out [19]. The intensity of activity, injury risk and exercise mode predict adherence [19]. Little research has examined the determinants of adoption and adherence of these different characteristics in contact sport.

This study is the first to explore participation in contact sports whilst examining differences in pain responses. Changes in pain reporting over time has been measured in experimental settings using healthy non-athletes [e.g. 20], however many studies have only taken measurements over a few days or hours [21] and none have examined athletes. We examined participation in contact sports over an athletic season alongside measures of cold and ischemic pain tolerance, pain bothersomeness and pain coping styles; non athletes were not included as previous work has already established that they differ from athletes in their response to pain. Further, the study aimed to test the competing hypotheses that contact athletes are more pain tolerant at the outset of playing or that pain tolerance increases in participating contact athletes during their first season.

2. Materials and Method

2.1 Hypotheses

In order to test the following hypotheses, data were collected at three points over an eight month period. Participating contact athletes were compared with those who stopped participating, following cluster analysis.

H_1: Cold and ischemic pain tolerance would differ at each point in the season according to whether athletes participated in the sport or stopped participating. It was hypothesised that participating contact athletes would increase pain tolerance over the season.

H_2: Pain intensity ratings would differ at each point in the season according to whether athletes participated or stopped participating in the sport. It was hypothesised that pain intensity ratings would reduce over the season for participating athletes.

H_3: Bothersomeness of pain would differ at each point in the season according to whether athletes participated or stopped participating in the sport. It was hypothesised that bothersomeness would reduce over the season for participating athletes.

H_4: Participating athletes would demonstrate a higher direct coping style than non-participating athletes.

2.2 Participants

A total of 102 pain free student athletes, 47 males (mean age = 23.6 years, SD = 6.0 years) and 55 females (mean age = 20.5 years, SD = 3.6 years), who were new to both post-compulsory education and voluntary contact sports were recruited via university notice boards, direct contact with local clubs and through social media. The participants had all recently begun taking part voluntarily in a contact sport (rugby, n = 62; American Football, n = 15; mixed martial arts (MMA), n = 11; and kickboxing, n = 14). Participants were classed as new to contact sports if they previously had no experience of engaging in sports where contact is allowed within the rules. Sample sizes were calculated based on prospective estimates of power and effect size figures to achieve an acceptable power level of 0.8 and a large effect size of 0.138 [22]. Ethical approval for the study was granted by the University Research Ethics Committee.

2.3 Materials

2.3.1 Demographic questionnaire. Participants were asked to state the number of injuries they had suffered, previous sports played as well as age and gender. The participants were also asked three questions about their feelings regarding beginning their new sport, which were responded to on a five-point Likert scale: how much they were looking forward to the sport (1 = *not at all*, 5 = *extremely*); how much they thought they would enjoy the sport (1 = *not at all*, 5 = *extremely*); and how they thought they would feel about any pain experienced in the sport (1 = *dislike it very much*, 5 = *like it very much*).

2.3.2 Sports Inventory for Pain (SIP15) [23]. Participants completed three adapted versions of the SIP15 questionnaire that were altered to account for three different pain types; contact pain, exertion pain and injury related pain. The wording in the questionnaire was adapted to reflect the pain types; for example, where the SIP15 states "I see pain as a challenge and I don't let it bother me", the word "contact", "injury" or "exertion" was inserted before the word "pain" to allow participants to reflect on that pain type specifically, a definition each type of pain was provided.

The SIP15 was developed from the original Sports Inventory for Pain [24] and is a 15 item inventory that contains three subscales – Direct Coping, Somatic Awareness and Catastrophizing. Direct Coping (through action) is a positive coping style in relation to pain and assesses the extent to which someone uses direct coping strategies to deal with pain. People who score high on this scale tend to approach pain positively and are prepared to endure it [24]. The Catastrophizing scale measures whether individuals ruminate on pain, feel it is unbearable or simply give up when in pain. High scores on this scale indicate high catastrophizing. The Somatic Awareness scale assesses whether someone is hyposensitve or hypersensitive to pain stimuli, with high scores indicating hypersensitivity. The SIP15 yielded acceptable reliability values for the three factors; direct coping (α=.87), catastrophizing (α=.76) and somatic awareness (α=.54). The SIP15 showed a sound factor structure and is a reliable tool where brevity is required in the field [23].

2.3.3 Bothersomeness questionnaire. Participants were asked to rate bothersomeness of the three types of pain in terms of physical bothersomeness (how much the pain interfered with physical performance of their sport) and psychological bothersomeness (how much the pain interfered with psychological states during performance). This was measured on a five point scale of 1 = *not at all*, 5 = *extremely*.

Participants were also asked to rate how enjoyable they found the sport (1 = *not at all*, 5 = *extremely*) and how they felt about any pain experienced in the sport (1 = *dislike it very much*, 5 = *like it very much*). They were also asked whether they had any injuries or physical reasons for not playing their sport (such as being ill) that had prevented them for attending for at least 1 week.

2.3.4 Attendance. At the 4-month and 8-month points, coaches supplied attendance data for each athlete in the form of training registers. This was converted to a percentage of attendance at all possible training sessions and competitive matches. This was taken to establish at the end of the season, whether the participants were classed as participating in the sport or whether they had disengaged from it. Most of the sports had two training sessions per week plus one competitive match. The MMA and kickboxing athletes had two training sessions per week and competitions once every two weeks. The duration of training sessions for rugby and American football was 1.5 hours. The martial arts training sessions were 1 hour in length. The duration of rugby matches was 80 minutes, American football matches could be between 2 and 3 hours. Martial arts competitions varied in length from 5 minutes to 30 minutes. It should therefore be noted that the sports differed in duration both in training and competition. In addition the exposure to pain and the intensity of the activity also differed. For example American football players are not active for the whole game, and a rugby player may not get involved in many tackles depending on his or her position. It was therefore not possible to standardise the amount of exposure to pain in each sport whilst maintaining ecological validity.

2.3.5 Pain Tolerance. Both pain tolerance measures were performed in isolation from other participants and the athletes were asked not to share their experiences or results with anyone else.

2.3.51 Cold pressor. A tank containing iced water was used, with the water circulated using a pump and kept at 2-3ºC. Participants were asked to place their dominant hand in the water up to the wrist and were instructed to keep it there for as long as possible. Pain tolerance was measured as time to withdraw in whole seconds, using a stopwatch. A ceiling time of 5 minutes was imposed, though participants were blind to this. At one minute intervals participants were asked to rate the intensity of pain on a visual analog scale (VAS), consisting of a 10 cm horizontal line with anchors at each end indicating the severity of the pain, these ranged from 0 (*no pain*), to 100 (*the most pain imaginable*). A measurement was then taken, in millimetres, from the no pain end of the scale to the mark made by the participant. Such scales have proved to be reliable and valid for measuring the intensity of acute pain [25].

2.3.5.2 Ischemia. Pain was induced using a sphygmomanometer and a handgrip dynamometer, following the submaximal effort tourniquet protocol outlined by [26]. Participants initially performed 3 maximal hand-grip exercises using a hand grip dynamometer. Their mean hand-grip score was calculated and was used to establish 50% of their maximum hand-grip. Participants were then asked to raise their non-dominant arm above their head for 30 seconds, after which a blood pressure cuff was placed round the upper arm and inflated to 230mm Hg at a rate of 40mm Hg per second. Full cuff inflation was taken as time 0 and participants rated on the VAS the intensity of their pain at this point. Participants then lowered their arm to the horizontal position and performed 20 handgrip dynamometer exercises at 50% of their maximum grip strength for a period of one minute. One exercise counted as a 2 second grip, followed by a 2 second rest. VAS ratings were then taken at minute intervals to a blind ceiling time of 5 minutes or when the participant asked for the test to be stopped. When the test stopped the cuff was gradually deflated as recommended by [27] to allow the volume of blood to gradually increase in the limb.

2.4 Procedure

Participants were tested at three data collection points. At the start of the season, participants first gave informed consent to participate, then completed a cold pressor test on the dominant hand and wrist. They then had a ten minute break in which they completed a demographic questionnaire and the SIP15. Following this, they were tested for ischemic pain tolerance using the submaximal effort tourniquet protocol on the non-dominant arm.

At subsequent data collection points, at month 4 and month 8, the same procedure was followed, with the addition of a bothersomeness questionnaire administered in the ten minute break. All participants returned for data collection at the mid-point of the season. A total of 17 participants did not return for the final data collection phase, meaning that data were available for 85 participants at all three collection points. Participants who had left the sport and did not return for final testing were contacted by telephone or email to state why they had stopped participating in the sport. Seven stated that they had other commitments that prevented them from continuing, and ten stated that they did not enjoy the sport anymore.

2.5 Data Analysis

To categorise participants as participating or non-participating at the end of the season (8 months) into an "engagement group", hierarchical cluster analysis was employed [22]. A total of 102 cases were included in the analysis. The variables used were percent attendance at the 4 month and 8 month points of the season. Between group linkage method was used, using a range of clusters from 2-4. Two clusters emerged and as a result, 47 participants were placed in a "participating" cluster (mean age = 23.0 years, SD = 6.34 years, male n = 27, female n = 20) and 55 were placed in a "non-participating" category (mean age = 21.0 years, SD = 3.5 years, male n = 20, female n = 35), (table 1). Participating athletes were those who were regularly attending training and competition, non-participating athletes were those who had either dropped out of the sport all together or who did not have regular attendance at training and as such were often not the coaches' first choice for competition. Following cluster analysis coaches were asked to comment on each athlete and state whether they thought athlete was indeed participating or non-participating. 100% of the cases were agreed by the coaches.

Independent samples t-tests for attendance at both time points revealed that the participating group had significantly higher attendance than the non-participating group ($p < 0.0001$); characteristics of the sample can be seen in table 1 and attendance figures can be seen in table 2.

Table 1, Sample Characteristics

	Overall sample	Participating Athletes	Non-Participating Athletes
Sport played before taking up contact sport	Netball n = 10 Cricket n = 6 Football n = 11 General exercise = 42 None n = 33	Netball n = 3 Cricket n = 5 Football n = 3 General exercise n = 21 None n = 15	Netball n = 7 Cricket n = 1 Football n = 8 General exercise n = 21 None n = 18
Current contact sport	MMA n = 11 Rugby n = 62 Kickboxing n = 14 American Football n = 15	MMA n = 7 Rugby n = 30 Kickboxing n = 8 American Football n = 8	MMA = 4 Rugby = 32 Kickboxing = 6 American Football n = 7
Injuries or illness that prevented attendance for at least 1 week	Injury n = 11 Illness n = 8	Injury n = 5 Illness n = 4	Injury n = 6 Illness n = 4

Data were analysed using IBM SPSS statistics version 21. MANOVA, mixed ANOVAs and t-tests were used to explore differences between the two groups of athletes and the measures taken over the season.

3. Results

3.1 Attendance, Enjoyment

Attendance at the 4 and 8 month points of the season was compared between the two groups. At both times the participating athletes had significantly higher attendance than the non-participating athletes; at 4 months ($t_{(100)} = 15.75$, $p < 0.0001$, $r = 0.84$), and at 8 months ($t_{(100)} = 37.10$, $p < 0.0001$, $r = 0.96$) (table 1).

Table 2, Attendance

Group	Four Months M (SD)	Min/max % at four months	Eight Months M (SD)	Min/max % at eight months
Participating	84.1 (13.8)	52%/100%	81.3 (14.1)	40%/100%
Non-participating	42 (13.1)	12%/72%	2.2 (6.7)	0%/30%

Average percentage attendance (mean [M] and standard deviation [SD]) for sport (training sessions and competition) and minimum and maximum attendance percentages for participating and non-participating athletes at 4 and 8 months

At the start of the season the groups did not differ for the question “how much are you looking forward to starting this sport?” and “how much do you think you will enjoy the sport?” $p > 0.05$. However for the question “how do you think you will feel about any pain you experience in the sport?” the non-participating athletes reported that they would dislike it more than the participating athletes, $t_{(100)} = 4.11$, $p < 0.0001$, $r = 038$. The participating athletes enjoyed their sport significantly more than the non-participating athletes at the 4 month point ($t_{(100)} = 4.16$, $p < 0.0001$, $r = 0.38$), and also at the 8 month point ($t_{(83)} = 5.58$, $p < 0.0001$, $r = 0.52$). They also felt significantly more positively about the pain they endured at 4 months ($t_{(100)} = 2.78$, $p = 0.006$, $r = 0.26$) and at 8 months ($t_{(83)} = 4.51$, $p < 0.0001$, $r = 0.44$).

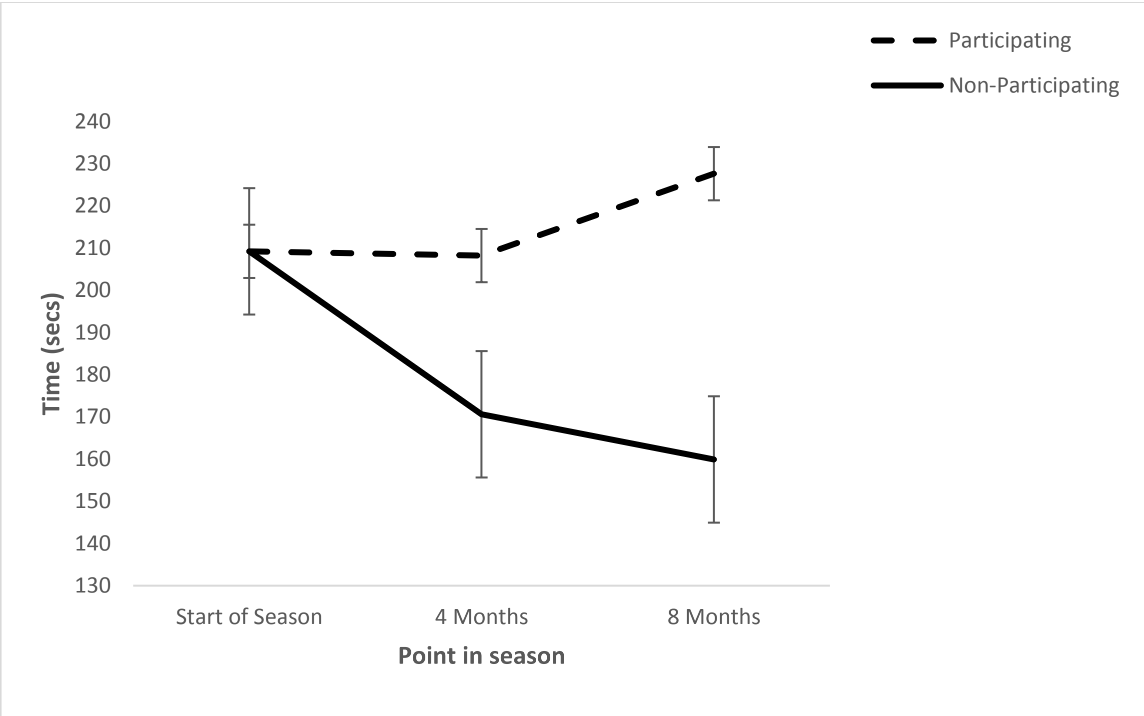
3.2 Cold Pressor

A 2x3 mixed ANOVA was conducted to examine differences between participating and non-participating contact athletes in cold pressor tolerance at the start of the season and at 4 and 8 months. There was no significant main effect of point in season on cold pressor tolerance regardless of engagement group (participating or non-participating) ($F_{(126, 1.56)}$ =

2.97, p = 0.06, r = 0.81). However there was a significant interaction effect of engagement group on cold pressor tolerance ($F_{(2, 1.52)}$ = 7.93, p = 0.002, r = 0.91).

Independent samples t-tests using a Bonferroni adjusted alpha of $p < 0.016$, showed that the participating athletes had significantly higher pain tolerance than the non-participating athletes at 8 months ($t_{(83)}$ = 3.91, p < 0.0001, r = 0.39), but not at the start of the season ($t_{(100)}$ = 1.18 p = 0.23, r = 0.11) or at the 4 month point ($t_{(100)}$ = 2.15, p = 0.03, r = 0.21); (figure 1). Therefore hypothesis 1 was partially supported.

Figure 1, Cold Pressor Tolerance.



Measurement of cold pressor tolerance (time in seconds) at the start of the season, at 4 months and at 8 months for participating and non-participating athletes.

To examine whether pain tolerance was significantly different only within the participating athlete group at the three different points in the season, a repeated measures ANOVA was conducted. There were no significant differences between pain tolerance at the start, 4 month or 8 month points in the participating group ($F_{(1.5, 69.3)}$ = 1.47, p = 0.24, r =

0.14). However to test the hypothesis that pain tolerance would increase in participating contact athletes, a paired samples t-test was conducted to compare cold pressor tolerance at the start of the season to 8 months. This revealed that there was no significant difference in pain tolerance at months 8 compared to the start of the season, $t_{(46)} = -1.31$, $p = 0.19$, $r = 0.16$.

In contrast, for non-participating athletes there was a significant main effect of cold pressor tolerance over the season ($F_{(1.5, 56.9)} = 11.95$, $p < 0.0001$, $r = 0.41$). Paired samples t-tests using a Bonferroni adjusted alpha of $p < 0.016$, revealed that the non-participating group were significantly more pain tolerant at the start of the season than at 8 months ($t_{(37)} = -3.99$, $p < 0.0001$, $r = 0.54$). There were no other significant differences between time points.

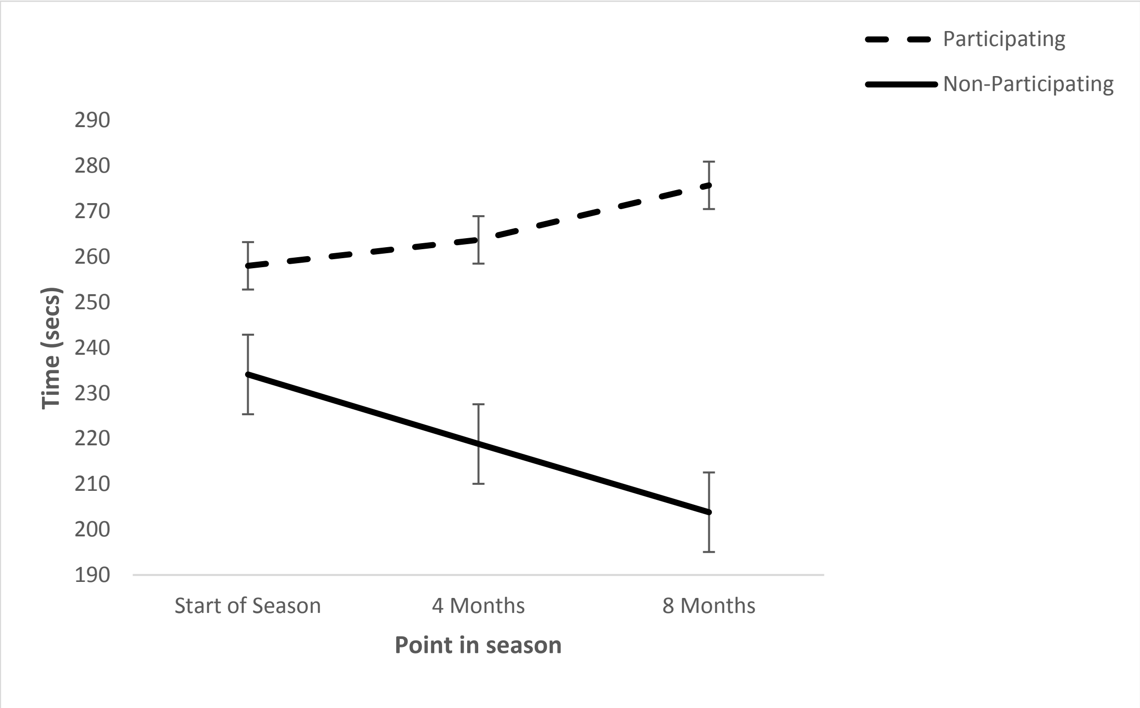
VAS scores at minute 1 were compared using a mixed 2x3 ANOVA. There was no significant main effect of cold pain intensity over the three time points ($F_{(1.64, 136.3)} = 2.78$, $p = 0.07$, $r = 0.14$). There was no interaction effect, meaning there were no significant differences between participating and non-participating athletes over the season ($F_{(1.64, 136.3)} = 1.54$, $p = 0.21$, $r = 0.11$). Therefore hypothesis 2 was not supported.

3.3 Ischemic Pain

A 2x3 mixed ANOVA was conducted to examine differences in ischemic pain tolerance across the season according to whether the participant adhered to the sport or not. There was no significant main effect of point in season on ischemic pain tolerance ($F_{(1.8, 149)} = 0.62$, $p = 0.52$, $r = 0.06$). However there was a significant interaction effect of engagement group on ischemic pain tolerance ($F_{(1.8, 149)} = 8.36$, $p = 0.001$, $r = 0.23$), indicating that ischemic pain tolerance was different according to whether the athlete participated in the sport or disengaged from it.

Independent samples t-tests were conducted to explore differences between groups at the three time points in the season, using a Bonferroni corrected alpha of $p < 0.016$. The participating athletes had higher pain tolerance than the non-participating athletes at the start of the season ($t_{(100)} = 2.83$, $p = 0.05$, $r = 0.27$), a small effect size. Participating athletes also had higher ischemic pain tolerance than the non-participating group at 4 months ($t_{(100)} = 4.57$, $p < 0.0001$, $r = 0.41$), a medium effect size. Participating athletes also had higher pain tolerance than non-participating athletes at 8 months ($t_{(83)} = 6.33$, $p < 0.0001$, $r = 0.57$), a large effect size. Taken together these results suggest that the participating athletes were more tolerant of ischemic pain throughout the season compared to the non-participating group (figure 2); accordingly, hypothesis 2 was supported.

Figure 2, Ischemic Pain Tolerance.



Measurement of ischemic pain tolerance (time in seconds) at the start of the season, at 4 months and at 8 months for participating and non-participating athletes.

To examine whether ischemic pain tolerance was significantly different within the participating athlete group at the three different points in the season, a repeated measures ANOVA was conducted. There were no significant differences between pain tolerance at the start, 4 month or 8 month points in the participating athletes ($F_{(2, 92)} = 2.79$, $p = 0.07$, $r = 0.17$). However to test the hypothesis that pain tolerance would increase in participating contact athletes a paired samples t-test was conducted to compare ischemic pain tolerance at the start of the season to 8 months. This revealed that there was a significant increase in pain tolerance at months 8 compared to the start of the season, $t_{(46)} = -2.05$, $p = 0.04$, $r = 0.28$.

A repeated measures ANOVA for the non-participating athletes revealed that there was a significant main effect of ischemic pain tolerance over the season in this group ($F_{(2,74)} = 5.61$, $p < 0.05$, $r = 0.25$). Paired samples t-tests using a Bonferroni correction revealed that this group were significantly less pain tolerant at 8 months compared to the start of the season ($t_{(37)} = 2.90$, $p = 0.006$, $r = 0.43$), a medium effect size. This indicates that non-participating athletes became less tolerant of ischemic pain as the season progressed.

A 2x3 mixed ANOVA revealed that there was no significant main effect of ischemic pain intensity over the three time points ($F_{(2,164)} = 1.33$, $p = 0.26$, $r = 0.08$). There was also no interaction effect ($F_{(2,164)} = 0.99$, $p = 0.37$, $r = 0.07$); there were no VAS differences according to whether the athlete participated or stopped participating in the sport. Therefore, hypothesis 3 was not supported.

3.4 Bothersomeness

A 3x2x2x2 (pain type, bothersomeness type, time in season, engagement group) mixed ANOVA was conducted to examine differences between participating and non-participating athletes in bothersomeness of injury, contact and exertion pain, both physical and psychological at 4 and 8 months, (table 3).

Table 3, Descriptive Statistics, Bothersomeness

Bothersomeness Measure	Time Point	Engagement Group	M	SD
Contact Pain Physical	4 months	Participating	2.2	0.9
		Non-participating	2.3	0.9
	8 months	Participating	1.8*	0.8
		Non-participating	2.5	0.9
Injury Pain Physical	4 months	Participating	2.7	0.9
		Non-participating	2.4	1.0

	8 months	Participating	2.5	0.9
		Non-participating	2.7	0.9
Exertion Pain Physical	4 months	Participating	2.1	0.9
		Non-participating	1.6*	0.6
	8 months	Participating	1.8	0.7
		Non-participating	1.5	0.5
Contact Pain Psychological	4 months	Participating	2.0*	0. 9
		Non-participating	2.4	0.8
	8 months	Participating	1.7*	0.8
		Non-participating	2.7	0.8
Injury Pain Psychological	4 months	Participating	2.5	0.9
		Non-participating	2.5	0.8
	8 months	Participating	2.5	0.9
		Non-participating	2.7	0.8
Exertion Pain Psychological	4 months	Participating	2.1	0.8
		Non-participating	1.7*	0.6
	8 months	Participating	1.7	0.8
		Non-participating	1.6	0.5

Means (M), and standard deviations (SD) for bothersomeness of contact, injury and exertion pain at 4 and 8 months for participating and non-participating athletes.
**indicates significant differences between participating and non-participating athletes, p < 0.05*

There was a significant 4-way interaction effect of pain type x time point in the season x bothersomeness x engagement group ($F_{(2, 166)}$ = 3.14, p = 0.04, r = 0.44), indicating that the three types of pain were different according to whether the person adhered or not to the sport, the time point in the season and according to whether they found the pain psychologically or physically bothersome.

At 4 months, participating athletes found exertion pain more physically bothersome than the non-participating athletes ($t_{(83)}$ = 2.68, p = 0.009, r = 0.28), a small effect size. In addition at 8 months, participating athletes found contact pain to be significantly less physically bothersome compared to non-participating athletes ($t_{(83)} = -3.79$, $p < 0.0001$, $r = 0.38$), a medium effect size.

At 4 months, participating athletes found exertion pain significantly more psychologically bothersome compared to non-participating athletes ($t_{(83)} = 2.36$, $p = 0.02$, $r = 0.25$), a small effect size. At 4 months participating athletes also found contact pain to be significantly less psychologically bothersome than non-participating athletes ($t_{(100)} = -1.96$, $p = 0.05$, $r = 0.19$), a small effect size. In addition, at 8 months participating athletes found contact pain significantly less psychologically bothersome compared to non-participating athletes ($t_{(83)} = -5.41$, $p < 0.0001$, $r = 0.51$), a large effect size.

Participating athletes found contact pain to be less physically bothersome at 8 months compared with 4 months ($t_{(46)} = 5.49$, $p < 0.0001$, $r = 0.60$), a large effect size. They also found contact pain significantly less psychologically bothersome at 8 months compared to 4 ($t_{(46)} = 3.93$, $p < 0.0001$, $r = 0.5$), a large effect size. Injury pain was also more physically bothersome at 8 months compared with 4 months ($t_{(46)} = 2.65$, $p = 0.01$, $r = 0.36$), a medium effect size, but there were no differences for psychological bothersomeness at the two time points. Exertion pain was significantly less physically bothersome at 8 months compared with 4 months ($t_{(46)} = 3.19$, $p = 0.003$, $r = 0.42$), a medium effect size, and also less psychologically bothersome at 8 months compared with 4 months ($t_{(46)} = 4.07$, $p < 0.0001$, $r = 0.51$). Taken together these results indicate that all pain types were significantly less physically and psychologically (apart from injury pain) bothersome by the 8 month point for the participating athletes, supporting hypothesis 3.

For non-participating athletes, physical bothersomeness of exertion pain was not significantly different between the 4 and 8 month points of the season ($p = 0.16$). However contact pain was significantly more physically bothersome at 8 months compared to 4 months ($t_{(37)} = -2.13$, $p = 0.03$, $r = 0.32$), a medium effect size. Contact pain was also more psychologically bothersome at 8 months compared to 4 months ($t_{(37)} = -2.97$, $p = 0.005$, $r = 0.43$), a medium effect size. Injury pain was also significantly more physically bothersome at 8 months compared to 4 months ($t_{(37)} = -2.48$, $p = 0.01$, $r = 3.7$), a medium effect size, but there were no differences for psychological bothersomeness. Taken together these results suggest that contact pain, in particular, became more bothersome, both physically and psychologically as the season progressed for the non-participating group.

3.5 SIP15

A 2x3 MANOVA (engagement group, SIP15 subscale) was conducted using the SIP15 subscales as dependent variables. There was a significant main effect of engagement group on SIP subscales ($F_{(27,57)} = 10.57$, $V = 0.83$, $p < 0.0001$, $r = 0.39$). Each subscale is discussed below. Pillai's Trace statistics are reported where scales did not meet the assumption of homogeneity of variance [28].

3.5.1 Direct Coping. There was a significant main effect of engagement group on direct coping ($F_{(9,75)} = 13.77$, $V = 0.62$, $p < 0.0001$, $r = 0.39$). Univariate tests revealed that participating athletes had higher scores than the non-participating athletes at the following time points: at the start of the season for injury pain ($F_{(1,83)} = 26.47$, $p < 0.0001$, $r = 0.49$) and also for contact pain ($F_{(1,83)} = 43.5$, $p < 0.0001$, $r = 0.58$). At 4 months, participating athletes also had higher scores for injury pain ($F_{(1,83)} = 36.5$, $p < 0.0001$, $r = 0.55$) and contact pain ($F_{(1,83)} = 23.5$, $p < 0.0001$, $r = 0.46$). At 8 months participating athletes continued to have higher scores than non-participating athletes for injury pain ($F_{(1,83)} = 64.78$, $p < 0.0001$, $r = 0.66$) and also for contact pain ($F_{(1,83)} = 56.38$, $p < 0.0001$, $r = 0.63$). There were no significant differences for exertion pain. These results indicate that the participating athletes exhibited higher direct coping for contact and injury pain than non-participating athletes at all three time points across the season. This supports hypothesis 4, (table 4).

Table 4: Descriptive Statistics, Sports Inventory for Pain 15 subscales

Scale	Engagement Group	Pain Type	Start Season *M(SD)*	4 months *M(SD)*	8 months *M(SD)*
Direct coping	Participating	Injury	25.1(3.9)[a]	25.5(2.9)[b]	25.8(2.8)[c]
		Contact	26.2(3.8)[d]	25.6(3.3)[e]	26.2(3.2)[f]
		Exertion	24.4(2.9)	25.0(3.0)	25.4(3.1)
	Non-participating	Injury	21.4(2.1)[a]	21.8(2.5)[b]	21.1(2.5)[c]
		Contact	21.7(2.0)[d]	22.5(2.3)[e]	21.5(2.2)[f]
		Exertion	24.6(2.4)	24.9(3.1)	24.3(3.1)
Catastrophizing	Participating	Injury	17.7(2.8)	12.8(3.5)[g]	12.5(3.2)[h]
		Contact	12.3(3.8)	12.9(3.3)	12.5(3.2)
		Exertion	12.0(3.6)	13.2(3.9)	12.0(3.0)
	Non-participating	Injury	17.3(2.5)	18.6(3.2)[g]	19.1(3.3)[h]
		Contact	13.1(2.5)	13.0(2.4)	13.4(1.9)
		Exertion	12.5(2.7)	12.1(2.8)	11.8(2.6)
Somatic Awareness	Participating	Injury	8.7(1.2)	9.2(1.3)	9.6(1.4)
		Contact	8.8(2.0)	8.9(1.9)	8.9(2.0)
		Exertion	8.5(2.0)	9.0(1.9)	9.1(1.8)
	Non-participating	Injury	8.7(1.0)	9.2(1.4)	9.3(1.3)
		Contact	8.6(1.7)	8.5(2.2)	8.5(2.2)
		Exertion	8.3(1.6)	8.3(1.7)	8.5(1.8)

Means (M) and standard deviations (SD) for SIP15 subscales for exertion, contact and injury pain at the start of the season, at 4 months and at 8 months for participating and non-participating athletes. Superscript letters indicate significant differences between participating and non-participating athletes, p < 0.05

3.5.2 Catastrophizing. There was a significant main effect of engagement group on catastrophizing ($F_{(9,75)} = 15.83$, $V = 0.65$, $p < 0.0001$, $r = 0.41$). Univariate tests revealed that the participating athletes had lower catastrophizing scores than the non-participating athletes for injury pain at 4 months ($F_{(1,83)} = 60.55$, $p < 0.0001$, $r = 0.64$) and at 8 months ($F_{(1,83)} = 83.37$, $p < 0.0001$, $r = 0.71$).

In addition there was a significant change in catastrophizing for injury pain over the season in the participating athlete group; $F_{(2,1.11)} = 52.74$, $p < 0.0001$, $r = 0.98$. Bonferroni tests revealed that catastrophizing was significantly reduced at month 4 and 8 compared to the start of the season, $p < 0.0001$, but there were no differences between month 4 and 8.

3.5.3 Somatic Awareness. There was no significant main effect of engagement group on somatic awareness ($F_{(9,75)} = 0.48$, $\Lambda = 0.94$, $p > 0.05$).

4. Discussion

The aim of this study was to examine pain tolerance, bothersomeness and coping styles over a season, whilst accounting for participation in contact sports. Results indicated that participating athletes were more pain tolerant than non-participating athletes after 8 months for both pain measures. They also found pain less bothersome and had higher direct coping than those who disengaged from contact sports. Whilst the participating athletes did not become significantly more pain tolerant of cold pain, they were more tolerant of ischemic pain at 8 months compared to the start of the season. In contrast and surprisingly, the non-participating athletes became significantly less pain tolerant over the season for both measures.

4.1 Pain Tolerance

Pain tolerance differences were found between participating and non-participating athletes; hypothesis 1 was partially supported for cold presssor as participating athletes had higher cold pain tolerance than non-participating athletes only at the end of the season. Hypothesis 1 was fully supported regarding ischemic pain, as the participating group had higher tolerance than the non-participating group at all three time points, though it should be noted that at the start of the season the difference was small ($r = 0.27$). In addition the participating athletes had significantly higher ischemic pain tolerance at month 8 compared to the start of the season.

The fact that pain tolerance results differed slightly for ischemia and cold pain may be a result of the protocol, and the gradual build-up of ischemic pain [29] compared to the intense immediate pain felt using cold pressor [30] which can then subside [31]. Studies have shown that cold and ischemic pain differ in their intensity and unpleasantness [32] and therefore it recommended that a number of stimuli are used to determine pain sensitivity [29]. Such differences in responses to cold and ischemic pain have been found in other studies using athletes [33]. It has been suggested that athletes learn about certain types of pain and therefore view and respond to them differently [33]. It has been posited by Addison et al [30] that ischemic pain is similar to exertion pain and that cold pain is experienced by some athletes in the form of ice packs or baths. Therefore the athletes may have attached a certain meaning to each stimulus depending on their experience of it, resulting in the differences between the pain induction methods.

The changes in pain tolerance over time for the participating athletes are interesting, as this group maintained cold pain tolerance and showed increased ischemic pain tolerance at the end of the season compared to the start. This suggests that these athletes may have learned to cope with ischemic pain particularly well. It should be noted that at 8 months 38% of this group reached the 5 minute ceiling time for the ischemic stimulus. 36% reached the ceiling time for cold pressor. It therefore cannot be discounted that ceiling effects are present, and had the participants been able to continue, differences in tolerance may have been noted over the whole season for both measures.

The results suggest that participation in contact sports may not be solely dependent upon pain tolerance at the outset; rather a combination of physical and psychological factors may help athletes cope with pain and therefore foster adherence. It is possible that participation in the sport may have produced a learning effect on the participating group, supporting Geva and Defrin's [12] suggestion that participation in regular exercise may moderate responses to pain. Indeed fear of pain has been shown to be inversely related to hours spent training, indicating that the more one engages with painful activity, the less one fears it [12]. As such fear of pain could explain the decline in pain tolerance in the non-participating group. Perhaps due to exposure to pain in the form of contact sports, this group became more fearful of it, echoing research suggesting that pain related anxiety has been shown to reduce pain tolerance over time [17]. This links to the finding that the non-participating group catastrophized more about pain than the participating group. A further suggestion, though not directly measured, is that the non-participating group had low pain related self-efficacy, which has also been shown to reduce tolerance to pain [34] or that negative affect regarding the sport (reflected in their low enjoyment ratings) increased their sensitivity to pain [35].

There were no differences in pain intensity between groups or time points using VAS after one minute of pain, meaning hypothesis 2 was not supported. Therefore even though the groups differed for pain tolerance, they both perceived the initial pain to be of a similar intensity. Previous studies have found that pain intensity as measured by VAS is often independent of pain tolerance [e.g. 36]. Participating athletes may have employed coping strategies [26] or, they may have viewed pain differently to the non-participating athletes [37]. Indeed participating athletes felt more positively about pain and had higher direct coping and lower catastrophizing scores for contact pain compared to non-participating athletes. It also cannot be discounted that the non-participating athletes may have lacked motivation to partake in the pain tasks. The participant information and consent forms for the study highlighted that the focus of the research was on contact sports participants; as these athletes had reduced their participation, they may not have felt that they were important to the research.

The result that participating athletes did not show any significant changes in pain ratings over the season (according to VAS) accords with other research that has found that pain perception does not necessarily change as a result of repeated exposure to pain [38]. Therefore experience of pain within sports may not influence pain perception per se and significant decreases in perceived pain intensity may not be necessary for continued participation in contact sports. On the other hand, significant reductions in pain tolerance may result in reduced engagement in sports as demonstrated by the non-participating athletes' results. Collectively the pain tolerance results suggest that participating athletes may have learned how to adapt to pain, whereas the non-participating group may have failed to do so within the sport and the pain tasks presented.

4.2 Bothersomeness

Participating athletes found contact pain both physically and psychologically less bothersome than non-participating athletes at 8 months, supporting hypothesis 3. In addition the participating athletes found all three types of pain less bothersome at 8 months compared to 4 months. This suggests that either conditioning may have taken place, or that these athletes simply learned to cope more effectively with pain. In addition, better endogenous pain inhibition [11] or reduced fear of pain and catastrophizing as a result of experience may be responsible [12].

The non-participating athletes found contact pain to be significantly more psychologically and physically bothersome at 8 months compared to at 4 months. They also found contact and injury pain to be more physically bothersome at 8 months. This may explain their lack of engagement and reduced enjoyment in their sport. It has been suggested that pain-related self-efficacy may predict whether someone approaches or avoids situations [39]. Athletes with low pain related self-efficacy may reduce involvement in sport, whereas those who are able to ignore or cope with pain may continue participation [40].

The participating athletes found exertion pain more physically and psychologically bothersome than non-participating athletes at 4 months, however their attendance at this point was significantly higher. Thus despite being more bothered by exertion pain, the participating athletes continued to engage with the sport. Exertion related pain is often viewed positively and is seen as a necessary part of developing as an athlete [41]; therefore participating athletes may have accepted this pain despite its bothersomeness. This could be a result of using coping strategies more effectively [8] or a function of motivational and self-efficacy factors [42].

4.3 SIP15

The SIP15 results supported hypothesis 4 that participating athletes had higher direct coping scores than non-participating athletes for injury and contact pain throughout the season. The participating group therefore viewed this pain more positively and were willing to endure [23]. It is interesting that participating athletes had higher direct coping at the start of the season as well as at the other two time points. This suggests that participating athletes had a different attitude towards pain from the outset. High direct coping has been linked to resilience [23]. It is therefore possible that the participating athletes were more resilient to begin with. Resilience has also been linked to habituation to pain [14], which may explain the maintained pain tolerance in the participating group.

Participating athletes also felt more positive about the pain they experienced compared to the non-participating group. The non-participating group, with significantly lower direct coping scores, did not view injury or contact pain as something to "tough out". Indeed, they catastrophized significantly more about injury pain at 4 months compared to participating athletes. In addition, the participating athletes catastrophized less about injury pain at 4 and 8 months compared to the start of the season. Injury pain is not usually within the control of the athlete and can cause stress and anxiety [37], however coping strategy use has been shown to reduce fear and anxiety in athletes with injury pain [43]. Athletes who feel in control of their pain and do not find it stressful may have higher pain tolerance than those who ruminate about pain [12]. Catastrophizing has been shown to reduce pain tolerance [43], which also accords with these results.

Although this study adds to the athletic pain literature there are some limitations: First, laboratory induced pain can never reflect the real world of sporting collisions, unexpected injuries and fatigue. In addition participants were aware that the pain stimulus was finite and safe. The pain stimuli were different in nature, resulting in a discrepancy between pain tolerance results, with ischemic pain yielding differences between groups at all three time points, whereas cold pain did not. More research therefore is required using a variety of pain stimuli to fully explore differences between participating and non-participating athletes.

Second, psychological factors such as motivation may have influenced results. As the study required participation at three different time points, testing fatigue may have been present (which is also reflected in the drop-out rate). In addition, order effects may have existed in the repeated pain tolerance testing. Whilst athletes were not informed of their exact tolerance time so they could not try to better it, they may have experienced increased anxiety or on the other hand, familiarity with the protocol.

In addition in order to achieve an appropriate sample size, athletes were drawn from four different contact sports. It was not possible therefore to examine athletes who all had the same experiences of pain. Further, both team based and individual sports were used and due to the differences in sample size (77 team based athletes compared to 25 individual athletes) it was not possible to make comparisons between different sports types. Further research should aim to examine one sport in particular, as the nature of the sport may have an impact on results.

No control group using healthy non athletes was included due to previous research findings indicating that athletes and non-athletes respond differently to pain [3]. Future studies should however aim to include a control group to examine whether non-participating contact athletes and healthy non-contact athletes respond in the same way to experimental pain over 8 months. It would be interesting to discover whether there are any differences between those who drop out of contact sports and those who play non-contact sports or those who choose to avoid sport all together. Given the different direction of results for participating versus non-participating athletes it seems that exposure to pain can result in sensitisation (in the case of non-participating athletes) and potential habituation (in the case of the participating athletes).

Future studies should attempt to measure pain responses over a longer period of time and explore the mechanisms behind differences within athletic groups. This study focused only on one athletic season; it is therefore unknown beyond this time frame how athletes respond to pain. More detailed questions via qualitative methods should also be asked about how athletes feel about pain experienced within sports over time.

5. Conclusions

This longitudinal study is the first to suggest that commitment to high contact sports is linked to maintained or increased experimental pain tolerance and decreases in pain bothersomeness over an athletic season. Reductions in pain tolerance over time in the non-participating group suggest that other factors are responsible for engagement in sport and not just pain tolerance at the outset. For example individuals who catastrophize about pain or have a low direct coping style may choose to drop out of contact sports. In addition, finding pain bothersome may also influence attrition rates. As pain intensity (as measured by VAS) did not differ between participating and non-participating athletes, it could be suggested that participating athletes perceived pain in the same way as non-participating athletes, but they did something different to cope with and endure it. Higher direct coping and reduced catastrophizing were demonstrated by participating athletes, suggesting that their view of pain was indeed different to non-participating athletes. Participating athletes also enjoyed their sport more and felt more positively about the pain they experienced. It is postulated that the participating group learnt to cope with pain and adapted to it over the season, potentially due to resilience [14]. A likely reason for significant reductions in pain tolerance in the non-participating group is a decrease in motivation and a lack of interest in the testing protocols. Though not directly measured, fear of pain [18] or low pain related self-efficacy [44] or negative affect [35] may account for these results.

6. Implications

Taken together these results suggest that those who adhere to contact sport may tolerate more experimental ischemic pain as the season progresses. They also find pain less bothersome, catastrophize less about injury pain over time and have a high direct coping style. These results can help us to understand attrition in sports where pain is likely. This study also provides a platform for further investigation into how athletes cope with pain and suggests that coping styles (as measured by SIP15) and bothersomeness of pain may account for participation in contact sports. This study extends previous recent research focusing on pain modulation within athlete populations [45,7] and differences between athletes and non-athletes [3]. We have shown that attrition in contact sport may be related to psychological and physical responses to pain and that habituation to pain may occur over time in participating athletes.

Ethical Issues

All participants provided informed consent to participate and the study was approved by the University Research Ethics Committee. The study was not registered. There are no conflicts of interest.

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References

[1] Hall EG, Davies S. Gender differences in perceived intensity and affect of pain between athletes and non athletes. Percept Mot Skills 1991;73:779-86.

[2] Sullivan MJL, Tripp DA, Rogers WM, Stanish W. Catastrophizing and pain perception in sport participants. J Appl Sport Psychol 2000;12:151-67.

[3] Tesarz J, Schuster AK, Hartmann M, Gerhardt A, Eich W. Pain perception in athletes compared to normally active controls: a systematic review with meta-analysis. Pain 2012;153:1253-62.

[4] Ryan ED, Foster R. Athletic participation and perceptual augmentation and reduction. J Pers Soc Psychol 1967;6:472-6.

[5] Ryan ED, Kovacic CR. Pain tolerance and athletic participation. Percept Mot Skills 1966;22:383-90.

[6] Raudenbush B, Canter RJ, Corley N, Grayhem R, Coon J, Lilley S, Meyer B, Wilson I. Pain threshold and tolerance differences among intercollegiate athletes: Implications of past sports injuries and willingness to compete among sports teams. N Am J Psychol 2012;14:85-91.

[7] Tesarz J, Gerhardt A, Schommer K, Treede R, Eich W. Alterations in endogenous pain modulation in endurance athletes: An experimental study using quantitative sensory testing and the cold-pressor task. Pain 2013;154:1022-29.

[8] Scott V, Gijsbers K. Pain perception in competitive swimmers. BMJ 1981;283:91-3.

[9] Tajet-Foxell B, Rose FD. Pain and pain tolerance in professional ballet dancers. Br J Sports Med 1995;29:31-4

[10] Ord P, Gijsbers K. Pain thresholds and tolerances of competitive rowers and their use of spontaneous self-generated pain coping strategies. Percept Motor Skills 2003;97:1219-22

[11] Rhudy JL. Does endogenous pain inhibition make a better athlete, or does intense athletics improve endogenous pain inhibition? Pain 2013;154:2241-2.

[12] Geva N, Defrin R. Enhanced pain modulation among triathletes: A possible explanation for their exceptional capabilities. Pain 2013;154:2317-23.

[13] Crombez G, Eccleston C, Baeyens F, Eelen P. Habituation and the interference of pain with task performance. Pain 1997;70:149-54.

[14] Smith BW, Tooley EM, Montague EQ, Robinson AE, Cosper CJ, Mullins PG. The role of resilience and purpose in life in habituation to heat and cold pain. J Pain 2009;10:493-500.

[15] Dar R, Ariely D, Frenk H. The effect of past injury on pain threshold and tolerance. Pain 1995;60:189-93.

[16] Sheiner E, Sheiner EK, Shoham-Vardi I. The relationship between parity and labor pain. Obstet Gynecol Int J 1998;63:287-8.

[17] Saisto T, Kaaja R, Ylikorkala O, Halmesmak E. Reduced pain tolerance during and after pregnancy in women suffering from fear of labor. Pain 2001;93:123-7.

[18] Byerly PN, Worrell T, Gahimer J, Domholdt E. Rehabilitation compliance in an athletic training environment. J Athl Training. 1994;29:352-355.

[19] Buckworth J, Dishman RK, O'Connor PJ, Tomporowski PD. Exercise psychology. Champaign, IL: Human Kinetics; 2013. P.341-2.

[20] Bingel U, Schoell E, Herken W, Buchel C, May A. Habituation to painful stimulation involves the antinociceptive system. Pain 2007;131:21-30.

[21] Rennefeld C, Wiech K, Schoell ED, Lorenz J, Bingel U. Habituation to pain: Further support for a central component. Pain 2009;148:503-8.

[22] Clark-Carter D. Quantitative psychological research: A student's handbook. Hove: Psychology Press, 2008.

[23] Bourgeois AE, Meyers MC, LeUnes AD. The Sport Inventory for Pain: Empirical and confirmatory factorial validity. J Sport Behav 2009;32:19-35.

[24] Meyers MC, Bourgeois AE, Stewart S, LeUnes A. Predicting pain response in athletes: Development and assessment of the Sports Inventory for Pain. J Sport Exerc Psychol 1992;14:249-61.

[25] Bijur PE, Silver W, Gallagher EJ. Reliability of the visual analog scale for measurement of acute pain. Acad Emerg Med 2001;8:1153-7.

[26] Manning EL, Fillingim RB. The influence of athletic status and gender on experimental pain responses. J Pain 2002;3:421-28.

[27] Bae Y & Lee S. Analgesic effects of transcutaneous electrical nerve stimulation and interferential current on experimental ischemic pain models: Frequencies of 50Hz and 100Hz. J Phys Ther Sci 2014;26:1945-8.

[28] Field A. Discovering Statistics Using SPSS (3rd edition). London: Sage; 2009.

[29] Bhalang K, Sigurdsson A, Slade GD, Maixner W. Associations among four modalities of experimental pain in women . J Pain 2005;6:604-11

[30] Addison T, Kremer J, Bell R. Understanding the psychology of pain in sport. Irish J Psychol 1998;19:486-503.

[31] Rainville P, Feine JS, Bushnell C, Duncan GH. A psychophysical comparison of sensory and affective responses to four modalities of experimental pain. Somatosens Mot Res 1992;9:265-77

[32] Janal MN, Glusman M, Kuhl JP, Clark WC. On the absence of correlation between noxious heat, cold, electrical and ischemic stimulation. Pain 1994;58:403-11

[33] Jaremko ME, Silbert L, Mann T. The differential ability of athletes and non-athletes to cope with two types of pain: A radical behavioural model. Psychol Rec 1981;31:265-75.

[34] Bandura A, O'Leary A, Barr Taylor C, Gauthier J, Gossard D. Perceived self-efficacy and pain control: Opioid and nonopioid mechanisms. J Pers Soc Psychol 1987;53:563-71.

[35] Gedney JJ, Logan H. Pain related recall predicts future pain report. Pain 2006;121:69-76

[36] Lee JE, Watson D, Frey Law LA. Lower order pain-related constructs are more predictive of cold pressor pain ratings than higher-order personality traits. J Pain 2010;7:681-91

[37] Taylor J, Taylor S. Pain education and management in the rehabilitation from sports injury. Sport Psychol 1998;12:68-88.

[38] Maeoka H, Hiyamizu M, Matsuo A, Morioka S. The influence of repeated pain stimulation on the emotional aspect of pain: a preliminary study in healthy volunteers. J Pain Res 2015;8:431-6.

[39] Pen LJ, Fisher CA. Athletes and pain tolerance. Sports Med 1994;18:319-29.

[40] DeRoche T, Woodman T, Yannick S, Brewer BW, Le Scanff C. Athletes' inclination to play through pain: A coping perspective. Anxiety Stress Coping. 2011;24:579-87.

[41] Kress JL, Statler T. A naturalistic investigation of former Olympic cyclists' cognitive strategies for coping with exertion pain during performance. J Sport Behav 2007;30:428-52.

[42] Johnson MH, Stewart J, Humphries SA, Chamove AS. Marathon runners' reaction to potassium iontophoretic experimental pain: Pain tolerance, pain threshold, coping and self-efficacy. Eur J Pain 2011;16:767-74.

[43] Driediger M, Hall C, Callow N. Imagery use by injured athletes: A qualitative analysis. J Sports Sci 2006;24:261-71.

[44] Baker SL, Kirsch I. Cognitive mediators of pain perception and tolerance. J Pers Soc Psychol 1991;61:504-10.

[45] Egan S. Acute-pain tolerance among athletes. Can J Sport Sci 1987;12:175-8.