Pressure pain threshold response to aerobic exercise in elite rowers with actual low back pain

Daphne van der Heijden, Jurryt de Vries Msc.

Master Sports Physical Therapy, Master Sportfysiotherapie 2009. Hogeschool Rotterdam, Transfergroep, Rochussenstraat 198, 3015 EK Rotterdam, The Netherlands. Correspondence to: daphneiris@hotmail.com

ARTICLE INFO

August 2014

Keywords:

Pressure Pain Threshold
Low Back Pain
Rowing athletes
Aerobic Exercise

ABSTRACT

Low back pain is named as first or second most common injury in rowing athletes. This is mainly due to excessive hyperflexion and twisting. The two risk factors in developing low back pain in rowing are the use of a rowing ergometer for a duration of 30 minutes or more and weight lifting. Cardiovascular training plays an important role in performance, prevention of injury and lumbar stability. Research shows that a submaximal aerobic cycling exercise increases pain thresholds in patients with low back pain.

This study examined if a 20 minute, 75-85% training heart rate (THR), cycling ergometer exercise leads to a higher pressure pain threshold (PPT) on a handheld pressure algometer test on the lower back in rowing athletes with actual low back pain. The aim of the study is to examine the short term effect of an aerobic cycling exercise on pressure pain thresholds in the lower back. Voluntary rowing athletes with actual low back pain performed a 20 minute cycling ergometer exercise on 75-85% of their Training Heart Rate. Before and after the exercise the assessor measured the Pressure Pain Threshold in the lower back at fixed sites, L3 and L5 bilateral with a pressure algometer.

PPT means were calculated and The Paired Samples T-Test gave a significant ($p \leq 0{,}05$) change in PPT means on three out of four measurement points. The levels L5 left, L3 right and L5 right were significant. At L3 left there were no significant changes in the PPT.

INTRODUCTION AND THEORY

Low back pain is named as first or second most common injury in rowing athletes (Bahr et al. 2004; Rumball et al. 2005; Hosea and Hannafin 2012; Kristine and Karlson 2012; Ng et al. 2012; Strange Foss et al. 2012; Socratis et al. 2013). The continuous repetitive motion in rowing stresses different anatomic regions, including the lower back. (Hosea and Hannafin 2012). Rowing injuries are primarily overuse related.(Hosea and Hannafin 2012). The knee, lumbar spine and ribs are most commonly affected. The injury incidence is directly related to the volume of training and technique (Hosea and Hannafin 2012). The most frequent injured region is the low back, mainly due to excessive hyperflexion and twisting (Rumball et al. 2005).

One of the named risk factors in developing low back pain in rowing is the use of the rowing ergometer for >30 minutes at one time (Rumball et al. 2005; Kristine and Karlson 2012). Injuries sustained during winter training on the ergometer commonly continue after transitioning to the boat in the spring. (Kristine and Karlson 2012) Weight lifting is also stated as a cause of injury (Socratis et al. 2013).

Cardiovascular training may not only be important for performance, but also for lumbar stability and prevention of injury (Rumball et al. 2005). Therefore it is important for an athlete to, while the athlete suffers from low back pain, stay in shape for the season to come, also with cardiovascular training. But with these risk factors in mind it would not be advisable to do any row ergometer training or weight lifting during a period of low back pain.

The majority of rowing athletes with an injury state that they implement rest periods, sometimes in combination with medical treatment in order to recuperate from the injury (Socratis et al. 2013). Treatment involves relative rest, physiotherapy and medical interventions such as anti-inflammatory drugs, injections and rarely surgery (Secher and Volianitis 2007).

A lot of research has been done in examining exercise induced analgesia and pain thresholds over the past years (Koltyn 2000). Most often a running or cycling exercise was used to examine the effect of an exercise on pain thresholds (Koltyn 2000). Different pain stimuli were used in these studies. Analgesia showed mostly in studies using electrical or pressure stimuli, less in temperature stimuli (Koltyn 2000). Also different types of exercise were examined, mostly aerobic and sometimes isometric or resistance exercises (Kosek and Ekholm 1995; Koltyn et al. 1996; Koltyn and Arbogast 1998; Koltyn 2000; Koltyn et al. 2001; Hoffman et al. 2004; Hoffman et al. 2005; Hoffman et al. 2007; Meeus et al. 2010).

The stimuli used in these experiments, measuring pain sensitivity, such as pressure stimuli, is dependent on both the peripheral and central nervous system (Zhang et al. 2013). Some researchers state that this change in sensitivity comes from a stress trigger releasing a natural stimulus which can trigger pain suppression (Koltyn 2000). The most commonly tested hypothesis for exercise induced analgesia has been that activation of the endogenous opioïd system during exercise may be responsible for the analgetic response that occurs following exercise (Koltyn 2000).

Typically, a noxious stimulus is applied before and following exercise to see if analgesia occurs following exercise (Koltyn 2000). Mechanically evoked pain, and in particular the pressure pain threshold (PPT), is a popular model for inducing acute, experimental pain. Algometry is a useful technique in determining PPT measures, and has been used widely in both clinical and laboratory settings (Chesterton et al. 2007).

Pressure pain threshold (PPT) is considered a reliable and easily assessed pain perception measurement and has been identified as a useful predictor and prognostic indicator of multiple clinical pain states (Zhang et al. 2013). Several studies state that pressure pain sensitivity is elevated in patients with low back pain (Farasyn and Meeusen 2002; Hoffman et al. 2005; Zhang et al. 2013). Another study shows that people taking part in sport or physical activity have significantly increased PPT's (Farasyn and Meeusen 2005).

Research shows that a submaximal aerobic cycling exercise increases pain thresholds in patients with chronic low back pain (Meeus et al. 2010) for more than 30 minutes following the exercise (Hoffman et al. 2004; Hoffman et al. 2005; Hoffman et al. 2007). They state that intensities of over 70% of maximal aerobic capacity are required, and that pain threshold increases with increasing intensities above this level (Hoffman et al. 2007). An exercise of 30 minutes at 75% maximal oxygen uptake showed a significant exercise analgesia effect, but 30 minutes at 50% or 10 minutes at 75% did not show the effect (Hoffman et al. 2004; Hoffman et al. 2007). Some studies used a general pain sensitivity measurement on the index finger, and did not use a pressure algometer (Koltyn and Arbogast 1998; Koltyn 2000; Koltyn et al. 2001; Hoffman et al. 2004; Hoffman et al. 2005; Hoffman et al. 2007). Others use local PPT measurements on the lower back with a pressure algometer (Farasyn and Meeusen 2002; Farasyn and Meeusen 2005; Farasyn 2007; Hirayama et al. 2006; Schenk et al. 2007; Meeus et al. 2010; de Oliveira et al. 2013).

In physical therapy treatment it is useful to know the short term effect of a cycling exercise on lower back pain in rowing athletes to indicate if this can be part of treatment or training. This will give a first indication on weather this influences the lower back pain positively when using it, for example, in a warming up or medical training.

Secondly, when this cycling exercise gives a positive effect on the PPT it can be a way for the patient to influence their pain without the help of a physical therapist at that moment.

An exercise performed at 75-85% maximum heart rate is considered as a cardiovascular aerobic training (Willmore et al. 2008).

Combining this information, the aim of this study was to examine the short term effect of a 75-85% training heart rate aerobic cycling exercise in rowing athletes with actual low back pain on the pressure pain threshold in the lower back.

The objective of this study was to examine if a cycling exercise, on a cycling ergometer, of 20 minutes at 75-85% training heart rate (THR), leads to a higher pressure pain threshold (PPT) on a handheld pressure algometer test on the lower back in rowing athletes with actual low back pain.

METHODS

Subjects

The recruitment of volunteers to this study took place through the board members of rowing clubs, coaches, rowers and members of the regional training centre Zuid-Holland. Next to that social media were used to notify athletes.

Inclusion criteria:

- Minimum of 18 years old
- National competition rowers
- Both skull and sweep rowing (due to practical reasons, literature states differences between low back pain in sweep and skull rowing)
- Minimum of 6 training moments a week
- Present low back pain
- Specific and non-specific low back pain

Exclusion criteria:

- Medication use that influences pain or pain experience

No VAS-scale or other differentiation in complaints intensity or duration of complaints through exclusion criteria was use, due to expected major exclusion. Subjects singed an informed consent prior to the participation in the study.

Instrumentation

The pressure algometer

The measurement of pain by means of pressure algometry is reliable according to the data in the literature and is consequently applied when determining the effect of treatments (Farasyn 2007).

The force application of a Pressure algometer was perpendicular to the body surface (Kinser and Sands 2009; de Oliveira et al. 2013). The rate on witch the preassure was applied with the algometer was approximately 1kg*cm^2*s or 10N/s to increase reliability. Application of force at a faster rate may provoke a low false threshold reading (Kinser and Sands 2009). Different studies use a rate of 5N/s (Chesterton et al. 2003; de Oliveira et al. 2013) , 50kps/s (Hirayama et al. 2006) or

1kpa/s (Schenk et al. 2007) on the lower back.
The pressure algometer has a high reliability and validity values when compared with force plate readings. Average Pearson Correlations between the maximum force reading of an algometer and a force plate in two trials were, r=0.990 and r=0.999 (Kinser and Sands 2009). Other studie described an acceptable intra-examiner reliability of pressure rate application. Considering this results, it may be safe to claim that, with practice, the use of an algometer is reliable and valid (Chesterton et al. 2007, Kinser and Sands 2009).
The pressure algometer used in this study has the following characteristics:

- Probe: 1,52cm^2
- Handheld, analogue
- Brand: Baseline
- Measures accurate to 0.1 kg/cm^2, with a range from 1-10kg/cm^2

T0	I: Intervention	T1
PPT measurements	20 minutes cycling on 75-85% THR	PPT measurements

Figure 1

<u>Measurements</u>
Athletes performed a cycling exercise at 75-85% Training Heart Rate (THR) for 20 minutes (I). Before (T0) and shortly after (T1) the exercise, (within 30 minutes after exercise) (Hoffman et al. 2004) Pressure Pain Thresholds were determined with a handheld pressure algometer. To start, the assessor explained the measurement by one test measurement on the upper back.
The physical therapist/ assessor performing the PPT measurements previously became familiar using the pressure algometer, to prevent measurement BIAS.
Subject were informed verbally about the experiment. The participants were informed that the measurement involves a pain threshold, not a pain tolerance test. (Hirayama et al. 2006)
To determine the PPT, measurements took take place prior to and shortly after the intervention. Patient was lying prone on an examination table, with both forearms over the sides. (Farasyn 2007) The physical therapist will measure at the following sites:

- Bilateral, (Schenk et al. 2007) paravertebral (Farasyn 2007) on segment L3, L5. 3cm lateral to the processus spinosis (Farasyn and Meeusen 2002; Farasyn and Meeusen 2005; Hirayama et al. 2006; de Oliveira et al. 2013).

During the first measurement (T0), measurement sites were marked to make sure the same point is measured during the procedure, along T0 and T1.
The sequence in which the assessment of PPT is evaluated does not influence the result (Farasyn 2007). In this study the sequence was from cranial to distal and from left to right.
During PPT measurement, the assessor positioned the algometer's circular probe (1.52cm^2) perpendicular to the skin and pressed at a rate of approximately 1kg/cm2/second. The participant was asked to say "stop" when the sensation of pressure or discomfort becomes a clear sensation of pain. (Hirayama et al. 2006; de Oliveira et al. 2013). Three measurements were collected for each site in the lower back, at 30 seconds intervals. The mean of 3 measurements was used in data analysis (Farasyn 2007; Meeus et al. 2010; de Oliveira et al. 2013[24]) The three measurements were named A_{left}, B_{left} and C_{left} or right, and filled up on the measurement form.
After the first PPT measurement the training heart rate (THR) was calculated by: $THR_{75\%}=HR_{rest}+0.75(HR_{max}-HR_{rest})$ and

$THR_{85\%}=HR_{rest} + 0.85(HR_{max}-HR_{rest})$
(Willmore et al. 2008)
Seven rowing athletes were familiar with their maximum heart rate (HR_{max}), and most of them with their rest heart rate (HR_{rest}). In the other seven, the maximum heart rate (HR_{max}) was calculated by using: $HR_{max}=208-(0.7*age)$ (Willmore et al. 2008). Athletes were asked to measure their rest heart rate if they were not familiar. Two atheletes did not measure their rest heart rate and were put at $HR_{rest}=60$.
During the intervention the athlete used a Polar Heart Rate band with a watch to determine the actual HR. The assessor adjusted the resistance of the cycling ergometer to a level on which the THR is reached. The THR was between 75 and 85%. The was no the rate per minute (RPM) limit, because the cycling ergometers used were not all capable of calculating the RPM. The data collecting took place at different rowing clubs in The Netherlands or at the practice of M&O Fysiotherapie in The Hague, The Netherlands. Measurements will all be done by the same assessor. There was no control group. It was not possible to blind participants or assessor.

Data analysis
PPT mean were calculated by:
$PTT_{mean\ L1\ left} = (PTT_{L1,Aleft} + PPT_{L1,Bleft} + PPT_{L1,Cleft}) / 3$
The difference of the means, between the PPT before and after the intervention, was calculated by:
$PPT_{mean\_diff} = PPT_{T0} - PPT_{T1}$
T0 in the baseline score, prior to intervention. T1 is after intervention.
This may result in a positive score (hypoalgesic / less pain) or a negative score (hyperalgesia / an increase in pain) (Chesterton et al. 2003).
A Paired Samples T-test was conducted to compare the Pressure Pain Thresholds (PPT) pre- (T0) and post- (T1) exercise in all four measurement points.

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	14	19	28	22,14	2,507
Rowing experience (years)	14	,5	8,0	4,250	1,9290
Competition experience (years)	14	,5	7,0	3,321	1,7498
Valid N (listwise)	14				

Table 1, Descriptive Statistics

RESULTS

A total of 17 rowers were available for research, 3 were excluded due to non-actual complaints. A group of 14 (n=14) elite rowers, all with non specific low back pain, were included. The mean age is 22,14 years old (SD=2,51) with a minimum age of 19 to a maximum of 28. (Table 1) Five are female, 9 male. The years of rowing experience varies from 0,5 years to 8 years (M=4,25 SD=1,93). Competition experience varies from 0,5 years to 7 years (M=3,32 SD=1,75). (Table 1)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sweep	7	50,0	50,0	50,0
	Skull	2	14,3	14,3	64,3
	Both	5	35,7	35,7	100,0
	Total	14	100,0	100,0	

Table 2, Type of Rowing

Seven subjects were in sweep rowing competitions, 2 in skull and 5 were in both. (Table 2) The duration of their low back pain varies from two weeks to 6 years, some had persistent complaints, in others it was varying.
The Paired Samples T-Test gave a significant ($p \leq 0{,}05$) change in PPT means on the levels L5 left (MD= -0,67 SD=1,04 with t(14)=-2,42), L3 right (MD=-1,07 SD= 1,17 and t(14)= -3.44) and L5 right (L5 right MD= -1,31 SD=1,29 t(14)=-3,80). (Table 4)
At L3 left there were no significant changes (p=0,424) in PTT means (MD=-0,19, SD=0,87) with t(14)=-0,83 between T0 and T1. (Table 4)
The negative mean difference can be explained by a higher PPT on T1 than on T0. (Table3)

		T0 L3 left	T0 L5 left	T0 L3 right	T0 L5 right	T1 L3 left	T1 L5 left	T1 L3 right	T1 L5 right
N	Valid	14	14	14	14	14	14	14	14
	Missing	0	0	0	0	0	0	0	0
Mean		5,06	4,83	4,34	4,67	5,26	5,50	5,41	5,98
Median		4,40	4,20	3,85	4,15	4,50	4,60	5,85	6,30
Std. Deviation		2,122	2,341	2,059	2,453	2,095	2,549	2,354	2,645

Table 3, mean and median on T0 and T1

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
L3 left	T0 - T1	-,193	,874	,234	-,697	,312	-,826	13	,424
L5 left	T0 - T1	-,671	1,037	,277	-1,270	-,072	-2,422	13	,031
L3 right	T0 - T1	-1,071	1,166	,312	-1,745	-,398	-3,437	13	,004
L5 right	T0 - T1	-1,307	1,288	,344	-2,051	-,563	-3,797	13	,002

Table 4, results paired samples T-test

CONCLUSION

As the mean difference in three measurements is negative ($T1_{mean}$ higher than $T0_{mean}$) and the mean difference is significant (2-tailed, $p \leq 0{,}05$) we can say that on these measurement points, after a cycling exercise of 20 minutes on 75-85% THR, pressure algometry shows a significant increase in the PPT in rowing athletes with actual low back pain. The level of L3 left shows no significant increase the PPT in rowing athletes with actual low back pain. These results suggest that a cycling exercise on 75-85% THR may cause a higher pressure pain threshold in elite rowing athletes with actual low back pain.

DISCUSSION

One subject already experienced low back pain before he started rowing. Two of the subjects had to stop rowing before, due to low back pain. One of these two did not proceed rowing, the other one did, but during the time of the intervention both still experienced low back pain. Another athlete had cardiac problems in the past, but after surgery has a normal heart function. During the intervention one athlete had to cycle on an unusual high resistance to get the heart rate to the right range. Measuring the saturation gave 93%. These differences give a less narrow subject group and should be avoided by more excluding criteria.

In this research an algometer with a scale from 1-10kg was used, two subjects gave a PPT of 10 on T0 on different measurement sites, a ceiling effect. These subjects were included in the statistical tests, when excluded the results may come out with a larger mean difference, but due to a small sample size they were included. They described a different feeling before and after cycling on the measurement sites. Both stated that at T0 there was an unpleasant feeling on the measurement site and after cycling, at T1, there was not. An algometer with a different scale may give different, more reliable results.

Feedback from subjects is that although a minimum of 1 hour between training and testing was taken, the time of day, or moment of testing, will probably give different results as they felt more or less pain before or after a regular training session. A longer duration of the exercise may also give a different change in PPT's. This information should be used in a following measuring protocol.

Two of the subjects were not familiair with their rest heart rate, in these subjects the rest heart rate was put at 60. This lack of information could be a point of exclusion in a next study.

In 3 out of 4 measurement sites there was a significant change in the PPT after the cycling exercise.The fact that L3 left does not make a significant change in the PPT may be explained by a learning curve during the measurements. More test measurements before the actual measurements would be recommended, as different subjects stated that they find it difficult to sign at the right moment for the change between an unpleasant feeling and pain, the PPT.

To indicate if an cycling exercise at 75-85% THR would be a useful instrument in treatment or training of rowing athletes with actual low back pain, more research would be recommended.

For example with a bigger sample size, an algometer with a larger range, a longer duration of the exercise or different measurement sites. And a more narrow population in duration of complaint, intensity of the pain via VAS scale, rowing experience and a differentiation between sweep and skull rowing, age and sex.

Another option in research could be to match the site of the low back pain with the measurement sites as the subjects in this research were not selected on the precise site of the low back pain, but were selected on low back pain in general.

However, this study gives a positive first indication of the usefulness of an aerobic exercise in warming up or training in rowing athletes with actual lower back pain. And follows the results in previous research with the same intensity of aerobic cycling exercises, done on other patients with low back pain.

With low back pain as first or second most common injury in rowing athletes, this research gives therapists and patiënts a little more understanding in the effects of an cycling exercise during a period of low back pain in rowing athletes. And may be of help in a next step in research for an effective treatment of rowing athletes with low back pain.

As cardiovascular training is of importance for lumbar stability and in rowing, and with the risk factor of ergometer training in low back pain, this indicates that a cycling exercise may be of use in cardiovascular training in rowing athletes with low back pain.

REFERENCES

Bahr R, Ove Anderson S, et al. Low back pain among endurance athletes with and without specific back loading – a cross sectional survey of cross-country skieers, rowers orienteers and nonathletic controls. Spine 2004; 29(4): 449-454

Chesterton L, Foster N, et al. Effects of TENS frequency, intensity and stimulation site parameter manipulation on pressure pain thresholds in healthy human subjects. Pain 2003; 106:73-80

Chesterton L, Sim J, et al. Interrater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters. Clinical journal of Pain 2007; 23: 760-766

Farasyn A. Meeusen R, Pressure pain thresholds in healty subjects: influence of physical activity, history of lower back pain factors and the use of endermology as a placebo like treatment. Journal of bodywork and movement therapies 2003; 7(1): 53-61

Farasyn A, Meeusen R, The influence of non-specific low back pain on pressure pain thresholds and disability. European journal of pain 2005; 9: 375-381

Farasyn A, Pressure pain algomtery in patients with non-specific low back pain. Faculty of physical education and physiotherapy Vrije Universiteit Brussel. 2006-2007 Chapter: 2

Hirayama J, Yamagata M, et al. Relationship between low-back pain, muscle spasm and pressure pain thresholds in patients with lumbar disc herniation. European Spine Journal 2006; 15: 41-47

Hoffman MD, Shepanski MA, et al. Intensity and duration threshold for aerobic exercise induced analgesia to pressure pain. Physical and medical rehabilitation 2004; 85: 1183-1187

Hoffman MD, Shepanski MA, et al. Experimentally induced pain perception is acutely reduced by aerobic exercise in people with chronic low back pain. Journal of rehabilitation research and development 2005; 42(2): 183-190

Hoffman MD, Lee J, et al. Pain perception after running a 100-mile ultramarathon. Physical and medical rehabilitation 2007; 88: 1042-1048

Hosea TM, Hannafin JA, Rowing Injuries. Sports Health 2012; may 4(3): 236-245

Kinser A, Sands W, Reliability and validity of a pressure algometer. Journal of strength and conditioning research 2009; 23(1): 312-314

Koltyn KF, Garvin AW, et al. Perception of pain following aerobic exercise. Medicine and science in sports and exercise 1996; 28(11): 1418-1421

Koltyn KF, Arbogast RW, Perception of pain after resistance exercise. British journal of sports medicine 1998; 32: 20-24

Koltyn KF, Analgesia following exercise. Sports medicine 2000; 29(2) 85-98

Koltyn KF, Trine MR, et al. Effect of isometric exercise on pain perception and blood pressure in men and women. Medicine and science in sports and exercise 2001; 33(2) 282-290

Kosek E, Ekholm J, Modulation of pressure pain thresholds during and following isometric contraction. Pain 1995; 61:481-486

Kristine A, Karlson MD, Rowing: Sport-specific Concerns for the Team Physician. Current Sport Medicine Reports 2012; sept-oct; 11(5): 257-61

Meeus M, Roussel N, et al. Reduced pressure pain thresholds in response to exercise in chronic fatigue syndrome but not in chronic low back pain: an experimental study. Journal Rehabilitation Medicine 2010; 42: 884-890

Ng L, Perich D, et al. Self-Reported prevalence, pain intensity and risk factors of low back pain in adolescent rowers. Journal of Science and Medicine in Sport 2013; S1440-2440

de Oliveira R, Liebano R, et al. Immediate effects of region-specific and non-region-specific spinal manipulative therapy in patients with chronic low back pain: a randomized controlled trial. Physical Therapy 2013; 93:748-756

Rumball JS, Lebrun CM, et al. Rowing Injuries. Sports Med 2005; 35(6): 537-555

Schenk P, Laeubli T, et al. Validity of pressure pain thresholds in female workers with and without recurrent low back pain. European Spine Journal 2007; 16: 267-275

Secher N, Volianitis S. Rowing. Massachusetts: Blackwell Publishing 2007; p124-140

Socratis K, Elini D, et al. Injuries of greek rowers participating on different competitive categories. Biology of Exercise 2013; 9(2): 29-39

Stange Foss I, Holme I, et al. The prevalence of Low Back Pain Among Former Elite Cross-Country Skieers, Rowers, Orienteerers and Nonathletes: A 10-year Cohort Study. American Journal of Sports Medicine 2012; 40: 2610-2616

Willmore J, Costill D, Larry Kenney W. Physiology of sport and exercise. 2008 fourth edition. Champaign: Human Kenetics; 2008 fourth edition. p: 198, 460

Zhang Y, Zhang S, et al. Factors associated with the pressure pain threshold in healthy chinese men. Pain medicine 2013; 14:1291-1300