University of Chester

Difference between low cadence-high resistance and high cadence low resistance in relation to muscle breakdown in cyclists.

Robert Stanley

1324573

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Acknowledgements-

Abbreviations

Beats Per Minute - BPM

Creatine Kinase - CK

Fast Twitch - FT

Functional Threshold Power - FTP

High Intensity Interval Training - HIIT

Millimetres - MM

Millimeter of Mercury - mm/Hg

Product of Resistance - N

Representative Perceived Effort - RPE

Revolutions Per Minute - RPM Slow Twitch - ST

Visual Analogue Scale - VAS

Watts Per Kilogram - W/KG

Literature Review

Introduction

Training at different cadences provides a different training stimulus (Brisswalter et al, 2000) which can be metabolic adaptations or skeletal muscle hypertrophy. Studies have considered the role of cadence in metabolic efficiency and/or participants perceptions of effort (Coyle et al, 1991. Cangley et al, 2009) however there is little literature measuring the efficiency of cadence in relation to muscle breakdown. This may be due to it being difficult to measure muscle breakdown in a non-invasive manner and without conducting a muscle biopsy. Creatine Kinase can be used as a marker of increased muscle breakdown and it is measured using a finger prick blood sample however this indirect method of measuring muscle breakdown is not as reliable and discrepancies in the results can occur as a result of differing response rates between participants or other health issues causing an increase in creatine kinase levels (Brancaccio et al, 2007). Coaches and athletes often use high intensity interval training as a method of improving metabolic efficiency (Laursen et al. 2005) however there is little research into the effects of high intensity interval training for skeletal muscle hypertrophy and strength training in cyclists. This literature review will form the basis for a research project that will consider the effects of differing cadences on muscle breakdown during a high intensity interval training protocol. This research hopes to provide recommendations for coaches and well trained cyclists to improve the training that they conduct to have the desired training stimulus they hope to achieve whether that be increasing muscle breakdown to cause hypertrophy and increase strength or increase adenosine triphosphate production by improving metabolic efficiency. By considering the existing literature surrounding cadence, this review hopes to provide potential reasoning for the results of the proceeding research project. The method's for how best to conduct the research shall also be reviewed along with a discussion about the use of high intensity interval training protocol's for well trained cyclists.

Review of previous studies on cadence

A study by Brisswalter et al (2000) found an 'optimum cadence' of between 70-86 revolutions per minute and a further study by Foss & Hallen (2004) deemed 80 revolutions per minute to be the most efficient. Both of these studies used metabolic cost as a determinant of 'optimum cadence' using Vo2 max as a measure of performance in both studies. Brisswalter et al (2000) conducted the study in an hour long time trial designed to emulate the cycling section of a triathlon which was the main sport of his participants whereas Foss & Hallen (2004) used a incremental ramp test protocol to measure time to exhaustion at different cadences. The protocol used by Brisswalter reflects a time trial where by change of pace is less likely to be an issue than in a road race or other bunch cycling event therefore the participant is more likely to be able to maintain a constant cadence throughout whereas the protocol used by Foss & Hallen (2004) is not designed to emulate a competitive situation therefore the practical application of the results from this study may not be useful in practice. Brisswalter et al (2000) recruited triathletes to compete in their study who would likely have differing physiological characteristics to the elite cyclists studied by Foss & Hallen (2004) as demonstrated by Laursen et al (2002) who showed cyclists and triathletes of a similar trained status to have a significant difference in 40 kilo meter time trial performance as a result of better ventilatory threshold's in cyclists. Foss & Hallen (2004) however recruited elite cyclists averaging power outputs between 312 and 351 watts at Vo2 max. The participants in the Foss & Hallen study are more likely to benefit from high intensity interval training (Laursen et al, 2005) as their discipline is more likely to include changes of pace and intensity which is emulated by high intensity interval training. Brisswalter et al (2000) recruited ten triathletes whilst Foss & Hallen (2004) recruited 6 elite cyclists, whilst neither sample sizes were large, recruitment of well trained participants for research can prove difficult as athletes have busy racing and training schedules and/or do not wish for their training data to be published for their competitors to see therefore these sample sizes are in keeping with similar studies using well trained athletes.

The studies by Brisswalter et al (2000) and Foss & Hallen (2004) are similar protocols to what the proceeding research will use therefore this review has been able to draw conclusions as to the best methodology to use. As this research will be recruiting well trained cyclists similar to Foss & Hallen (2004), the exercise protocol will be high intensity interval training to reflect the change of pace nature of bunch cycling unlike Foss & Hallen who were seeking to find a maximum exercise capacity and did not use a protocol to reflect the discipline of their participants. The sample size for this research will try to recruit similar numbers to the studies by Brisswalter (2000) and Foss & Hallen (2004) so that direct comparisons can be made. Similar to Foss & Hallen (2004) well trained athletes who will be determined by Jeukendrup et al (2000) study that dictates well trained cyclists have a maximum aerobic power of 4.0 watts per kilogram.

Review of the methodology for testing muscle breakdown

Creatine Kinase is the enzyme that catalyses phosphocreatine to produce adenosine triphosphate and is therefore predominantly produced when the workload is high and increased force is required for a short period of time. Phosphocreatine does not require oxygen in order to regenerate adenosine triphosphate which it does by giving up a phosphate group to an adenosine diphosphate molecule to become adenosine triphosphate however phosphocreatine cannot be used for prolonged periods of time as it produces adenosine triphosphate in large amounts (43.1 kilojoules per molecule (Berg et al, 2007) compared to glucose 6-phosphate which produces 13.8 kilojoules per molecule (Berg et al, 2007)) which show's that it's use by skeletal muscle is indicative of an increased workload.

Creatine kinase is measured using a blood sample taken with a finger prick and then analysed. Measuring creatine kinase is an indirect method of measuring muscle breakdown and is only an indication that muscle breakdown has occurred. Other factors other than the training stimulus may contribute to an increase or decrease in creatine kinase such as an illness (Brancaccio et al, 2007)

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or genetic predisposition to produce higher levels of creatine kinase (Brancaccio et al, 2007) there-fore the results of studies that use creatine kinase as a marker of muscle breakdown should be either backed up with other physiological testing or a solid explanation for the resulting muscle breakdown. A study by Brown, Day & Donnelly (1998) used creatine kinase as a marker of muscle breakdown after a bout of concentric and eccentric muscle actions however the study used un-trained participant's. There is no research that examines whether the training status of individuals has an effect on the amount of creatine kinase they produce as a result of muscle breakdown (Brancaccio et al, 2007) therefore this existing published research can be used as justification for using creatine kinase as a marker of muscle breakdown.

Creatine Kinase can remain elevated and carry on elevating for up to 24 hours after exercise (Brancaccio et al, 2007) meaning that the true extent to which muscle has broken down may not show for up to 24 hours after the exercise has taken place. This presents a problem for measuring the muscle breakdown in this way as over the course of 24 hours the participants would need to have the same nutritional intake and conduct the exact same physical activities to ensure that the creatine kinase levels being produced are as a result of the exercise and not of other stimulus's such as further training or nutritional intake creating a difference in muscle breakdown. As well as this, measuring the creatine kinase levels 24 hours later would requite participants to attend extra sessions in the laboratory which may hinder the recruitment of participants. It is therefore best to measure the creatine kinase both directly before and directly after the exercise as then the time in-between can be controlled to ensure only the exercise produces the training stimulus and despite creatine kinase levels continuing to increase, this would outweigh trying to manage muscle break-down for a 24 hour period. As a result of this however, as creatine kinase can be elevating for up to 24 hours after the exercise, repeated trials should be conducted at least 24 hours apart in order to ensure that the measures are as a result of that visit's protocol and not a continuation of the elevat-ing creatine kinase levels from the previous visit.

Another indirect method of measuring muscle breakdown that could be used for backing up the results produced by studies using creatine kinase is measuring C-reactive Protein before and after the bout of exercise. C-reactive protein increases in blood plasma as a result of cells dying (Thompson, Pepys, Wood, 1999). Although C-reactive protein is an acute response to inflammation and should reflect in the results immediately after a bout of exercise (Ridker, 2003) it is measured using a venous blood sample as opposed to a finger prick and is therefore more intrusive to the participant as well as more expensive to conduct the test. C-reactive protein is also an indirect measurement of muscle breakdown therefore the same cautions taken when measuring creatine kinase should be taken when measuring C-reactive protein.

The most accurate way in which to measure muscle breakdown is to conduct a muscle biopsy as this allows a section of the participants muscle to be ground down and the individual proteins analysed to assess the amount of muscle breakdown that has occurred (Wolfe, 1992). The limitation to this method is that only a small proportion of the muscle is being analysed and there is a chance it may not reflect the amount of muscle damage that has occurred in the rest of the muscle and even less likely to reflect the muscle damage that has occurred in the other muscles that have been used during the exercise therefore it is not 100% accurate but provides a more valid result than indirect methods such as measuring creatine kinase and measuring C-reactive protein. A muscle biopsy is also very intrusive to the participant and requires a qualified surgeon to conduct making it a method that is not only very expensive but also uncomfortable for participants.

Despite being an indirect measurement of muscle breakdown and potentially inaccurate as a result, creatine kinase provides the best method of measuring muscle breakdown in the study that will proceed this literature review. Measuring creatine kinase is the least intrusive method to participants which will help prevent potential participants being put off by invasive procedures and is also relatively cheap to conduct in comparison with measuring C-reactive Protein or taking a muscle biopsy.

Review of High Intensity Interval Training Protocols

Laursen et al (2005) demonstrated that high intensity interval training improves ventilatory threshold and anaerobic capacity in well trained athletes and suggests that it does this by improving the efficiency of glycolytic methods of producing adenosine triphosphate. Many cyclists and coaches use High Intensity Interval Training protocols in their training as they emulate the physiological demands of bunch racing therefore the proceeding research will seek to provide coaches and riders with knowledge about how they can adapt high intensity interval training protocols to provide the training stimulus they require whether that be a metabolic adaptation or strength gain through manipulating cadence.

Most cycling disciplines require changes in pace and effort from the riders as a result of changes in terrain, corners and responding to changes in pace from other riders trying to win. High intensity interval training emulates changes in pace and effort and allows the participant to make physiological adaptations that will allow them to meet this demand of racing. Research by Brisswalter et al (2000) and Foss & Hallen (2004) has demonstrated that cadence can be used to provide a different training stimulus in a time trial and incremental exercise test however it both of these pieces of research are making the presumption that the rider is always able to freely choose their cadence. Mognoni & di Prampero (2003) demonstrated that gravitational force and not riders choice was the reason for average cadence dropping from 100 revolutions per minute to 70 revolutions per minute in their study. This shows that the research produced by Brisswalter et al (2000) and Foss & Hallen (2004) is only valid for training where by the rider is able to choose their cadence such as on an indoor ergometer similar to those used in the laboratory or on a flat training course with relatively little wind and external factors dictating changes in pace such as other vehicles. The use of ca-

dence as a tool for training should be conducted with caution as the environments in which is can work are limited however manipulating cadence could increase the training stimulus from a particular exercise.

Review of Visual Analogue Scale and Representative Perceived Effort Scores

The use of a visual analogue scale and representative perceived effort score in exercise research allows a comparison to be made between the intensity of the exercise and how hard the participant think's they are working. This is a particularly interesting measure to take when considering the effects of cadence as it may provide some explanation as to why cyclists choose a particular cadence when they are freely allowed to do so. A study by Whitty, Murphy, Coutts and Watsford (2009) found that cyclists freely choose a cadence that is not metabolically efficient and instead opted for a cadence that minimised muscle strain. From this the proceeding research should expect to find that Visual analogue scale scores in relation to the pain felt in the participants legs should be higher at the cadence which provides the most muscle breakdown but representitive perceived effort scores which will represent the participants overall feeling and therefore metabolic cost will be higher at the cadence causing the most metabolic stress which according to Whitty, Murphy, Coutts and Watsford (2009) would be upwards of 100 revolutions per minute. This is reaffirmed by a study by Leung, Chan, Lee & Lam (2004) that correlated a visual analogue scale with muscular fatigue after a fatigue protocol in the arms of participants and found that although further research is needed to correlate visual analogue scales with lower loads, there was a significant correlation between chronic muscle fatigue and visual analogue scale scores.

Conclusion

This research has been designed in order to aid coaches and riders in prescribing specific cadence drills that will increase the training stimulus obtained from a bout of high intensity interval

training. This literature review has presented gaps in the evidence which the following research project will aim to fill. Brisswalter et al (2000) and Foss & Hallen (2004) have demonstrated that cadence plays a role in the efficiency of a cyclist in terms of metabolic cost however there is no evidence to show that any particular cadence has an effect on muscle breakdown. The studies by Brisswalter and Foss & Hallen have provided research protocols that can be emulated by the proceeding research in order to incorporate these studies and make direct comparisons including sample size, training protocol and participant recruitment. Three methods of testing for muscle breakdown have been presented including two indirect methods: measuring creatine kinase and measuring C-reactive protein that both present problems of accuracy due to their indirect measurement (Brancaccio et al 2007. Ridker et al, 2003) and a direct measurement of a muscle biopsy which presents it's own problems of being very localised and very intrusive to the participant (Wolfe et al, 1992). As a result, creatine kinase measurements will be taken in the proceeding study as the present the most affordable and least intrusive method of measuring muscle breakdown. High intensity interval training has been shown to be a protocol that improves the performance of well trained athletes (Laursen et al, 2005) however the proceeding research will aim to expand on the research provided by Brisswalter et al (2000) and Foss & Hallen (2004) and demonstrate how cadence can be manipulated to change the desired effect high intensity interval training has on the participant. The participants representative perceived effort and visual analogue scale scores will allow the following research project to be compared against previous studies of cadence and contribute to the ongoing debate surrounding why cyclists opt to freely choose a cadence that has been shown to not be metabolically efficient (Brisswalter et al, 2000).

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Proposal For Recommended Journal

Physiological Reports, US National Library of Medicine.

This research could be published in the *Physiological Reports* Journal published by the US National Library of Medicine to compliment the recent work of Formenti, F. Minetti, & A. Borrani, F. (2015) on cadence. This study similarly deduced a greater amount of muscle breakdown at lower cadences. This research has been designed to give knowledge to practitioners of sports physiology working in cycling in order to help them better understand the manipulation of cadence in order to achieve a required training stimulus, the journal *Physiological Reports* appeals to this audience and therefore would best compliment this research.

Lower cadence - higher resistance causes greater amount of muscle breakdown in well trained cyclists conducting a High Intensity Interval Training protocol.

Introduction

Research exists showing the performance benefit of High Intensity Interval Training (HIIT) for well trained athletes (Laursen,2005) and also demonstrating the relationship between cadence and gross efficiency in cycling (Ansley, 2009) however there is no research to determine whether an efficient cadence produces an optimal training stimulus. Laursen (2005) states that HIIT increases performance by creating an adaptation in skeletal muscle that enhances lipid oxidation over carbo-hydrate oxidation however, despite Ansley (2009) demonstrating that differing cadences have differing effects on metabolic cost and muscular stress, there is no research that combines the two to establish an optimal cadence for HIIT. This research has shown there to be a significant difference (p=.038) in the levels of creatine kinase produced as a result of a HIIT protocol at 70,90 and 110 revolutions per minute (RPM) which is indicative of a difference in muscle breakdown and training stimulus. 70RPM was found to produce the greatest increase in creatine kinase (p=.040) suggesting that lower cadences with greater resistance are able to produce a greater amount of muscle breakdown and therefore training stimulus. Serum Creatine Kinase levels can be used in healthy individuals as a marker of muscle damage and can be correlated with physical training stimulus (Brancaccio et al, 2007) therefore as 70RPM produced the greatest increase in serum creatine kinase levels, it can be assumed that this cadence provided the greatest training stimulus. Despite the difference in creatine kinase levels produced, participants showed no significant difference between different cadences when asked to provide a Representative Perceived Effort (RPE) score and Visual Analogue Scale (VAS) score which were taken at 2 minute intervals throughout each test in order to assess the participants total perceived effort and sensation in the legs respectively. This suggests that participants did not recognise any specific cadence to have any training benefit over another. This research has been conducted on participants who are regular cyclists and compete at least 10 times a year and are able to produce 4 watts per kilogram maximal anaerobic power. By using participants from this group deemed to be 'well trained' this research hopes to provide knowledge to sport scientists and coaches working with competitive cyclists that helps to

increase the efficiency of their protocols when it comes to prescribing high intensity interval training.

Hypothesis

There will be a significant difference ($p<.05$) between levels of creatine kinase produced after cyclists complete high intensity interval training at a low cadence with high resistance in comparison to completing the same exercise with a high cadence and low resistance.

There will be a significant difference ($p<.05$) between Representative Perceived Effort scores after cyclists complete high intensity interval training at a low cadence with high resistance in comparison to completing the same exercise with a high cadence and low resistance.

There will be a significant difference ($p<.05$) between Visual Analogue Scale scores after cyclists complete high intensity interval training at a low cadence with high resistance in comparison to completing the same exercise with a high cadence and low resistance.

Methods

7 well trained (Jeukendrup, 2000) male cyclists who compete in cycling events at least 10 times per year conducted a 20 minute Functional Threshold Power (FTP) test from which FTP was calculated at 95% of the average power produced (305±45Watts(W)) and maximal aerobic power was calculated as the highest average power sustained for 1 minute during the second half of the test (359±44W). In order to meet the criteria to be deemed a 'well trained' cyclist, participants had to reach a maximal aerobic power of 4.0 watts per kilogram (W/KG) (5.03±0.78W/KG).

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The 7 participants then underwent a high intensity interval training (HIIT) protocol where by they would sustain 125% FTP (381±56W) for 40 seconds followed by 20 seconds recovery in a set of 10 repetitions. The participants repeated the test at 3 different cadences, 70, 90 and 110 revolutions per minute (RPM) with at least a 24 hour gap between tests. Before each test, creatine kinase (CK) levels were measured using a finger prick blood sample to establish a baseline and the same measurement was taken again immediately after the test.

Throughout each testing protocol the participants were asked at the end of every 2nd interval to point out a representative perceived effort (RPE) (6-20) score to indicate the participant's overall perceived exertion level as well as a visual analogue scale (VAS) (1-10) score which they were asked to point out in relation to the sensation of perceived effort in their legs.

Before each test participants conducted a 5 minute warm up at 100W and a 5 minute cool down at 100W after the test.

All of the tests were conducted in the same laboratory at the University of Chester. The tests were conducted using the same cycle ergometer (Wattbike) and all of the participant's had their bike fit measurements taken at the start of the first protocol to ensure the bike was set up the same for each test, all of the participants conducted the test using the same crank length (172.5mm). Creatine Kinase was measured using Reflotron testing strips and equipment.

Each participant completed an informed consent form (Appendix 2) and health screen questionnaire (Appendix 1) before participation in any of the protocols. Blood pressure

was also measured using a sphygmomanometer which was not to exceed 145/95mmHg at rest and a resting heart rate was measured with a Polar heart rate monitor which was not to exceed 90 Beats Per Minute (BPM) at rest.

Ethical approval for this research was granted by the University of Chester Faculty of Life Sciences Research Ethics Committee on 01 June 2015.

Statistical Analysis

All data was collected and analysed using IBM SPSS Statistics for Windows, Version 20.0; Armonk, New York.

Hypothesis 1-

The data was collected in a repeated measures design. There were three trials and the data passed the Shapiro-Wilk test of normality therefore a One-way Repeated Measures ANOVA test was used to assess statistical significance followed by multiple t-tests for post hoc analysis.

Hypothesis 2-

The data was collected in a repeated measures design. There were three trials and the data failed the Shapiro-Wilk test of normality therefore a Friedman test was used to assess statistical significance.

Hypothesis 3-

The data was collected in a repeated measures design. There were three trials and the data failed the Shapiro-Wilk test of normality therefore a Friedman test was used to assess statistical significance.

Results

Statistical analysis showed there to be a significant difference (p=.038) in creatine kinase measurements before and after the HIIT protocol at 70, 90 and 110RPM. The paired T-tests reveal that the difference lies between the 70 and 90RPM protocols (p=.040) with the mean (+48.85) indicating that 70RPM produced the greatest increase in CK levels.

There were no significant differences in RPE between the different cadences at any point during the tests: 2 minutes (p=.956), 4 minutes (p=.878), 6 minutes (p=.304), 8 minutes (p=.199) and 10 minutes (p=.140) suggesting that overall participants did not perceive any of the protocols to require a greater effort. Likewise there were also no significant differences between protocols in relation to VAS scores: 2 minutes (p=.325), 4 minutes (p=.247), 6 minutes (p=.382), 8 minutes (p=.326) and 10 minutes (p=.304) also suggesting that the participants did not deem any particular cadence to provide a greater sensation of workload in their legs.

The results therefore show the first hypothesis that here will be a significant difference (p<.05) between levels of creatine kinase produced after cyclists complete high intensity interval training at a low cadence with high resistance in comparison to completing the same exercise with a high cadence and low resistance can be accepted however the second and third; There will be a significant difference (p<.05) between Representative Perceived Effort scores after cyclists complete high intensity interval training at a low cadence with high resistance in comparison to completing the same exercise with a high cadence and low resistance and there will be a significant difference (p<.05) between Visual Analogue Scale scores after cyclists complete high intensity interval training at a low cadence with

high resistance in comparison to completing the same exercise with a high cadence and low resistance must be rejected.

Discussion

This research has found there to be an advantage to conducting HIIT at a lower cadence with an increased resistance at 125% of FTP in order to provide greater muscle breakdown in well trained cyclists. This concurs with Ansley et al (2009) who established there to be a difference in gross efficiency when cycling at different cadences in relation to muscular stress, energetic cost and perceived effort however unlike Ansley et al this research found no difference in perceived exertion between the cadences. Although this research has not taken any measurements of energetic/metabolic cost of different cadences, existing research studies have been presented within this area. A study by Formenti et al (2015) considered the validity of the American College of Sports Medicine recommended equation for calculating work rate (power) on a cycle ergometer (Lippincott, Williams & Wilkins, 2009) in relation to cadence. The study presented the notion that given a 6 metre distance per pedal revolution, whether an individual pedals at a resistance of about 53 N (product of resistance) and cadence of 30 RPM, or at a resistance of about 13 N and cadence of 2 120 RPM, the equation would present exactly the same work rate of 160 W, whereas the two physiological responses to exercise would be very different. This research has shown there to be an increased amount of muscle breakdown at lower cadences for the same output however other studies (Brisswalter, 2000) have shown similar cadences demonstrate metabolic efficiency reaffirming Fermenti et al (2015)'s notion that different cadences producing the same power output will have differing physiological effects.

Results in relation to published research

Studies that aim to establish a gross efficiency for cycling often consider power output in relation to the percent of maximal oxygen uptake (VO2max) as they are making the presumption that the cyclist can benefit from a lower metabolic cost relative to their power output (Coyle et al, 1991) however chronic fatigue caused by an increase in muscular breakdown will also play a part in a cyclists performance. A study by Brisswalter et al (2000) found a gross efficiency of 70-86RPM in relation to metabolic cost however this research has shown 70RPM to produce increased levels of muscle breakdown. This conflict of results show's how coaches and athletes can use cadence as a tool to create either muscular breakdown for hypertrophy and an goal of increasing strength or metabolic adaptations to improve endurance and efficiency. A later study by Foss & Hallen (2004) found an 'optimal' efficient cadence of 80RPM in elite cyclists when conducting a 30 minute time trial. Participants in this study produced average power outputs of between 312-351 watts which were more similar to the power outputs used in this research (325-438 watts) than those used by Brisswalter (80% Vo2max). Foss and Hallen suggest that differences in internal work defined as the power needed to overcome inertial and gravitational forces related to the movement of the legs (Ferguson et al, 2000) along with the efficiency of leg muscles contracting at difference frequencies (Foss & Hallen, 2004) provide explanation for greater efficiency at a higher cadence when participants are producing a higher power output.

Skeletal muscle is made up of type 1 (slow twitch (ST)) and type 2 (fast twitch (FT)) muscle fibres that are recruited when there is a difference in resistance and leg speed (Coyle, 1995), Coyle's study show's slow twitch muscle fibres are associated with endurance and are dominant when resistance is low but velocity (cadence) is high however fast twitch fibres are recruited when force (resistance) is increased and the velocity reduces. This association between fibre type and the cadence/resistance ratio suggests that fast twitch muscle fibres are more susceptible to being broken down as a result of training when correlated with the results from this study however Brancaccio et al (2007) stipulates that further research is needed to establish whether increases in creatine ki-

nase can be correlated to different muscle fibre types so a firm conclusion about the types of muscle fibre most susceptible to muscle breakdown cannot be made. Muscle fibres are recruited in a strict order where by slow twitch fibres are recruited first before fast twitch fibres (Henneman, Somjen, & Carpenter, 1965) a study by Wakeling, Ueli & Rozitis (2004) demonstrated a positive correlation between force required to produce a certain cadence and the recruitment of fast twitch muscle fibres which further suggests that there may be a correlation between resistance which causes the recruitment of fast twitch muscle fibres and muscle breakdown although other studies (Hautier et al,1996) have shown almost exclusive recruitment of fast twitch muscle fibres at cadences of 120RPM. It appears likely then that the recruitment of different muscle fibre types has no bearing on the amount of muscle broken down at different cadences as fast twitch muscle fibre recruitment correlates better to total workload than changes in resistance and cadence, this is backed up by studies such as Hansen et al (2002) that have considered muscle fibre characteristics such as mitochondrial density and membrane permeability to demonstrate that fast twitch muscle fibres do not break down easier than slow twitch muscle fibres.

Despite this research finding a significant difference between levels of creatine kinase produced after the HIIT protocols at different cadences, there were no significant differences between Representative Perceived Effort (RPE) scores used to measure the participants overall perception of difficulty or Visual Analogue Scale (VAS) scores used to measure the participants perception of pain in their legs. These results do not concur with a similar study conducted by Whitty, Murphy, Coutts and Watsford (2009) that explored cadence preference in relation to gross efficiency, the study concluded that non-cyclists freely choose a cadence that minimises muscle strain as opposed to being metabolically efficient. Although the research design differed in that the participants training status' were different and the protocols dictated different power outputs, a similar result could have been expected from this research. The study by Whitty, Murphy, Coutts and Watsford used 18 participant's compared with only 7 in this research as well as using a wider range (50-100 vs 70-110) and more options of cadence (5 vs 3) which adds weight to it's validity. Despite their being no signifi-

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cant difference between RPE and VAS scores in this research, the larger sample size of the Whitty, Murphy, Coutts and Watsford study suggests that the RPE and VAS results of this research are not accurate as a significant difference in VAS would be expected. RPE and VAS are both subjective measures and differences between the two studies could come down to something as simple as the way in which the scoring was explained to participants.

Limitations of the study

Much of the research on the effects of cadence on a cyclist has been conducted in a research laboratory environment where by cadence is can be controlled as per preference of the researcher or participant, studies that have considered 'optimal cadence' for cyclists from a perceived effort perspective have found 80-100RPM to be preferred (Sarre et al, 2003) however this presumes that cadence is always chosen by the cyclist and not dictated by non physiological factors such as terrain. A study by Mognoni & di Prampero (2003) identified a drop in cadence from 100RPM to 70RPM in professional cyclists when climbing hills and concluded that this was a result of gravitational force as opposed to the cyclists preference. Despite these disadvantages to conducting research on cadence in a laboratory environment, the HIIT protocol for which this research was intended could be conducted in training in a similar indoor environment and therefore this research becomes relevant.

Creatine Kinase has been used as a marker of muscle breakdown however (Brancaccio et al, 2007) suggested further research is needed in order to establish a relationship between creatine kinase and different muscle fibre types. Another method of measuring muscle breakdown could be used to re-affirm the results of this study or further trials could be con-

ducted to explore creatine kinase in relation to differing muscle fibre types. At this time, as creatine kinase can not be correlated with muscle fibre types, only assumptions about the recruitment of muscle fibre types being an explanation for increased muscle breakdown can be made. Despite this, other studies have used creatine kinase as an indirect marker of muscle breakdown (Brown, Day, Donnelly, 1999) as it is not as intrusive to participants as other methods of measuring muscle breakdown.

Gaps in evidence and future studies

This research has considered the effects of cadence on muscle breakdown in relation to one training protocol which was designed to imitate the demands of a short circuit or track cycling race with repeated efforts. Further research may take the same research design but change the protocol to imitate different demands of cycling such as a time trial protocol.

As previously presented, measuring creatine kinase as a measure of muscle breakdown is indirect and could be backed up with other measures. Alternative measures of muscle breakdown could be C-reactive Protein which increases in blood plasma as a result of cells dying (Thompson, Pepys, Wood, 1999) which is measured using a venous blood sample (Ridker, 2003) which provides more discomfort to participants. C-reactive protein is an acute response to inflammation however can be elevated by differences in genetics (Ridker, 2003) meaning like Creatine Kinase it is too unreliable to be taken as a sole marker of muscle breakdown. A muscle biopsy can also be used to assess muscle breakdown as a sample of the muscle can be ground down and the proteins analysed, this protocol (Wolfe, 1992)

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was used in a study by Glynn et al (2010) to assess muscle breakdown in relation to nutritional intake. This method of measuring muscle breakdown is more accurate than indirect measurements such as creatine kinase and c-reactive protein as a full analysis of the protein composition before and after exercise can be made however this is very intrusive to the participant. Further research could conduct the same protocol's but measure C-reactive Protein or take a muscle biopsy as well to re-affirm the findings of this research however C-reactive protein would unlikely produce anymore conclusive results than has already been established and a muscle biopsy is too intrusive.

Further research should be conducted into a larger range of cadences to match those presented by Fermenti et al (2015) so that direct comparisons between metabolic cost, perceived effort and muscle breakdown can be made. Further research could also examine different power outputs, this research used 125% of functional threshold power for the intervals however a larger relative power would recruit different metabolic systems and muscle fibre types and therefore provide further insight into the comparison between metabolic cost and muscle breakdown for any given cadence.

Conclusion

Cadence is a tool that can be used by coaches and athletes to produce differing training adaptations depending on their goal. This research has demonstrated that a low cadence with a high resistance during high intensity interval training produces an increased amount of muscle breakdown and therefore lends itself to strength training however other studies (Brisswalter et al, 2000. Coyle et al, 1991. Sara et al, 2003) have demonstrated differ-

ences in metabolic cost at different cadences, Brisswalter et al (2000) suggested that cadences between 70 and 86RPM offer a low metabolic cost which suggests training at a higher cadence will increase oxidative stress and stimulate adaptations that will improve endurance and metabolic efficiency. The results of this research did not concur with the result's of other studies that have considered cadence in relation to representative perceived effort (RPE) and a visual analogue scale (VAS) (Whitty, Murphy, Coutts and Watsford, 2009) as no significant differences were produced at any particular cadence, this is likely as a result of the subjective nature of RPE and VAS scores and it would be expected that a significant difference would occur to show a higher VAS score at lower cadences if the sample size were to be increased or different participant's used as Whitty, Murphy, Coutts and Watsford (2009) found cyclists to opt for a cadence that minimises muscle strain rather than being metabolically efficient when allowed to freely choose cadence. Differences in the recruitment of different muscle fibre types between cadences may provide an explanation for the difference in muscle breakdown between cadences as Coyle (1995) demonstrated that type 2 muscle fibres are recruited when resistance is high but cadence is low however type 1 muscle fibres are recruited when the resistance is low but the cadence is high. This can be correlated to the results of this study which then suggests more muscle breakdown occurs as a result of the recruitment of fast twitch muscle fibres however despite this there is no research to show that creatine kinase levels increase more as a result of the recruitment of fast twitch muscle fibres (Brancaccio et al, 2007). Using creatine kinase as an indirect measurement of muscle breakdown presents issues of reliability, a muscle biopsy where by the construction of proteins in the muscle before and after exercise would have been a more reliable way to measure muscle breakdown however this is very intrusive to the participants, the same protocol could be carried out again using C-reactive protein as a further marker of muscle breakdown to re-affirm the results found in this research. This research along with all of the other studies referenced have studied ca-

dence in a laboratory environment where by the cadence has been at the discretion of the researcher or participant however Mognoni & di Prampero (2003) demonstrated how cadence is often dictated to the rider by external factors such as terrain meaning this research is limited to providing recommendations for indoor or flat terrain training where cadence can be dictated easier by the rider. Further research could consider different exercise protocols such as a prolonged time trial or different interval ratio, a wider range of cadences and different power outputs to see if they make a difference to the outcome and establish whether any correlations may exist.

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Appendices

Pre-test Questionnaire

Difference between low cadence-high resistance and high cadence low resistance in relation to muscle breakdown in cyclists.

Researcher *: Robert Stanley*

Name:_____ Test date:_____

Contact number:_____ Date of birth:_____

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor?   YES/NO

2. Do you feel pain in the chest when you perform physical activity?   YES/NO

3. In the past month, have you had chest pain when you were not performing physical activity?   YES/NO

4. Do you lose your balance because of dizziness *or* do you ever lose consciousness?   YES/NO

5. Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity?   YES/NO

6. Is your doctor currently prescribing drugs for your blood pressure or heart condition?   YES/NO

7. Are you pregnant, or have you been pregnant in the last six months?   YES/NO

8. Have you injured your hip, knee or ankle joint in the last six months?   YES/NO

9. Do you know of any other reason why you should not participate in physical activity?   YES/NO

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

Consent Form

Difference between low cadence-high resistance and high cadence low resistance in relation to muscle breakdown in cyclists.

Researcher *: Robert Stanley*

Please initial box

1. I confirm that I have read and understand the information sheet
   for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to
   withdraw at any time, without giving any reason and without my
   legal rights being affected. ☐

   ☐
3. I agree to take part in the above study.

_____   _____   _____
Name of Participant   Date   Signature

_____   _____   _____
Researcher   Date   Signature