

**EFFECT OF KNOWLEDGE OF EXERCISE DURATION ON PREDICTED, ACTUAL,  
AND SESSION LEG MUSCLE PAIN RESPONSES DURING CYCLE ERGOMETRY**

by

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**PURPOSE:** The purpose of this investigation was to examine the effect of knowledge of exercise duration on *predicted*, *actual*, and *session* ratings of leg muscle pain (RMP-Legs) during cycle ergometry. **METHODS:** Subjects were 36 females and 36 males, ages 18-30 yrs. Each subject performed one baseline graded exercise test to exhaustion and one isotime (20 minute) cycle trial at 70%  $\text{VO}_{2\text{peak}}$ . Based on random assignment, the subject was told they would exercise for one of the following durations: a 20 minute trial (Accurate Duration; ACC-20), a 30 minute trial (Long Duration; LONG-30), or a 10 minute trial (Short Duration; SHORT-10). A *predicted* RMP-Legs was reported immediately prior to exercise. *Actual* RMP-Legs were reported at two min intervals during exercise. *Session* RMP-Legs was reported 10 min post-exercise. **RESULTS:** For the female sample, no differences were found in *predicted* RMP-Legs between knowledge of duration conditions. The interaction effect was significant. *Actual* RMP-Legs were higher in the SHORT-10 than LONG-30 condition at minutes 2, 4 and 6. *Actual* RMP-Legs were lower in the SHORT-10 than ACC-20 condition at minutes 14, 16, 18, and 20. *Actual* RMP-Legs were lower in the LONG-30 than the ACC-20 condition at minutes 4 and 20. Compared to the *predicted* RMP-Legs, *actual* RMP-Legs for the ACC-20 condition were lower at minutes 2, 4, and 6. *Actual* RMP-Legs for the LONG-30 condition were lower at minutes 2, 4, 6, 8, 10, and 12 compared to the *predicted* rating. *Actual* RMP-Legs for the SHORT-10 condition were lower at minutes 2, 12, 14, 16, 18, and 20 compared to the *predicted* rating. *Session* RMP-Legs did not differ. For the male sample, *actual* RMP-Legs were lower at minutes

2 and 4 compared to the *predicted* rating. There was no significant difference in RMP-Legs between conditions. *Session* RMP-Legs did not differ between knowledge of duration conditions. **CONCLUSIONS:** In general, pre-participation knowledge of exercise duration did not have an effect on *predicted*, *actual*, and *session* RMP-Legs for young recreationally active females and males. Future research should examine knowledge of exercise intensity as a possible teleoanticipatory factor that influences leg muscle pain responses during prolonged exercise.

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## **PREFACE**

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## 1.0 INTRODUCTION

The purpose of this investigation was to examine the effect of knowledge of exercise duration on *predicted*, *actual*, and *session* ratings of leg muscle pain during cycle ergometry. Naturally occurring, non-clinical muscle pain has been reported for both aerobic and resistance exercise (17, 41, 53). In general, exercise-induced muscle pain increases as a function of the intensity of the physical activity and to a somewhat less extent throughout the duration of the activity. The present investigation explored exercise pain responsiveness using a teleoanticipation paradigm. In the context of exercise performance, knowledge of duration can be considered a construct of *teleoanticipation* (62). Teleoanticipation is defined as the learned perceptual anticipation that originates in the central nervous system in response to either: a) a pre-performance practice exercise trial, or b) specific knowledge of exercise duration (62). The present investigation employed the theoretical framework underlying the second of these constructs. The teleoanticipation concept has been used to explain improvement in athletic performance, as a consequence of more precise intensity self-regulation skills during both training and competition (26, 62). Pre-performance knowledge of exercise duration has been shown to produce a more precise link between metabolic demand and exertional perceptions during exercise of varying durations. Although this perceptual calibration technique involving knowledge of duration has been shown to have a favorable influence on a number of psychophysiological processes during physical performance, teleoanticipation's influence on ratings of naturally occurring exercise-

induced muscle pain is unclear. Specifically, the effect of pre-performance knowledge of exercise duration on *predicted*, *actual*, and *session* muscle pain responses is unknown.

## 1.1 RATIONALE

### 1.1.1 Predicted and Actual Pain Responses

Pain sensation has both intensity and affect components (43). Pain intensity is often measured on a response continuum using a category scale format and is the primary construct of interest of the present investigation. Affect measures focus on emotional feelings associated with a painful experience (i.e. unpleasantness) (51). In the context of this investigation, a *predicted* pain rating was measured immediately prior to exercise. This rating is expected to provide information about the intensity of muscle pain an individual expects (i.e. anticipates) during the exercise session that is about to be performed. An *actual* pain rating is the sensory measurement determined during the exercise performance *per se*. This rating reflects the momentary measure of the pain intensity the subject is experiencing at specific time points throughout the exercise session.

In a clinical context, research has shown a consistent mismatch between *predicted* and *actual* pain responses (44). A match-mismatch experimental paradigm has been used to study individuals' ability to accurately link the intensity of their *predicted* and *actual* pain (6). A mismatch pattern is evident when an individual predicts that the level of pain they expect to experience is greater or less than the level of pain actually experienced. When *predicted* pain is equal to the *actual* pain reported, the response is considered a sensory match. It has been



proposed that a mismatch involving an over-prediction of expected pain intensity can lead to poor levels of adoption and maintenance of physical activity (44). The mechanism underlying a pain mismatch response remains unclear. A mismatch suggests that there may be a sensory disconnect between the muscle pain that an individual anticipates experiencing and what is actually experienced. A mismatch has been shown to be eliminated following subsequent exposures to painful stimuli (46, 48). In such a case, the repeated exposure to the noxious stimuli may function as a teleanticipation feedback loop, accurately connecting expectations with actual experiences.

To date, no research has examined whether pre-performance knowledge of exercise duration promotes a match between *predicted* and *actual* pain responses. The presence of a pain match or mismatch could be dependent of whether the individual has been provided accurate information regarding the duration of exercise to be performed. In this regard, it is postulated that a mismatch may be corrected using a pain management intervention that focuses on pre-participation knowledge of exercise duration. The present investigation determined if knowledge of exercise duration affects pain responses during exercise according to the predictions of a teleanticipation model. That is, teleoanticipation may play a role in explaining a mismatch between *predicted* and *actual* pain responses during exercise. Findings may provide a rationale for the inclusion of precise information regarding exercise duration as a component of intervention strategies to promote physical activity participation.

Ulmer (62) proposed that both feedback and feedforward systems influence the neuromuscular and metabolic signals sent to the brain during and after exercise. The feedback system allows the individual to continuously adjust performance intensity according to a metabolically efficient strategy. Ulmer termed this in-task calibration process teleoanticipation.

The feedforward system relies on analysis of past experience by the individual to gauge current exercise intensity. The combined effects of the feedforward and feedback systems allow individuals to develop more efficient pacing strategies for the upcoming exercise task.

An extension of the feedback and feedforward components of the teleoanticipation concept may have application in understanding factors that affect naturally occurring muscle pain during exercise. Expectation regarding an impending experience has been closely linked to the concept of predicted sensory and behavioral outcomes (16). Acceptance of pain as a noxious stimulus requires that the individual first be exposed to that level of the painful stimulus (i.e. the manifestation of teleoanticipation). Hence, using teleoanticipation modeling, the individual is exposed to the stimulus as an initial event, during which they establish a sensory reference point for pain intensity. It follows that an individual can more accurately predict pain intensity once they accept that they will experience a certain level of pain. Receiving pre-performance knowledge of the exercise duration as part of a teleoanticipation feedforward system may influence *predicted* pain response. If individuals are given the knowledge that the duration of exercise will be comparatively short, they may predict a lower pain response since they anticipate the noxious experience will be comparatively more bearable. If individuals are given knowledge that the exercise will be comparatively longer in duration, they may predict a higher pain response due to the anticipation of extended exposure to noxious properties of the exercise.

Previous investigations have manipulated pre-performance knowledge of the duration of an impending exercise session using an isotime paradigm (1, 3, 10). This paradigm was used to determine if manipulating pre-performance knowledge of exercise duration influenced *actual* ratings of perceived exertion (RPE) when measured over multiple aerobic exercise sessions of equal intensity and duration (1, 10). However, research to date has not employed isotime

exercise protocols as part of a match-mismatch paradigm to study the effect of knowledge of exercise duration on non-clinical exercise induced muscle pain. Therefore, the purpose of this investigation was to examine the effect of knowledge of exercise duration on *predicted* and *actual* pain responses during prolonged (i.e. 20 minutes) sub-maximal cycle ergometry. The investigation employed an isotime paradigm where actual exercise duration was constant across cycle ergometer trials but subjects were informed that they performed for different durations. Theoretically, an individual should experience similar muscle pain responses for each trial, given the fixed duration and metabolic intensity of the exercise challenge. However, if pain response differs across trials, such responses would suggest that knowledge of exercise duration may be an influential factor in determining both expected and actual muscle pain response to exercise.

### **1.1.2 Session Pain Responses**

Foster et al. (24) were the first to assess Session RPE. *Session* RPE has been shown to be a valid method of quantifying the overall intensity of single or multiple training days (24, 25). Using a perceptual construct analogous to that employed by Foster et al. (24), a *session* pain rating is a post-exercise measure that provides a global measurement of the pain intensity experienced throughout an entire exercise session. A *session* rating of pain intensity is typically provided by the individual 5 to 30 minutes after completion of a specified exercise task. Previous preliminary research paradigms have examined *session* pain ratings to determine if they can be used in a manner similar to that of *session* RPE (28, 30, 61). To date, it has not been determined whether knowledge of the duration of the impending performance will affect *session* pain ratings during prolonged exercise.

The current investigation examined the effect of pre-performance knowledge of exercise duration on *session* pain ratings. Consistent with the teleoanticipation model, pre-performance knowledge of exercise duration may directly influence individual's rating of *session* pain. Such knowledge regarding exercise duration may play a key role in the teleoanticipation feedforward processing system, providing a strategy to complete the exercise task. How well the individual strategizes performance based on knowledge of a specific exercise duration may affect the *session* pain rating provided at the end of the exercise task. *Session* pain ratings may be incorporated into a pain management intervention. The result of such an intervention may be that the individual is better prepared to accept the muscular pain experienced for a total exercise session that is to be subsequently performed.

## **1.2 CLINICAL SIGNIFICANCE**

### **1.2.1 Predicted and Actual Pain Responses**

Measurement of pain responsiveness associated with exercise performance has public health implications. A mismatch between *predicted* and *actual* pain responses during physical activity may lead to poor adoption and maintenance of physical activity, especially for individuals who report generally low levels of participation. Examining the effect of providing knowledge of the duration of an impending exercise performance on pain responsiveness may assist in understanding an individuals' perceptual barrier to exercise participation. If the duration of exercise is not known or is inaccurate, pain responsiveness may be intensified. Such a sensory response may be a factor in adherence to an exercise regimen. That is, individuals may have

reservations about participating in exercise if they anticipate the activity will be more painful than will be actually experienced. The current study is among the first to investigate knowledge of exercise duration as a possible contributor to a mismatch between *predicted* and *actual* pain responses for recreationally active individuals performing cycle ergometer exercise. If indeed a mismatch is found between *predicted* and *actual* muscle pain response due to the effect of knowledge of exercise duration, future research could examine pre-participation cognitive strategies to overcome this potential barrier to physical activity participation. Finding ways to encourage an individual to expect and accept tolerable levels of muscular pain during exercise based on accurate knowledge of performance duration may lead to improved physical activity behaviors.

### **1.2.2 Session Pain Responses**

The present investigation is among the first to examine the effect of knowledge of exercise duration on *session* ratings of leg muscle pain. Findings will help determine applications of a global rating of the muscle pain experienced during an entire exercise task, but measured at a specific post-exercise time point. As with perceived exertion, measures of *session* pain may prove to be helpful in providing information about the totality of an individual's noxious experience during prolonged sub-maximal exercise. The importance of measuring *session* pain responses may be analogous to those of *predicted* and *actual* pain responses. If it is shown that knowledge of exercise duration effects *session* ratings of muscle pain, interventions can be developed to use such information in prescribing physical activity programs. Measures of *session* pain may also be used in treatment programs for chronic pain patients where the upper limit of exercise intensity is often determined by the global pain experienced over a complete

training protocol. Such treatment programs can include information about the duration of the impending training bout, which in turn may advantageously influence the patients willingness to accept the global pain experienced over the entire session.

### **1.3 STATEMENT OF THE PROBLEM**

#### **1.3.1 Predicted and Actual Pain Responses**

The present investigation determined if knowledge of exercise duration prior to performance affects *predicted* and *actual* leg muscle pain responses reported by recreationally active females and males during prolonged cycle exercise at 70% of peak oxygen uptake ( $\text{VO}_{2\text{peak}}$ ).

#### **1.3.2 Session Pain Responses**

The present investigation also determined if knowledge of exercise duration prior to exercise affects *session* pain responses reported by recreationally active females and males following prolonged cycle exercise at 70% of  $\text{VO}_{2\text{peak}}$ .

## 1.4 HYPOTHESES

### 1.4.1 Predicted and Actual Pain Responses

For both females and males, it was hypothesized that in comparison to leg muscle pain (*predicted* and *actual*) associated with a 20 minute sub-maximal cycle ergometer trial where subjects are given accurate information regarding exercise duration:

- 1) leg muscle pain would be greater where subjects were told the exercise duration would be 30 minutes when actually performing for 20 minutes, and
- 2) leg muscle pain would be less where subjects were told the exercise duration would be 10 minutes when actually performing for 20 minutes.

It was also hypothesized that *predicted* ratings of leg muscle pain

- a) would be more intense than *actual* leg muscle pain ratings where subjects were told they would exercise for 30 minutes, when performance was 20 minutes.
- b) would be less intense than *actual* pain ratings where subjects were told they would exercise for 10 minutes, when performance was 20 minutes, and
- c) would be equally intense as *actual* pain ratings where subjects were provided with accurate knowledge of exercise duration (i.e. 20 minutes).

### 1.4.2 Session Pain Responses

For both females and males, it was hypothesized that in comparison to *session* leg muscle pain responses for a 20 minute sub-maximal cycle ergometer trial where subjects were given accurate information regarding exercise duration:

- 1) *session* leg muscle pain would be greater where subjects were told the exercise duration would be 30 minutes when actually performing for 20 minutes, and
- 2) *session* leg muscle pain would be less where subjects were told the exercise duration would be 10 minutes when actually performing for 20 minutes.



## **2.0 REVIEW OF LITERATURE**

### **2.1 PAIN PERCEPTION**

#### **2.1.1 Definition**

Pain is defined as “an unpleasant sensory and emotional experience, associated with actual or potential tissue-damage or described in terms of such damage” (31). Pain sensation has both sensory intensive and affective dimensions that can be assessed separately during exposure to a noxious stimulus such as exercise (42). With moderate-to-high intensity exercise, most individuals should expect to experience a certain level of naturally-occurring muscle pain that is not typically associated with an aversive experience or severe enough to cause tissue damage. However, pain perception is an individualized response and is subject to an individual’s emotions and experiences (40). Muscular pain during exercise can be linked to a variety of factors. Physical deconditioning or inability to perform or sustain at a certain exercise intensity can lead to increased lactic acid production and related sensations of muscular pain and/or discomfort. In particular, depletion of muscle glycogen can cause the muscles to fatigue leading to noxious sensations often described as pain. Fatigue in exercising muscles (i.e. legs) necessitates recruitment of additional muscle fibers to offset the decrease in force production as exercise continues (59). The resulting sensation is naturally-occurring muscle pain. These pain

perceptions can play a prominent role in an individual's willingness and ability to participate in physical activity. Unacceptable levels of muscle fatigue or pain are common reasons for individuals to terminate exercise. Therefore, an individual's perception of a noxious exercise experience and the memory attached to that experience could influence the intensity of exercise-induced pain (31).

### **2.1.2 Pain Intensity**

Previous research has investigated the theory that an individual's experience of pain intensity is directly related to the meaning attached to the eliciting stimulus (4). Using experimental manipulation involving temperature, individuals were told that their responses to being touched on the back of the neck with different heat or cold stimuli were going to be measured. With each trial, the experimenter provided the subject with information that the stimulus (i.e. touch) would be a very hot or very cold metal bar. However, under both conditions the object was the same metal bar cooled to -25° Celsius. Immediately following the trial, subjects used visual analog scales to rate the intensity of the experience based on how hot or cold the stimulus was, how painful it felt, and how much tissue-damage was thought to have occurred. Results showed that individuals tended to believe the experimenter's information. The Cold-Hot ratings reported by the subject were influenced by whether they were told the stimulus was very hot or very cold. Individual's rated the experience as more painful when told that the stimulus was hot, as compared to when they were told it was cold. When the stimulus was rated as more painful, the subjects associated the experience with greater possible tissue-damage. It was proposed that these outcomes were due to the type of information that the experimenter provided to the subject. The information provided the subject with a cognitive reference giving meaning to the upcoming

experience. The investigation concluded that the meaning or memory of pain that an individual attaches to a noxious stimulus influences both experienced and reported painfulness (4).

The findings of Arntz and Claassens (4) regarding factors that influence pain intensity rating may be applicable to an exercise setting. For example, in the present investigation, it is expected that knowledge of a longer exercise duration will negatively influence the individual's experience of pain. That is, they may relate a longer exercise duration with less tolerance for the stimulus resulting in a more painful experience. Performing a series of exercise trials of the same duration and relative metabolic rate sufficient to induce a moderate level of naturally-occurring muscle pain while presenting accurate and inaccurate knowledge of exercise duration, may be helpful in determining factors that influence pain response. Previous research has determined that when individuals are not given information regarding duration of an impending exercise performance, they will tend to under-predict *perceived exertion*. This has been linked to increased predictions of exertion for subsequent trials, in turn leading to patterns of poor exercise performance and poor exercise adherence (10). However, the effect of accurate and inaccurate knowledge of exercise duration on *pain* responses has not been reported.

Previous research theorizes that pain responses may be attenuated when using attentional processes such as distraction (36, 37). Although findings regarding this effect derive from thermal pain stimuli, it has also been suggested that similar analgesic effects may be seen during or following exercise (23). This analgesic effect could be linked to mediators such as pain threshold, mood (fear/anxiety) and previous experience with the exercise stimulus. Studies have also shown that anticipation of intense exercise or athletic competition alone can provide sufficient emotional stress to induce an analgesic or masking effect of pain intensity (60, 65). Providing information regarding an impending exercise trial may establish a cognitive reference

for a similar effect on pain responses during and immediately following exercise. This paradigm may provide insight pertaining to inter-individual differences in pain responses. In the present investigation, subjects will predict their pain response after receiving knowledge of the impending exercise duration. It is expected that they in turn will use the information as a guide (i.e. possible cognitive distraction) when progressing towards completion of the exercise task. Being told they must exercise for a comparatively longer duration, the individual may report more intense muscle pain. Alternately, being told they must exercise for a comparatively shorter duration, the individual may report less intense muscle pain. Presently, it is unknown what effect manipulating knowledge of exercise duration has on pain responses associated with an exercise trial.

### **2.1.3 Muscle pain assessment during cycle exercise**

Previous psychophysiological research has focused on understanding the role of knowledge of exercise duration on perceived exertion responses during different modes of exercise. Perceived exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that is felt during exercise (39). Various RPE scales have been developed to measure perceived exertion during exercise. Borg's 6-20 scale was one of the initially validated metrics to measure the perception of physical exertion during exercise (14). Since the introduction of the Borg 6-20 scale, many other category metrics of perceived exertion have been developed. Among these are the Borg CR-10 Scale (13) and the OMNI RPE scale (54). A unique feature of the OMNI Scale is that it employs interchangeable pictorial descriptors generally consistent with the type of exercise to be performed (54). Only recently have researchers recognized the possible importance of assessing other perceptual responses that may impact exercise performance, such

as muscle pain. Muscle pain has been measured using the Borg CR-10 scale (15, 34). However, using the same scale to measure perceived exertion and assess muscle pain is cause for concern, in that individuals may not be able to effectively differentiate between exertion and pain responses. The result is cross-scale demand bias. The Cook Pain Intensity Scale is a modification of the Borg CR-10 Scale format and was specifically developed to assess the intensity of naturally occurring muscle pain experienced during exercise (17). The Cook Pain Intensity Scale consists of 12 categories with numerical descriptors ranging from 0 to 10. Verbal descriptors ranging from “no pain at all” to “extremely intense/almost unbearable pain” are used to assist in selecting the rating response. An unnumbered category with a large dot and the verbal descriptor “unbearable pain” serves as the open ended upper response category on the scale (Figure 1).

<b>PAIN INTENSITY SCALE</b>	
<b>0</b>	<b>No pain at all</b>
<b>0.5</b>	<b>Very faint pain (just noticeable)</b>
<b>1</b>	<b>Weak pain</b>
<b>2</b>	<b>Mild pain</b>
<b>3</b>	<b>Moderate pain</b>
<b>4</b>	<b>Somewhat strong pain</b>
<b>5</b>	<b>Strong pain</b>
<b>6</b>	
<b>7</b>	<b>Very strong pain</b>
<b>8</b>	
<b>9</b>	
<b>10</b>	<b>Extremely intense pain (almost unbearable)</b>
<b>•</b>	<b>Unbearable pain</b>

**Figure 1. Cook Pain Intensity Scale**

From Cook DB, O'Connor PJ, Oliver SE, Lee Y. Sex differences in naturally occurring muscle pain and exertion during maximal cycle ergometry. *International Journal of Neuroscience* 1995;95:183-202 (19).

Previous research has shown that healthy individuals who are free of musculoskeletal injuries consistently experience leg (quadriceps) muscle pain during moderate and high-intensity

cycle exercise (15, 17, 19). Those investigations however, focused on specific pre-selected power outputs to stimulate various pain responses. O'Connor and Cook (41) examined the ability of individuals to produce and sustain moderate-intensity quadriceps muscle pain during a 20 minute cycle exercise bout. Intensity was initially set at a power output that corresponded to each subject's muscle pain threshold (0.5 on the Cook Pain Intensity Scale). This threshold had been detected during a peak exercise test performed on a separate day prior to the 20 minute experimental bout. Individuals were then asked to adjust the power output to maintain a moderate-intensity of leg (quadriceps) muscle pain. Results showed that young healthy female subjects were able to produce and maintain moderate-intensity muscle pain (i.e. 3 on the Cook Pain Intensity Scale) during a 20 minute exercise bout. It was also found that moderate-intensity muscle pain coincided with a perceived exertion response of 15 or "hard" on the Borg 6-20 scale. Oxygen uptake associated with the moderate-intensity muscle pain responses was equivalent to 69-74%  $\text{VO}_{2\text{peak}}$ . The investigators concluded that college aged females can produce and maintain moderate-intensity muscle pain during cycle exercise (41).

#### **2.1.4 Session Pain**

Previous research has examined global perceptual responses as reported for an entire exercise session. Developed by Foster et al., a *session* rating represents a single global assessment of the intensity of perceived exertion experienced for an entire exercise bout (24, 25). The *session* rating is typically obtained from 5 to 30 minutes post-exercise. The *session* rating of perceived exertion has been shown to provide approximately the same information regarding the relative intensity of a given training bout as heart rate responses (11, 25). Although validity of the *session* rating of perceived exertion has been established, evidence on the benefits of using

*session* ratings of muscle pain has not been determined. Preliminary investigations examining *session* pain ratings observed a rebound response when compared with the *actual* ratings that were determined during load incremented cycle ergometer exercise (28, 30). That is, individuals tend to overpredict pain intensity of the exercise and then report a *session* rating that is similar to the initial overprediction but higher than the *actual* (i.e. momentary) perceptual response. In this instance, the *actual* pain ratings given during exercise are less than either the *predicted* or *session* ratings.

An individual may recall previous pain experience while consciously preparing for a subsequent exercise bout. This recollection may contribute to the overprediction of exercise-induced pain that will actually be experienced during the upcoming exercise performance. If not corrected, an individual may continue the cycle of overpredicting pain before exercise. In effect, the *session* ratings of pain intensity estimated after completion of exercise may not be similar to *actual* ratings of pain estimated during exercise, i.e. a perceptual-cognitive mismatch. This warrants further investigation into the link between *predicted* and *session* pain rating responses, especially as the perceptual match or mismatch may be influenced by knowledge of exercise duration. Establishing correspondence between *predicted* and *session* pain ratings may be accomplished through pain management intervention, the result being that the individual is better prepared for the potentially noxious experiences associated with subsequent exercise participation.

Determining the effect of knowledge of exercise duration on *session* pain may provide direction in developing interventions to promote exercise adherence. Knowing that the individuals assessment of the global pain experience for the entire session is the final cognitive impression of the sensory experience may contribute to expectations of the pain experience in

sessions to come. Therefore, it is important to determine if the session response is effected by pre-participation knowledge of the exercise duration.

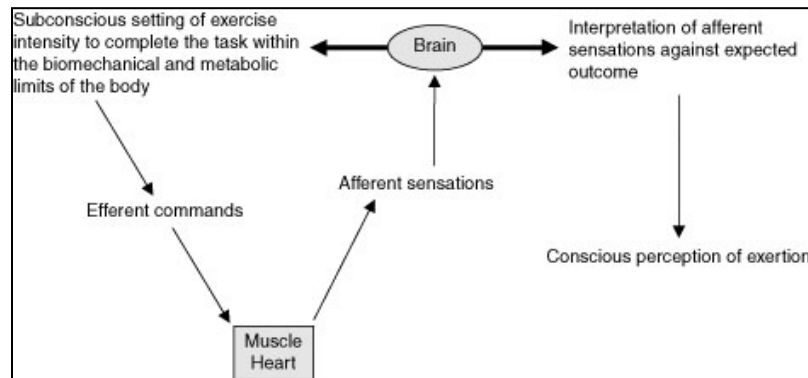
## **2.2 TELEOANTICIPATION**

### **2.2.1 Conceptual background**

Ulmer (62) theorized that the body has a central programmer in the brain which subconsciously calculates the time needed to complete a physical activity bout while maintaining a balance in all bodily systems, i.e. homeostasis. Along with time expectation, it is known that individuals use past experience to help prepare for a given task (i.e. physical activity). This concept is termed teleoanticipation and includes feedforward and feedback systems to help regulate exercise intensity. The systems adjust power output to achieve an intensity and duration of performance that can be maintained without risk of bodily harm. Initially, information is sent via a feedforward system originating in the brain. This information allows the individual to set exercise pace (i.e. intensity) based on previous experience with a given exercise type or based on specific knowledge of time or distance of the exercise. This initial information enables the individual to subconsciously determine an exercise pace that will allow he/she to complete the exercise task without depleting energy stores. Optimal use of energy stores concurrently reducing negative afferent signals. Once exercise is underway, a feedback system sends afferent signals from the periphery back to the brain. This feedback allows the individual to self-regulate pace to most effectively complete the task while maintaining an energy reserve. These afferent signals are then interpreted by the brain and are used in part to develop conscious sensations of



perception of exertion (Figure 2) (29, 62). It is anticipated that this process is similar for other sensations that involve afferent signals during exercise, such as naturally-occurring muscle pain.



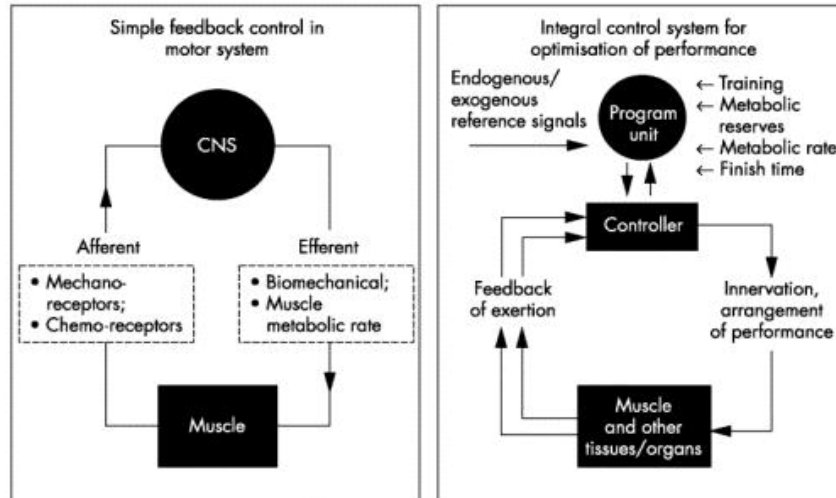
**Figure 2. Teleoanticipation Process**

From Hampson DB, St. Clair Gibson A, Lambert MI, Noakes TD. The influence of sensory cues on the perception of exertion during exercise and central regulation of exercise performance. *Sports Medicine* 2001; 31(13):944 (29).

The psychophysiological feedback system described by Ulmer (62) is achieved by an in-task adjustment of power output on an ergometer or adjustment of pace on a track or in a swimming pool. The goal is that the exercise task is performed to planned completion, such that it is not prematurely terminated due to extreme fatigue or organ damage. St. Clair Gibson and colleagues (59) propose that this theory of a regulatory teleoanticipation may be the reason for the decrease in power output during exercise even when metabolic reserves are still available for use. In this case, the initial performance intensity can no longer be maintained. Therefore, the decrease in power output as performance continues is a conscious adjustment of the individual's subconscious reference point to ensure completion of the exercise task. This occurs as part of the individual's subconscious mental calculation when adjusting to feelings of fatigue.

Previous research has incorporated Ulmer's theory into a central integrative model which proposes that physical exhaustion during exercise is due to relative, not absolute, physiological mechanisms (Figure 3) (58). This model proposes that before and during exercise the brain

determines the metabolic cost of completing the activity taking into consideration current environmental conditions and present physical state of the individual performing exercise. These factors assist in implementing an optimum pacing strategy. Such a strategy allows completion of the exercise task most efficiently while maintaining internal homeostasis and protecting metabolic and physiological reserve capacity. Establishing the optimum pacing strategy to complete the exercise task can be facilitated by either an anticipatory practice trial or by providing pre-participation knowledge of performance duration. The use of a practice trial or knowledge of intended exercise duration allows the brain to set an endpoint of a specific task and gauge force produced (i.e. intensity) accordingly. This allows the individual to develop pacing strategies by creating an algorithm in the brain relevant to completion of a given task. This “algorithm” incorporates past experience with an exercise task, as well as the necessary time and associated effort needed to complete the task. It is theorized that the body has different algorithms for different exercise tasks. These algorithms may be based on duration of the activity. Depending on the metabolic cost to complete the exercise, different pacing strategies may be implemented. Therefore, it appears that knowledge of an exercise endpoint when provided in the form of expected performance time or distance to be traversed may act an important factor in regulating the metabolic activity of peripheral physiological systems as well as influencing perception of effort (57, 62). The present investigation anticipates a similar influence of the central feedback system with respect to muscle pain response during moderate intensity exercise. Knowledge of exercise duration may be a key component in an individual’s subconscious expectation of how difficult the exercise is. Therefore, the information directly contributes to the conscious perception of pain response before, during and following the exercise task.

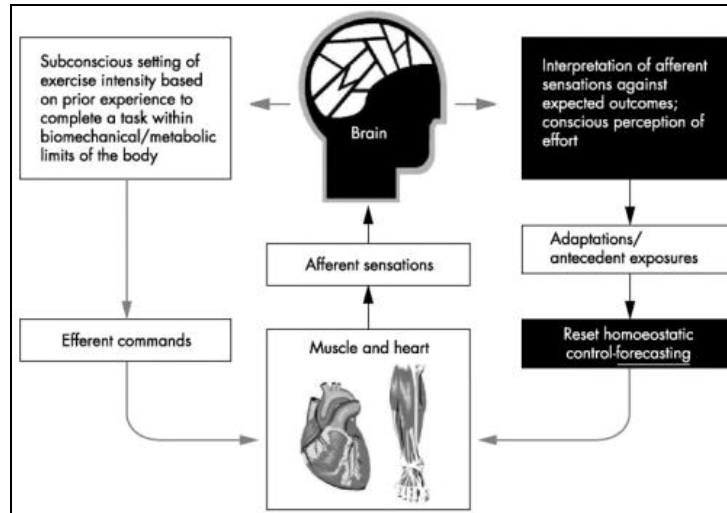


**Figure 3. Feedback control (Right) and Integral control system (Left)**

From Lambert EV, St. Clair Gibson A, Noakes TD. Complex systems model of fatigue: integrative homeostatic control of peripheral physiological systems during exercise in humans. *British Journal of Sports Medicine* 2005;39:54 (33). Reproduced from Ulmer (62).

### 2.2.2 Challenges to the central governor theory

It has been argued that a central (“brain”) governor is responsible for an individual’s ability to perform at a certain intensity or the ability to complete the duration of a specified exercise task. This theory predicts that with information provided about the impending exercise task, individuals subconsciously set physiological system limits necessary to complete the exercise. A central governor allows a level of performance that maintains homeostasis, prevents tissue damage, and helps preserve a metabolic reserve capacity (Figure 4) (58).



**Figure 4. Central governing response**

From Lambert EV, St. Clair Gibson A, Noakes TD. Complex systems model of fatigue: integrative homeostatic control of peripheral physiological systems during exercise in humans. *British Journal of Sports Medicine* 2005;39:54 (33).

Recent reports challenge the central governor theory, stating there are too many flaws in the correlates measured that shape the concept. As an example, the correlates examined only included controller limits to working muscles, did not observe a plateau in oxygen consumption is seen, attained less than maximal EMG activity at peak effort, and demonstrated an absence of a ceiling value in cardiac output. These limitations question whether a central controller regulates correlates of exercise performance. As such, it is not clear whether central brain function is regulated to maintain homeostasis and prevent tissue damage during exercise. In addition, the central governor model could be influenced by such factors as physical fitness level, personal motivation, external verbal motivation/encouragement, environmental factors, or onset of mental fatigue (55). These are all plausible factors underlying termination of exercise or choice of performance intensity. Specifically, strong associations between mental fatigue and brain activity have been linked to decreased cognitive function which effects information processing. This may also be relevant in an activity such as exercise, where perceived exertion

or muscle pain response derives from physiological and metabolic demand placed on the body. Demand on the physical body can lead to onset of mental fatigue or other factors leading to exercise termination (18).

There are many arguments both supportive and contradictory regarding the central governor model. However, little research thus far has examined the role of the central governor model in explaining the possible effect of knowledge of exercise duration on pain responses during exercise. The findings of the present investigation may provide insight on the effect of knowledge of exercise duration on leg muscle pain responses and associated physiological mediators during cycle ergometry.

### **2.2.3 Pre-participation/Anticipatory trial**

Teleoanticipation has been used to enhance athletic performance, relying on prior experience as a preparatory reference point to establish optimal pace. This prior experience may serve as practice or a calibration in preparation to perform a subsequent exercise task. Due to this preparatory experience, individuals are able to develop pacing strategies appropriate to completing the exercise task, and doing so efficiently. Foster et al. (26) demonstrated teleoanticipation effectiveness in competitors performing successive cycling tours. Subjects completed two, three-week cycle tours, one per racing season in consecutive seasons. Although specific courses and tours varied between the two years, general format of the tours including number of stages, total distance and number of rest days within each tour were similar. Baseline assessment identified heart rate associated with three metabolic zones corresponding to effort below the ventilatory threshold (VT1) (zone 1, low intensity – less than 70%  $\text{VO}_{2\text{max}}$ ), between VT1 and the respiratory compensation threshold (VT2) (zone 2, medium intensity – between 70

and 90%  $\text{VO}_{2\text{max}}$ ), and above VT2 (zone 3, high intensity – above 90%  $\text{VO}_{2\text{max}}$ ). During the tours, heart rates were used to calculate a training impulse score that estimated energy expenditure according to the individual's intensity zone. Day-by-day and week-by-week comparisons of heart rate impulse score were made between the tours for each subject. Results showed similar training impulse scores between the two tours, suggesting similar pacing strategies were employed during competitions up to three weeks in duration. The study concluded that highly-trained individuals are able to accurately monitor their metabolic energy reserves and adjust their performance strategy throughout the competition to optimize overall performance. This suggests that athletes are able to regulate their energy expenditure on the basis of both previous experience with the activity and sensory feedback developed throughout an event, supporting the regulatory effects of teleoanticipation (26).

#### **2.2.4 Knowledge of exercise duration – Open vs. Closed Loop**

Pre-participation knowledge of duration may be a key factor in regulating exercise perceptions. Closed loop activity is defined as a performance in which knowledge of distance or performance time is presented before initiation of the exercise (62). This information allows the individual to prepare for the exercise task at hand by gauging intensity and strategizing the most effective way to complete the task without depleting the body's energy sources or causing damage to any bodily systems. In open loop physical activity, knowledge of either distance or time is unknown beforehand making it difficult to adequately prepare for the task at hand (62). In this case, individuals are unable to properly prepare performance strategies, leading to inaccurate predictions of the intensity or effort that are required to complete the task at approximately the same times as energy reserves are depleted. The inaccurate predictions may lead to premature

termination before completing the exercise task. These unknowns regarding distance and/or time of the exercise task to be performed may also lead to future mismatches in predicted and actual perceptual responses (i.e. perceived exertion, muscle pain). Mismatches between predicted and actual perceptual responses have been shown previously to cause negative behaviors associated with adoption and adherence to exercise (7, 16, 38). A mismatch is indicated by a lower predicted response than actual response, or visa versa. A match in predicted and actual response that is somewhat incongruent with the exercise intensity can also be problematic. A match-mismatch model has been developed to examine such instances and to explain this phenomenon. This match-mismatch model will be explained in greater detail later in the chapter. The present investigation will examine the match or mismatch patterns of predicted and actual muscle pain responses when knowledge of exercise duration is manipulated. The present investigation intends to examine closed loop teleoanticipation activity by providing an individual with knowledge (true and false) of exercise duration (i.e. time) prior to performance. This closed loop paradigm will be used to determine the effect of pre-participation knowledge of exercise time on predicted and actual ratings of leg muscle pain, as well as on session leg muscle pain ratings. Pre-participation knowledge of exercise duration will be manipulated during exercise trials of the same duration and relative metabolic rate.

### **2.2.5 Knowledge of exercise duration as a teleoanticipation construct**

Previous investigations have used deception paradigms to determine the extent to which central neural factors influence an individual's exercise pacing strategy. One investigation examined the influence of pre-participation knowledge of performance duration using supramaximal exercise. Eight healthy males performed a series of Wingate Anaerobic Power Tests consisting of two 30

second bouts, two 33 second bouts, and two 36 second bouts. Each subject was told they would perform four 30 second bouts, one 33 second bout, and one 36 second bout. Results showed that individuals were able to perform at a higher power output during the 36 second *informed* trial when compared to the 36 second *deception* trial in which they were told they were only exercising for 30 seconds. In the *deception* trial, there was a significant decrease in power output. It was concluded that providing accurate information about high intensity exercise performance time as compared to inaccurate presentation of performance time resulted in the individual decreasing the pace to a more optimal intensity. This decrease may be linked to the theory that pacing strategy based on pre-programming exercise endpoints is a beneficial closed loop preparatory procedure. Such a pacing strategy suggests central regulation (3).

The effect of altering knowledge of expected performance duration on exercise pacing strategies has also been examined for comparatively longer durations and with well-trained individuals. Fifteen well-trained male cyclists were told they would perform four, 20 kilometer cycling time trials in which distance feedback (distance covered) would be provided every kilometer. During the initial 20 kilometer trial accurate feedback was provided every kilometer. Three additional 20 kilometer trials were performed. In these three trials, inaccurate feedback regarding performance distance was provided using the following format: increase in split time (every 1.25 kilometers), decrease in split time (every 0.775 kilometers), or random feedback (both increased and decreased split times). Although feedback regarding distance was manipulated, at each time point the individuals were told they completed another one kilometer. During the three experimental trials, distance feedback was given 25 meters before or after the actual kilometer mark, ultimately adding 25 meters to each of the deceptive trials. Results indicated no difference in time to complete all four 20 kilometer trials. No difference was found



in power output which was recorded each minute and averaged for an overall value as well as for the first and second 10 kilometers. Ratings of perceived exertion were also not found to be different between trials. This investigation found that providing incorrect distance feedback did not produce a change in exercise performance time or RPE. The investigation concluded that pacing strategy is determined prior to exercise and external distance feedback provided during the trial was not a factor (1).

Another paradigm to manipulate knowledge of exercise duration has recently been employed using the estimated time limit (ETL). Individuals were asked to rate not only their momentary RPE, but also how long they anticipated they could maintain the expected intensity before reaching exhaustion. Subjects performed 4 sessions of running on an outdoor track. Individuals first performed a maximal aerobic velocity (MAV) test to determine their running speed at maximal oxygen uptake. During the second session, subjects performed a constant velocity test at 90% MAV to determine their time limit (Tlim) and distance limit (Dlim) for this relative velocity. Subjects were then assigned in counterbalanced order to one of three groups and performed a test the length of which was 80% time limit and a test which was 80% distance limit. Both tests were performed at an intensity of 90% MAV. One group received accurate knowledge of exercise time and duration regarding performance of the 80% Tlim and Dlim, while the other two groups were deceived. The deception groups were told they were performing for 60% Tlim and Dlim or 100% Tlim and Dlim, but actually all performed the 80% Tlim and Dlim. Ratings of perceived exertion and estimated time limit values were recorded throughout the tests. Results indicated that while RPE and ETL values increased as a function of exercise duration, the instructions regarding knowledge of exercise duration or time did not

influence RPE or estimated time limit reports (21). Comparable results were reported by a similar study using 40%, 60%, and 80% Tlim (20).

Knowledge of duration did, however, cause a change in RPE in other investigations where a deception paradigm was employed. Rejeski and Ribisl (52) determined that individuals reported a lower RPE during a deception trial when told the expected duration was longer (i.e. 30 minutes) than the actual duration (i.e. 20 minutes) during treadmill exercise at 85%  $\text{VO}_{2\text{max}}$ . Each individual performed two trials. During the first trial, accurate knowledge of duration was provided. The second trial was of identical duration and intensity however, knowledge of duration was manipulated. It was determined that manipulation of knowledge of exercise duration resulted in a lower RPE response when the subjects expected a longer duration (52).

In a more recent investigation, Baden et al. (10) had subjects perform three separate 20 minute exercise bouts at 75% of their peak treadmill running speed. Trials were completed in a randomized order as follows: an informed 20 minute run, an informed 10 minute run followed by an unexpected additional 10 minutes of running, and a 20 minute run in which the duration of the bout was unknown to the subject. A significant increase in RPE was seen between minute 10 and 11 of the trial that involved the informed 10 minutes accompanied by the unexpected additional 10 minutes of running. This increase was not seen in either of the other two trials, i.e. the informed 20 minute or unknown 20 minute protocol. The increase in RPE during the transition from the informed 10 minute run to the unexpected additional 10 minutes at a constant speed suggests that perceived exertion was not solely a measure of physical strain. Other factors may have influenced the change in perception of exertion. This conclusion was reinforced in part by the association of perceived exertion response with affect scores throughout exercise. The affect scores decreased significantly as exercise duration progressed in the informed 10

minute trial followed by an additional 10 minutes trial. A decrease in “pleasantness” of the activity was reported between minutes 10 and 11 during the informed 10 minute trial followed by an unexpected additional 10 minutes of running. This decrease was not reported in the informed 20 minute trial. The investigation concluded that the presence and absence of correct or incorrect knowledge of duration had an impact on psychophysical responses during exercise (10).

Findings regarding the effect of knowledge of duration on selected performance outcomes are conflicting, especially when the experimental design employed a manipulation paradigm. While the use of inaccurate feedback is a methodological constant in all previous investigations, there are reported differences in duration (i.e. supramaximal vs. continuous submaximal) and modes of exercise (cycle vs. treadmill) (1, 3, 10, 52). These differences make it difficult to draw concrete conclusions regarding the effects of manipulating what individuals are told about the duration of exercise they are performing. In addition, no study to date has investigated the effects of knowledge of duration on exercise-induced muscle pain response.

## **2.3 MATCH-MISMATCH MODEL**

A sensory match or mismatch relates a feeling or mood response that influences expectation of an upcoming task. A sensory match is achieved when predicted sensation is the same as the sensation actually experienced. A mismatch is evident when a predicted sensation is either greater than or less than the sensation actually reported. Expectation, either positive or negative, related to the task provides a feeling or mood response which influences performance. For example, if an individual is nervous or anxious about an upcoming task, mood response

heightens to anticipate a certain task which can contribute to either a positive or negative performance outcome. In a mismatch scenario, an individual begins the actual task with a certain expectation that may or may not meet actual expectation. A sensory match would result from a correct expectation and acceptance of an upcoming task. An inaccurate match can be made by both expecting and accepting a positive effect to a negative stimulus or a negative effect to a positive stimulus. A mismatch would result from an incorrect expectation, positive or negative, to an upcoming task. In this case, steps toward expecting and accepting correct responses to a given task should be made. Such steps may involve repeated exposures to the task to familiarize an individual with accurate expectations.

A match-mismatch model has been developed to describe differences in *predicted* and *actual* responses related to anxiety and panic (45, 47, 49, 50). A *predicted* response is an anticipatory measure of intensity (i.e. level of anxiety/panic, perceived exertion, pain) the subject expects to experience during a given task. As an example, a *predicted* pain rating is provided by the subject immediately prior to the task. *Actual* responses are momentary measures of the pain intensity the subject experiences at specific time points throughout a given task. Therefore, the *actual* rating is measured at specific time points during the task. An extension of the match-mismatch model proposes that inaccuracy in predicting pain intensity prior to undertaking a specific exercise is related to inappropriately high expectations of the aversiveness of the upcoming experience (45). The pain an individual associates with a future experience will directly produce an inappropriate or inaccurate perceptual prediction (45).

Rachman and Lopatka (48) have specified three types of pain prediction: 1) underprediction, in which the intensity of future pain is underestimated, 2) overprediction, in which the impending pain is overestimated, and 3) accurate prediction. The first two types

represent a perceptual mismatch where the third is a perceptual match. First, applying these distinctions to anxiety disorders, it was reported that phobics who underpredict the aversiveness of a feared event tend to raise their expectations of the aversiveness of the next event. Those who overpredict aversiveness tend to lower their performance expectations of the next event. Finally, those with accurate expectations tend to maintain their accuracy throughout exposure to the actual event (45). The match-mismatch model regarding pain has led to the formulation of the following hypotheses: a) underpredictions will be followed by increases in *predicted* pain, b) overpredictions will be followed by decreases in *predicted* pain, c) overprediction will be followed by decreases in reported (*actual*) pain, d) *predicted* pain will not change after a correct match, e) reported (*actual*) pain will decrease over trials regardless of the occurrence of correct or incorrect matches, and f) accuracy of prediction of pain will increase with practice (49, 50). Many of these hypotheses have been tested to determine the generalizability of the model. These investigations confirmed each hypothesis with the exception of overpredictions being followed by a decrease in reported (*actual*) pain (6).

Underestimations of pain predictions associated with a given stimulus have led to long-term negative effects regarding fear of subsequent pain experiences. Such mismatch responsiveness leads to negative effects on future pain predictions (6). Following underestimations of pain predictions, individuals tend to sustain inaccurately high predictions for subsequent trials (5). Previous investigations have found that in many instances pain intensity was underpredicted relative to unexpectedly stronger pain actually experienced (5, 6, 8, 9). This underprediction led to an increase in pain predictions for subsequent trials, followed by a slow decrease in predictions of pain intensity. This pattern typically led to developing fear of the painful stimulus and ultimately triggered an escape from the underpredicted aversive event (5, 6,

8, 9). These findings can be explored in an exercise context. Individuals may terminate an activity that is interpreted as a noxious experience more abruptly after being exposed to an exercise bout, the intensity of which was unknown. The initial underpredictions associated with exercise of an unknown intensity may lead to avoidance behavior involving subsequent trials. The lack of uncertainty associated with the expectation of the task is a major contributor to the continued mismatch between *predicted* and *actual* responses (6). Therefore, it has been determined that unpredictable pain intensity has a negative effect on the ability to tolerate pain. Individuals are better able to tolerate more pain if the intensity of the pain stimulus is predictable and where expectation is accurate (9).

Previous research has examined the influence of expectation of task duration on subsequent performance. These research findings have associated more efficient muscular activity in static work with long task durations. The mechanism underlying this response was thought to involve less force production and maintenance of this force through a longer duration (63). Similar responses have been found with respect to fatigue experienced during a given task. Fatigue is associated with an unpleasantness that does not subside until the task is complete. When individuals are presented with a task and provided with information to complete the task (i.e. length/duration of the task), they are able to defer the unpleasant feelings by cognitively manipulating those feelings. This allows the individual to attempt to suppress those negative feelings completely or to postpone cognitive appraisal until later in the task when they are closer to completion (64). Otherwise, if feelings of unpleasantness take precedence before or immediately upon beginning the task, it will be more difficult to sustain exercise intensity and complete the task, likely leading to comparatively earlier termination. By expecting a certain level of unpleasantness and avoiding those feelings as much as possible, individuals can usually

succeed in completing their task with less discomfort. Matching expectations of an upcoming exercise task with accurate *predicted* and *actual* responses (i.e. acceptance of the relative intensity) may be achieved through subsequent experiences (i.e. teleoanticipatory trial) that may correct the underprediction. It has been shown that with practice, predictions of pain intensity may become more accurate and certainty of these predictions increases (5).

The above described experiments did not involve pain predictions and *actual* responses during exercise; they were performed using electrical stimulation with the individual in a resting state. Nevertheless, these previously reported responses may be similar to those experienced during exercise where the dependent sensory measure is muscle pain. The present investigation seeks to determine the effect of providing knowledge of exercise duration on *predicted* and *actual* pain responses during prolonged exercise. It is proposed that providing such knowledge prior to an exercise trial may effect *actual* pain responses in a positive manner. Such an effect can provide insight as to whether knowledge of duration is a key component of individuals' pain perceptions when assessed prior to and during an exercise trial. As an example, knowledge of a longer exercise duration may lead to increased pain predictions and therefore, contribute to avoidance behaviors commonly seen as a barrier to physical activity adherence.

## **2.4 SUMMARY**

Perceptual responses relating to exercise performance are crucial components in understanding how individuals interpret exercise intensity. Much is known regarding perceived exertion, however less is known regarding measures of naturally-occurring muscle pain responses related to exercise. Expectation of the exercise intensity initiates a subconscious reference to allow an

individual to prepare for successful completion of the exercise task. Using this reference point, the individual develops perceptual predictions for their upcoming performance. During exercise, individuals make conscious adjustments to their performance based on their actual perceptions of exercise intensity. Teleoanticipation is the specific process of using these feedforward and feedback systems to complete an exercise task. A component of teleoanticipation that will be the focus of the present investigation is pre-performance knowledge of exercise duration. The present investigation determined if knowledge of exercise duration prior to performance affects *predicted* and *actual* leg muscle pain responses reported by recreationally active females and males during prolonged cycle exercise.

Little is known regarding the application of session pain ratings reported following exercise. The effect of knowledge of exercise duration provided before an exercise task on session ratings of pain has not been examined. The present investigation sought to determine if knowledge of exercise duration prior to exercise effects *session* pain responses reported by recreationally active females and males when the measures are reported 10 minutes following prolonged cycle exercise. Examining *session* pain responses may determine whether pre-participation information influences pain responses reported following exercise that reflect the entire global experience during exercise. Such findings could expand the uses of *session* pain responses in wellness and competitive settings.



### **3.0 METHODS**

#### **3.1 SUBJECTS**

Seventy-two recreationally active female (N=36) and male (N=36) volunteers 18-30 years of age participated in this investigation. The characteristics of the female and male subjects are listed in Table 1 and Table 2, respectively. These tables present descriptive characteristics of female and male subject groups that were assigned to the experimental conditions. Groups are abbreviated as follows and will be referred to using these symbols in all tables presented throughout this section: ACC-20: knowledge of accurate duration – 20 minutes, LONG-30: knowledge of a longer duration – 30 minutes, and SHORT-10: knowledge of a shorter duration – 10 minutes. A one-factor analysis of variance (ANOVA) was performed for each subject characteristic within sex groups to determine if differences existed between experimental conditions. A summary of the ANOVA for female and male subject characteristics are reported in Appendix H. ANOVA indicated no significant differences in age, weight (wt), body mass index (BMI), body fat, and peak oxygen consumption ( $VO_{2peak}$ ) between the experimental conditions for the female sample ( $p > 0.05$ ). ANOVA did indicate that the female subjects in the SHORT-10 condition were greater in height (ht) when compared to both the ACC-20 and LONG-30 condition ( $p < 0.05$ ). In the male group, no significant differences were seen in any of the descriptive subject characteristics between the three experimental conditions ( $p > 0.05$ ).

**Table 1. Descriptive Characteristics of the Female Sample**

Condition	N	Age (yrs)	Ht (cm)	Wt (kg)	BMI (kg/m <sup>2</sup> )	Body Fat (%)	VO <sub>2peak</sub> (l/min)	VO <sub>2peak</sub> (ml/kg/min)
<b>ACC-20</b>	12	20.8 ± 3.3	162 ± 3.5	64.4 ± 9.5	24.6 ± 3.4	26.4 ± 6.9	2.01 ± 0.26	31.7 ± 5.1
<b>LONG-30</b>	12	21.1 ± 2.1	162 ± 4.4	60.5 ± 9.0	23.1 ± 2.4	25.1 ± 5.9	2.00 ± 0.29	33.4 ± 5.0
<b>SHORT-10</b>	12	21.1 ± 2.2	166 ± 5.7*	60.9 ± 9.8	21.9 ± 2.6	23.4 ± 7.4	2.19 ± 0.27	36.4 ± 4.9

\* Different compared to both ACC-20 and LONG-30 (p < 0.05)

Data are Mean ± Standard Deviation.

**ACC-20:** knowledge of accurate duration – 20 minutes

**Ht:** height    **Wt:** weight

**LONG-30:** knowledge of a longer duration – 30 minutes

**BMI:** body mass index

**SHORT-10:** knowledge of a shorter duration – 10 minutes

**VO<sub>2peak</sub>:** peak oxygen consumption

**Table 2. Descriptive Characteristics of the Male Sample**

Condition	N	Age (yrs)	Ht (cm)	Wt (kg)	BMI (kg/m <sup>2</sup> )	Body Fat (%)	VO <sub>2peak</sub> (l/min)	VO <sub>2peak</sub> (ml/kg/min)
<b>ACC-20</b>	12	20.3 ± 1.7	179 ± 8.2	79.0 ± 12.0	24.4 ± 2.9	13.5 ± 4.2	3.27 ± 0.65	41.5 ± 5.7
<b>LONG-30</b>	12	21.4 ± 3.3	177 ± 6.9	78.0 ± 12.5	24.9 ± 3.8	15.4 ± 6.7	2.83 ± 0.44	36.8 ± 6.0
<b>SHORT-10</b>	12	20.6 ± 1.1	172 ± 12.3	80.1 ± 12.0	26.3 ± 3.7	17.9 ± 7.0	2.91 ± 0.63	36.2 ± 5.6

Data are Mean ± Standard Deviation.

Subjects were free of musculoskeletal limitations to exercise and of diagnosed cardiovascular and metabolic disease. Subjects were classified as recreationally active. For purposes of this investigation recreationally active was defined as participation in aerobic activity of at least 20 minutes two times per week with a weekly total of no more than 150 minutes, and no participation in athletic competition in the past 6 months. In particular, participation in cycling/spinning exercise was limited to no more than 30 minutes per week including cycling as a mode of transportation, i.e. commuting to/from work/school.

Each subject signed an informed consent prior to participation, as well as completed the Medical History Form, and a Physical Activity Readiness Questionnaire (PAR-Q). Subjects were excluded from participation based on the following criteria:

1. Answering yes to one or more of the questions on the PAR-Q (unless physician clearance is provided).

2. Having a BMI  $\geq 30$  kg/m<sup>2</sup>.
3. Participating in aerobic training, (a) less than 20 minutes two times per week, (b) more than 150 minutes per week, and/or (c) currently participating in collegiate/professional athletics.
4. Performing more than 30 minutes of cycle/spinning exercise per week.
5. Female subjects who are currently pregnant.
6. Having implantable devices such as a pacemaker or automatic cardioverter defibrillator (AICD).
7. Presenting with orthopedic (acute or chronic musculoskeletal injury), cardiovascular (coronary artery disease), respiratory (chronic obstructive pulmonary disease or asthma), and/or metabolic conditions (diabetes) that would place them in the “high risk” stratification for non-physician supervised exercise testing according to the American College of Sports Medicine.
8. Are current smokers, defined as someone who continues to smoke or has quit less than six months ago.

Subjects were recruited from the University of Pittsburgh’s Oakland campus. Subject recruitment was undertaken using flyers posted throughout campus and distributed to basic instruction classes (soccer, volleyball, swimming, personal fitness, aerobics, yoga and weight training). The recruitment flyer listed initial inclusion criteria such as age and physical activity status (Appendix A). Interested subjects were asked to respond via phone or e-mail and subsequently scheduled for an appointment at the Human Energy Research Laboratory (HERL) to complete the subject recruitment packet consisting of the informed consent, Medical History Form, and PAR-Q (Appendix B). The Medical History Form documented the subject's current and past record of serious or unstable medical illness, surgeries and hospitalizations, orthopedic limitations, metabolic, respiratory, or cardiovascular conditions, and medication usage. The PAR-Q determined if the subject is clinically capable of performing physical activity and identify those for whom physical activity may be inappropriate. The PAR-Q included seven

questions that inquire about an individual's current health status as it relates to physical activity/exercise. Subjects agreeing to participate in the study and meeting all of the study entrance criteria had anthropometric measurements taken and performed a baseline graded exercise test on the day of their initial appointment. All experimental procedures were approved by the University of Pittsburgh's Institutional Review Board for human subject experimentation.

### **3.2 EXPERIMENTAL DESIGN**

A between-subjects, single-blind controlled experimental design was employed (Appendix C). Each subject performed one baseline graded exercise test (GXT) and one isotime sub-maximal cycle trial. Pre-participation knowledge of exercise duration was provided to each subject under one of the three possible conditions. Assignment to one of the three knowledge of exercise duration conditions was counterbalanced across subjects and within sex grouping. The term isotime means that the sub-maximal cycle exercise trial that is used in each of the three conditions will be the same duration (i.e. 20 minutes). The isotime cycle trial was performed at an exercise intensity equivalent to 70% of each subject's individually determined  $VO_{2peak}$ . Prior to the isotime cycle trial, each subject was randomly assigned to one of three experimental conditions. Based on the assignment, the subject was told by the principal investigator that they would be exercising for one of the following durations: a 20 minute exercise trial (Accurate Duration; ACC-20), a 30 minute exercise trial (Long Duration; LONG-30), or a 10 minute exercise trial (Short Duration; SHORT-10). Each subject performed only one of the experimental conditions. An equal number of males and females were assigned to each condition. The subject was not aware of the *actual* exercise time (i.e. 20 minutes) that would be

performed. Only the primary investigator administering the isotime cycle trials and staff assisting with data recording during the isotime trials were aware of the pre-trial information provided to the subject regarding exercise duration.

### **3.3 EXPERIMENTAL VARIABLES**

#### **3.3.1 Independent variable**

Pre-performance knowledge of exercise duration was manipulated for each isotime cycle trial to determine its effect on *predicted*, *actual*, and *session* ratings of leg muscle pain.

#### **3.3.2 Dependent variables**

*Predicted*, *actual*, and *session* leg (quadriceps) muscle pain intensity was recorded during the isotime cycle trial.

The *predicted* pain rating is an anticipatory measure of pain intensity that the subject expects to experience during an exercise trial. The *predicted* pain rating was provided by the subject immediately prior to undertaking the isotime cycle trial. The *actual* pain rating is a momentary measure of the pain intensity that the subject experiences at specific time points throughout the exercise trial. The *actual* pain rating was measured every two minutes during the isotime cycle trial. The *session* pain rating is a global assessment of the pain intensity that the subject experienced throughout the entire exercise trial. The *session* pain rating was measured 10 minutes after completion of the isotime cycle trial.

## **3.4 ASSESSMENT**

### **3.4.1 Pre-test instructions**

Subjects were instructed to wear loose fitting clothing (i.e. shorts and t-shirt), and running shoes, and to report to the HERL in a 3 hour postprandial state. To favor euhydration, subjects were instructed to drink approximately 500 ml of water 30 to 60 minutes prior to their testing sessions. Subjects were instructed not to consume caffeine or alcohol during the 24 hour period preceding the baseline GXT and the isotime cycle trial. In addition, subjects were asked to abstain from their regular exercise routine on the days of the GXT and isotime cycle trial. Subjects were also instructed to refrain from intense strenuous exercise for 24 hours preceding the GXT and isotime cycle trial. Between the GXT and isotime cycle trial, subjects were asked to refrain from heavy cycling exercise and heavy leg resistance training.

The GXT and the subsequent isotime cycle trial were conducted at the same time of day for a given subject. All standardized instructions for the exercise trials can be found in Appendix D. Subjects were tested individually with only one subject in the laboratory at any given time. Therefore, it was expected that subjects would have no contact with one another during the experiment. All baseline GXTs and isotime cycle trials were conducted in the HERL where ambient temperature ranged from 70°F to 74°F (21°C to 23°C) and percent humidity was less than 60%.

### **3.4.2 Body weight and height**

Body weight in kilograms (kg) and height in centimeters (cm) was determined using a Detecto-Medic Scale and attached standiometer (Detecto Scales Inc., New York). Subjects were weighed without their shoes and wearing shorts and a t-shirt.

### **3.4.3 Body composition**

Body fat and BMI was determined using a Tanita body fat analyzer (Tanita Corporation of America, Inc. Skokie, IL.). Subjects were instructed to remove their shoes and socks and to stand on the foot sensors with their bare feet until a body fat reading registered on the visual display. The subject's height, age, and sex were entered into the Tanita analyzer. The "standard" mode for calculating body fat was used for all subjects.

### **3.4.4 Baseline Graded Exercise Test**

The subject initially performed a GXT to peak intensity. This test was used to determine  $\text{VO}_{2\text{peak}}$ . In addition, the  $\text{VO}_2$  responses to each test stage were used to identify the power output (PO), in Watts (W), equivalent to 70%  $\text{VO}_{2\text{peak}}$  that would be performed during the isotime cycle trial. The GXT was also used to familiarize the subject with the pain assessment scale that was employed during exercise testing. The cycle ergometer GXT protocol increased in PO every two minutes until termination at peak intensity (Table 1). The cycle ergometer protocol has been standardized for use with the subject sample to be studied. The GXT was performed on a Lode cycle ergometer (Lode Corival Model 844, Groningen, Netherlands). An open circuit

respiratory-metabolic system (Parvo Medics, Salt Lake City, Utah) was used to measure:  $\text{VO}_2$ , ( $\text{L}\cdot\text{min}^{-1}$  and  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ); pulmonary ventilation ( $\text{V}_E$ ,  $\text{L}\cdot\text{min}^{-1}$ ); and respiratory exchange ratio (RER) in thirty second intervals. A standard respiratory valve (Rudolph, Model 2700, Kansas City, MO) with an adult mouthpiece was used for all respiratory-metabolic measurements. The respiratory-metabolic system was calibrated before each exercise trial. Heart rate ( $\text{b}\cdot\text{min}^{-1}$ ) was measured every minute throughout the graded exercise test and the isotime cycle trial using a wireless Polar Monitoring System (Woodbury, NJ). A Polar transmitter strap was fitted to the subject's chest, just below the pectoralis major muscles. A Polar wrist monitor was attached to the cycle to display the HR values.

**Table 3. Graded Cycle Ergometer Protocol**

		<b>Males</b>	<b>Females</b>
<b>Stage</b>	<b>Time (min)</b>	<b>PO (W)</b>	<b>PO (W)</b>
1	2	75	50
2	2	125	75
3	2	175	100
4	2	225	125
5	2	275	150
6	2	325	175
7	2	375	200
8	2	425	225

**Min:** minutes

**PO:** power output

**W:** watts

Subjects were instructed to maintain a pedal cadence of 50 revolution per minute ( $\text{rev}\cdot\text{min}^{-1}$ ), signaled by an electronic metronome, throughout the protocol. The actual pedal cadence was also visible to the subject on the cycle speedometer display unit. Test termination included: a) volitional cessation of exercise due to fatigue, b) the subject's inability to maintain a  $50 \text{ rev}\cdot\text{min}^{-1}$  pedal cadence for 10 consecutive seconds, or c) for any other reason determined by the subject. To ensure a physiologically valid  $\text{VO}_{2\text{peak}}$  was been obtained, at least one of the



following criteria was required: (a) a change of  $150 \text{ ml} \cdot \text{min}^{-1}$  in  $\text{VO}_2$  between contiguous stages at peak exercise intensity; (b) attainment of  $\pm 5 \text{ b} \cdot \text{min}^{-1}$  of the age-predicted maximal HR, or (c) an  $\text{RER} \geq 1.1$ . Oxygen uptake was recorded from :30 to :60 of each minute during the GXT. Heart rate was recorded during the last five seconds of each minute. During the last 15 seconds of each exercise minute the subjects were asked to rate their leg muscle pain (RMP-Legs) using the Cook Pain Intensity Scale (Appendix E; 17). Immediately following test termination, subjects were instructed to complete a two minute active cool-down period of pedaling at 0W.

Prior to the GXT, the subjects received standard instructions for rating leg muscle pain. These instructions included a definition of exercise-induced leg muscle pain, procedures to rate leg pain using a category scale, and an explanation of the low and high scale anchor points (17). Subjects were also given instructions for the cycle ergometer testing procedures. During the orientation, the Cook Pain Intensity Scale was placed directly in front of the subject as the instructions were being read. In addition, the scale was placed in direct view of the subject during the actual test. Subjects was first read the following definition of leg muscle pain:

*“Leg muscle pain is defined as the intensity of the pain you feel in your upper front leg (quadriceps) muscles of both legs during cycle exercise.”*

Subjects were then read the following instructions for use of the Cook Pain Intensity Scale (adapted; 41):

*“The scale before you contains the numbers 0 to 10. You will use this scale to assess the intensity of pain in the upper front leg (quadriceps) muscles of both legs during the exercise test. For this task, you are asked to rate the intensity of pain that you feel in your leg (quadriceps) muscles only. Don't underestimate or overestimate the degree of pain you feel, just try to estimate it as honestly and objectively as possible. The numbers on the scale represent a range of pain intensity from very faint pain (number 0.5) to extremely intense pain-almost unbearable (number 10). When you feel no pain in your leg (quadriceps) muscles, you should respond with the number zero. When the pain in your legs*

*(quadriceps) becomes just noticeable, you should respond with the number 0.5. If your leg (quadriceps) muscle pain feels extremely strong such that it is almost unbearable, you should respond with the number 10. You can also respond with numbers greater than 10. If the pain is greater than 10, respond with the number that represents the pain intensity you feel in relation to 10. In other words, if the pain is twice as great then respond with the number 20. Repeatedly during the test, you will be asked to rate the feelings of pain in your leg (quadriceps) muscles. When rating these pain sensations, be sure to attend only to the specific sensations in your leg (quadriceps) muscles and not report other pain you may be feeling (e.g., seat discomfort). It is very important that your ratings of pain intensity reflect only the degree of pain you are feeling in the quadriceps muscles of both legs. Do not use your ratings as an expression of fatigue (i.e. inability of the muscle to produce force) or exertion (i.e. how much effort you are putting into performing the exercise).*

*Do you have any questions on how to use the scale?"*

Once pain scaling procedures were complete, directions specific to the GXT were read to the subject :

*"Today we ask you to rate the intensity of any leg muscle pain that you feel in both legs during a maximal cycle exercise test. Please rate only the pain intensity that you feel in your upper front leg (quadriceps) muscles of both legs.*

*You will ride on the cycle for as long as you can. Every two minutes the resistance on the cycle will increase. Please maintain a pedal rate of 50 rev•min<sup>-1</sup> throughout the test. Use the signal of the metronome and the speedometer display to help keep the proper rate. At the end of each minute we will ask you to rate your feelings of leg muscle pain in both legs. Please point to the number on the scale that represents the intensity of pain in your upper front leg (quadriceps) muscles of both legs. Please give a maximal effort at the end of the test. When you cannot continue or cannot maintain the proper pedal rate for 10 consecutive seconds, the test will be ended.*

*Do you have any questions?"*

Once GXT instructions were read to the subject, pre-exercise pain predictions were measured:

*"How much leg (quadriceps) muscle pain in both legs do you anticipate experiencing during the entire maximal cycle exercise test?"*

In response to the prediction question, if a subject asked about the intensity of the exercise to be performed, the investigator responded with the following:

*“Rather than be concerned with the test intensity, we would like you to concentrate on test duration only.”*

During the GXT, subjects were asked to report their momentary pain response during the last 15 seconds of each minute:

*“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”*

Standard verbal encouragement (i.e. “good job, keep it up!”) were provided at the end of each test stage. Upon attainment of 85% of maximal heart rate, the standard verbal encouragement was provided ad libitum by the investigator to help achieve a maximal effort from the subject. Tests were conducted in a closed laboratory section, insuring that distractions were not present in the laboratory during the GXT. Following a two minute active cool-down at a PO of 0W, subjects were seated for eight minutes then asked to provide a session pain rating (a total of 10 minutes post-exercise):

*“How much leg (quadriceps) muscle pain in both legs did you actually experience during the entire maximal cycle exercise test?”*

### **3.4.5 Cook Pain Intensity Scale**

Leg muscle pain intensity ratings (RMP-Legs) were estimated using the Cook Pain Intensity Scale (17). The investigator asked each subject to give their pain rating using the numerical categories on the scale during the last 15 seconds of each minute. The pain scale was in the subject’s view at all times throughout the GXT and isotime cycle trial. Since the subjects were not able to speak clearly due to the position of the respiratory mouthpiece, they were instructed to point to the number on the scale to indicate the pain intensity in their leg muscles. To insure accuracy the investigator confirmed the pain rating by repeating it to the subject.

### 3.4.6 Isotime Cycle Trials

The isotime sub-maximal cycle trial was performed from 72 to 96 hours following the GXT. For the purpose of this investigation, the term *isotime* indicated that the sub-maximal cycle trial performed during each of the three experimental conditions would be the same exercise duration (i.e. 20 minutes) and required the subject to exercise at the same relative aerobic metabolic rate (i.e. 70%  $\text{VO}_{2\text{peak}}$ ). Prior to the isotime cycle trial, each subject was assigned to one of the three experimental conditions using a counterbalanced sequence. Each subject was told by the principal investigator that he/she would perform one of the following durations: a 20 minute exercise trial (ACC-20), a 30 minute exercise trial (LONG-30), or a 10 minute exercise trial (SHORT-10). The subject was not aware that all three possible isotime cycle trial conditions would actually be the same duration. The isotime cycle trial was performed on the same Lode cycle ergometer used during the GXT. Subjects were again instructed to maintain a pedal cadence of  $50 \text{ rev} \cdot \text{min}^{-1}$ , signaled by an electronic metronome, throughout the protocol. The actual pedal cadence was also visible to the subject on the cycle speedometer display unit. Exercise intensity was set at a cycle PO equivalent to 70%  $\text{VO}_{2\text{peak}}$  determined using each subject's  $\text{VO}_2$  responses to the GXT. In this procedure, regression analyses expressing  $\text{VO}_2$  as a function of PO was used to identify the target PO separately for each subject (Appendix F). This intensity has been shown to 1) evoke moderate intensity leg (quadriceps) muscle pain and 2) be sustainable for 20 minutes of sub-maximal cycle ergometer exercise (41). In addition, a relative metabolic rate equivalent to 70%  $\text{VO}_{2\text{peak}}$  is comparable to a typical exercise intensity prescribed to improve cardiorespiratory fitness.

Each subject performed a 20 minute isotime cycle trial after receiving one of the three knowledge of duration conditions. Prior to the isotime cycle trial, the subject were asked to rate

their current leg muscle pain. Subjects were asked to respond to a brief questionnaire regarding any leg muscle pain they may have been experiencing:

*“1. Are you currently experiencing any leg muscle pain? (If you answered no, go directly to question #2; if you answered yes, please answer the following before proceeding to question #2.)*

*If yes, is the muscle pain due to the previous exercise test?*

*If no, please specify what is the cause of your current leg muscle pain.*

*2. Using the scale below, please rate the intensity of any leg muscle pain you are experiencing. (Cook Pain Scale placed at the bottom of questionnaire)”*

If the subject rated any amount of leg muscle pain, the test was postponed until leg muscle pain was no longer evident. This was to ensure that leg muscle pain ratings provided on the day of testing were solely based on the effects of the experimental trial and not due to other factors (i.e. delayed muscle soreness, injury, accident). If the subject's rating indicated that no leg muscle pain was present in either leg, the exercise trial was administered according to the experimental protocol. The principal investigator re-oriented the subject to the Cook Pain Intensity Scale by reading the definition of leg muscle pain and instructions on how to use the scale. This orientation employed the same procedures as used previously during the GXT. Next, the subject was read instructions regarding the isotime cycle trial to be performed that day:

*“Today we ask you to rate your feelings of leg muscle pain during a 10/20/30\* minute cycle exercise trial. Remember, leg muscle pain is defined as the intensity of pain you feel in your upper front leg (quadriceps) muscles in both legs during cycle exercise. Please rate only the intensity of pain that you feel in the upper front leg (quadriceps) muscles of both your legs.*

*You will ride on the cycle ergometer for 10/20/30\* minutes. Please maintain a pedal rate of 50 rev•min<sup>-1</sup> throughout the exercise trial. Use the beat of the metronome and the speedometer display to help keep the proper pedal rate. You will be asked repeatedly to rate the pain you feel in your upper front leg (quadriceps) muscles of both legs. You will be given a brief warm-up before beginning your exercise trial.*

*Do you have any questions?”*

Once isotime cycle trial instructions were read to the subject, the pre-exercise pain predictions was obtained:

*“How much leg (quadriceps) muscle pain in both legs do you anticipate experiencing during the entire 10/20/30\* minute cycle exercise trial?”*

In response to the prediction question, if a subject asked about the intensity of the exercise to be performed, the investigator responded with the following:

*“Rather than be concerned with the test intensity, we would like you to concentrate on test duration only.”*

A two minute warm-up at 50W was given for females and at 75W for males. After the two minute warm-up, cycle break resistance was set at a PO that required 70% of  $\text{VO}_{2\text{peak}}$  determined separately for each subject and based on the GXT response. The subject then began the 20 minute exercise trial. No distractions were present in the laboratory during the isotime cycle trial.

Oxygen uptake was recorded from :30 to :60 of each minute. Heart rate was recorded the last 5 seconds of every two minute segment using a wireless Polar Monitoring System (Woodbury, NJ). Pain ratings were recorded the last 15 seconds of every two minute segment using the Cook Pain Intensity Scale. Every four minutes (@ 4:00, 8:00, 12:00, and 16:00) PO was adjusted by the investigator as needed to ensure the relative intensity was maintained at 70% of  $\text{VO}_{2\text{peak}}$ . If at any four minute checkpoint the subject exhibited a positive or negative drift in  $\text{VO}_2$  greater than  $150 \text{ ml} \cdot \text{min}^{-1}$ , PO was adjusted, in the appropriate direction (i.e. decreased or increased, respectively), by 25W for males and 13W for females to reestablish the target cycle intensity.

During the isotime cycle trial, subjects were asked every two minutes to report their momentary (actual) pain response:

*“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”*

Following termination of the isotime cycle trial, a two minute cool-down consisting of pedaling at 0W was performed. Subjects were then seated on a chair next to the cycle for eight minutes at which point (i.e. 10 minutes post-exercise) they provided a session pain rating in response to the following:

*“How much leg (quadriceps) muscle pain in both legs did you actually experience during the entire 10/20/30\* minute cycle exercise trial?”*

\* The pre-performance knowledge of duration condition that was assigned to that subject was used in the question, i.e. “10, 20, or 30 minute cycle exercise trial”.

In accordance with IRB policy pertaining to deception paradigms, once subject recruitment was complete and all data were collected, subjects were debriefed regarding actual exercise duration. This was done by personal letter from the principal investigator (Appendix G). Subjects were given the opportunity to contact the investigator if further explanation was desired.

### **3.5 STATISTICS**

Descriptive data for anthropometric (i.e. HT, WT, BMI, Body Fat) and physiological variables (i.e.  $\text{VO}_2$ , HR) was calculated as mean  $\pm$  standard deviation (SD). All analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 17.0, Chicago, Ill., USA). Statistical significance was set at an  $\alpha \leq 0.05$  level for all analysis.

The effect of knowledge of exercise duration on leg muscle pain (*predicted* and *actual*) was examined for the female subjects using a two-factor (knowledge (3) x measurement time

(11)) mixed model ANOVA with repeated measures on the second factor. One *predicted* rating and 10 *actual* ratings for each subject constituted the 11 measurement time points in the analyses. The effect of knowledge of exercise duration on *session* pain ratings was determined with a one-factor (knowledge) between-subjects ANOVA. Significant main and interaction effects were examined with a simple effects *post hoc* procedure. For the purpose of this investigation, sex was a categorical rather than an independent variable. Therefore, separate analyses of *predicted*, *actual*, and *session* pain responses were conducted for females and males.

Sample size was based upon the statistical power required to demonstrate an interaction effect in the analysis of variance. This power requirement is the most stringent among any of the statistical models employed and as such required the greatest number of subjects for each contrast cell. Using a power of 0.80, alpha of 0.05 and an effect size of 0.25, it was determined that a minimum of 36 males and 36 females are required to test both the main and interaction effects. The within subject factor in the power calculation assumed an intra-class correlation of 0.50 across repeated measures (22).



## 4.0 RESULTS

This investigation examined whether knowledge of exercise duration prior to performance affected *predicted* and *actual* leg muscle pain responses reported by recreationally active females and males during prolonged cycle exercise at 70%  $\text{VO}_{2\text{peak}}$ . This investigation also examined whether knowledge of exercise duration prior to performance affected *session* pain responses reported by recreationally active females and males 10 minutes following prolonged cycle exercise at 70% of  $\text{VO}_{2\text{peak}}$ . The investigation used a between-subjects, single-blind controlled experimental design consisting of: (a) one baseline graded exercise test (GXT) and (b) one isotime sub-maximal cycle trial. Subjects were randomly assigned to one of three experimental conditions where they performed a 20 minute isotime cycle trial, i.e. a standard trial and two deception trials. For the standard trial, the subject was given accurate information regarding the duration of the exercise they were to perform, i.e. 20 minutes (ACC-20). In the two deception trials, the subject was told he/she would be exercising for 30 minutes (LONG-30) or for 10 minutes (SHORT-10). Groups are abbreviated as follows and will be identified using these symbols in all tables and figures presented throughout this section: ACC-20: knowledge of accurate duration – 20 minutes; LONG-30: knowledge of a longer duration – 30 minutes; and SHORT-10: knowledge of a shorter duration – 10 minutes. Regardless of the exercise duration that the subject was told he/she was going to perform, all subjects actually exercised for 20 minutes. The GXT and isotime trials were separated by at least 3 days, with no more than 7 days

between trials depending on the subject's availability to return for the isotime trial. For the purpose of this investigation, sex was used a categorical rather than an independent variable. Therefore, separate analyses were done for females and males.

## **4.1 DESCRIPTIVE INFORMATION**

### **4.1.1 Oxygen consumption responses**

The isotime trial consisted of 20 minutes of sub-maximal cycle exercise. The initial power output corresponded to 70%  $\text{VO}_{2\text{peak}}$  as derived from results of the GXT and was periodically adjusted to maintain this relative aerobic metabolic rate throughout the 20 minute performance. Oxygen consumption was recorded at the end of each 2 minute measurement time point throughout the isotime cycle trials. Absolute  $\text{VO}_2$  for each 2 minute measurement time point within the three experimental conditions is reported in Table 4 and Table 5 for females and males, respectively. Percent of peak oxygen consumption ( $\%\text{VO}_{2\text{peak}}$ ) corresponding to each measurement time point is reported in Table 6 and Table 7 for females and males, respectively.

**Table 4. Absolute VO<sub>2</sub> by Measurement Time Point for the Female Sample**

Condition		VO <sub>2</sub> (L•min <sup>-1</sup> )									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	1.45	1.56	1.54	1.53	1.46	1.44	1.43	1.46	1.43	1.44
	SD	0.17	0.21	0.22	0.22	0.20	0.21	0.20	0.18	0.16	0.16
LONG-30	M	1.38	1.48	1.51	1.51	1.47	1.50	1.45	1.41	1.44	1.41
	SD	0.19	0.17	0.21	0.20	0.22	0.23	0.20	0.20	0.23	0.23
SHORT-10	M	1.49	1.63	1.62	1.66	1.53	1.51	1.50	1.51	1.52	1.50
	SD	0.18	0.19	0.22	0.23	0.16	0.13	0.20	0.22	0.23	0.23

Data are Mean (M) ± Standard Deviation (SD)

ACC-20: knowledge of accurate duration – 20 minutes

VO<sub>2</sub>: oxygen consumption

LONG-30: knowledge of a longer duration – 30 minutes

Min: minute

SHORT-10: knowledge of a shorter duration – 10 minutes

**Table 5. Absolute VO<sub>2</sub> by Measurement Time Point for the Male Sample**

Condition		VO <sub>2</sub> (L•min <sup>-1</sup> )									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	2.32	2.57	2.47	2.43	2.29	2.28	2.29	2.23	2.31	2.37
	SD	0.39	0.42	0.47	0.49	0.47	0.47	0.49	0.44	0.41	0.48
LONG-30	M	2.03	2.26	2.17	2.15	2.03	2.00	1.97	1.95	1.90	1.89
	SD	0.27	0.25	0.35	0.42	0.35	0.36	0.32	0.37	0.32	0.32
SHORT-10	M	2.10	2.36	2.22	2.21	2.00	1.96	1.99	2.03	2.07	2.05
	SD	0.38	0.46	0.44	0.43	0.48	0.53	0.39	0.38	0.48	0.54

Data are Mean (M) ± Standard Deviation (SD)

**Table 6. Percent VO<sub>2peak</sub> by Measurement Time Point for the Female Sample**

Condition		% VO <sub>2peak</sub>									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	72.5	77.4	76.4	76.2	72.8	71.7	71.1	72.7	71.3	72.0
	SD	3.8	3.6	4.4	5.4	4.7	4.8	3.6	2.1	5.4	4.1
LONG-30	M	69.2	74.7	75.9	75.6	73.7	74.9	72.9	70.7	71.8	70.5
	SD	5.3	5.0	3.5	4.3	4.1	3.6	2.6	3.4	3.5	4.4
SHORT-10	M	68.0	74.4	73.9	75.5	70.1	69.5	68.3	68.8	69.4	68.4
	SD	3.3	3.3	2.2	2.2	3.2	4.8	3.0	4.2	3.4	4.2

Data are Mean (M) ± Standard Deviation (SD)

%VO<sub>2peak</sub>: percent peak oxygen consumption

**Table 7. Percent VO<sub>2peak</sub> by Measurement Time Point for the Male Sample**

Condition		% VO <sub>2peak</sub>									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	71.4	78.9	75.5	74.2	69.8	69.6	69.8	68.3	71.0	72.4
	SD	3.4	4.1	3.8	3.1	3.9	6.3	4.2	4.8	4.3	5.2
LONG-30	M	72.0	80.3	76.6	75.7	71.7	70.6	69.5	68.5	66.9	66.7
	SD	5.9	7.4	3.8	5.4	3.4	5.2	5.3	6.4	3.1	6.6
SHORT-10	M	73.0	81.9	76.8	76.6	68.7	67.0	69.0	70.7	71.1	70.0
	SD	6.1	5.7	4.9	5.5	3.8	5.0	4.8	7.5	3.7	5.9

Data are Mean (M) ± Standard Deviation (SD)

Mean VO<sub>2</sub> and mean %VO<sub>2peak</sub> were calculated by averaging the values for all exercise measurement time points for each subject, then averaging the mean value of all subjects within each condition (Table 8). Summarys of the one-factor ANOVAs for VO<sub>2</sub> and %VO<sub>2peak</sub> for females and males are reported in Appendix H. For the female sample, ANOVA indicated that VO<sub>2</sub> did not differ between conditions ( $p > 0.05$ ). However, a significant difference in %VO<sub>2 peak</sub> attained during the isotime trials was found between conditions ( $p < 0.05$ ). Female subjects in the SHORT-10 condition performed at a lower %VO<sub>2peak</sub> than subjects in both the ACC-20 condition and the LONG-30 condition. Neither mean VO<sub>2</sub> nor %VO<sub>2peak</sub> differed between conditions for the male sample ( $p > 0.05$ ) (Table 9).

**Table 8. Mean VO<sub>2</sub> and %VO<sub>2peak</sub> for the Three Knowledge of Duration Conditions - Females**

Condition		Mean VO <sub>2</sub> (l/min)	Mean %VO <sub>2peak</sub>
ACC-20	M	1.48	73.4
	SD	0.18	2.3
LONG-30	M	1.46	73.0
	SD	0.20	1.4
SHORT-10	M	1.55	70.7*
	SD	0.19	1.9

\*Difference in mean %VO<sub>2peak</sub> compared to ACC-20 and LONG-30 ( $p < 0.05$ )

Data are Mean (M) ± Standard Deviation (SD)

**Table 9. Mean VO<sub>2</sub> and %VO<sub>2peak</sub> for the Three Knowledge of Duration Conditions - Males**

Condition		Mean VO <sub>2</sub> (l/min)	Mean %VO <sub>2peak</sub>
ACC-20	M	2.36	72.1
	SD	0.44	1.8
LONG-30	M	2.04	71.9
	SD	0.31	1.6
SHORT-10	M	2.10	72.5
	SD	0.44	2.5

Data are Mean (**M**) ± Standard Deviation (*SD*)

#### 4.1.2 Heart rate responses

Heart rate was recorded at the end of each 2 minute measurement time point throughout the isotime trial. Heart rate values for each measurement time point within the three experimental conditions are reported in Table 10 and Table 11 for females and males, respectively. Percent heart rate peak corresponding to each measurement time point is reported in Table 12 and Table 13 for females and males, respectively.

**Table 10. Heart Rate by Measurement Time Point for the Female Sample**

Condition		HR (b•min <sup>-1</sup> )									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	152	160	161	163	159	158	158	158	158	159
	SD	12	18	17	15	17	17	18	19	19	17
LONG-30	M	149	157	161	163	163	164	161	160	161	162
	SD	11	12	12	13	12	12	13	13	13	15
SHORT-10	M	155	162	165	169	164	164	164	165	164	167
	SD	14	14	12	12	15	14	14	15	14	13

Data are Mean (**M**) ± Standard Deviation (*SD*)

**HR:** heart rate

**Table 11. Heart Rate by Measurement Time Point for the Male Sample**

Condition		HR ( $\text{b}\cdot\text{min}^{-1}$ )									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	152	161	161	162	159	158	160	161	165	165
	SD	12	12	13	13	11	12	14	16	12	11
LONG-30	M	148	156	157	161	156	155	154	154	154	154
	SD	17	15	17	17	18	19	20	20	18	19
SHORT-10	M	146	158	156	158	150	150	154	155	156	157
	SD	15	16	18	18	15	15	17	18	14	15

Data are Mean (**M**)  $\pm$  Standard Deviation (*SD*)

**Table 12. Percent HR<sub>peak</sub> by Measurement Time Point for the Female Sample**

Condition		%HR <sub>peak</sub>									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	84.5	88.6	89.6	90.4	88.0	87.6	87.4	87.5	87.6	88.1
	SD	5.1	5.2	3.9	3.1	4.7	4.8	5.4	6.2	6.2	5.9
LONG-30	M	82.5	87.3	89.3	90.1	90.5	91.1	89.2	88.7	89.4	89.8
	SD	6.2	5.6	4.4	4.5	4.1	4.3	4.3	4.7	4.9	5.3
SHORT-10	M	83.6	87.3	89.1	90.7	88.0	88.0	88.4	88.9	88.4	89.8
	SD	5.3	4.5	4.0	3.3	4.6	4.5	4.5	5.1	4.4	4.4

Data are Mean (**M**)  $\pm$  Standard Deviation (*SD*)

%HR<sub>peak</sub>: percent heart rate peak

**Table 13. Percent HR<sub>peak</sub> by Measurement Time Point for the Male Sample**

Condition		%HR <sub>peak</sub>									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	83.5	88.6	88.5	89.2	87.3	87.0	88.1	88.6	90.4	90.6
	SD	4.0	4.4	4.3	4.6	4.8	6.2	5.4	5.9	4.9	5.0
LONG-30	M	82.9	87.3	88.0	89.9	87.4	87.0	86.3	86.1	86.2	86.2
	SD	6.4	4.3	6.1	6.2	6.2	7.2	8.7	9.6	8.8	8.9
SHORT-10	M	82.5	89.1	87.6	89.1	84.9	84.4	86.6	87.6	88.1	88.4
	SD	5.4	5.2	5.9	5.9	5.0	5.6	6.6	6.9	5.2	5.9

Data are Mean (**M**)  $\pm$  Standard Deviation (*SD*)

Mean HR and mean %HR<sub>peak</sub> were calculated by averaging the values for all exercise measurement time points for each subject, then averaging the mean value of all subjects within

each condition. Summary of the one-factor ANOVAs for HR and %HR<sub>peak</sub> for females and males are reported in Appendix H. The ANOVA indicated that mean HR and mean %HR<sub>peak</sub> did not differ between conditions for either the female sample or the male sample ( $p > 0.05$ ) (Table 14 and Table 15, respectively).

**Table 14. Mean HR and %HR<sub>peak</sub> for the Three Knowledge of Duration Conditions - Females**

Condition		HR (bpm)	%HR <sub>peak</sub>
ACC-20	M	159	87.9
	SD	17	4.6
LONG-30	M	160	88.8
	SD	12	4.2
SHORT-10	M	164	88.2
	SD	13	4.0

Data are Mean (M)  $\pm$  Standard Deviation (SD)

**Table 15. Mean HR and %HR<sub>peak</sub> for the Three Knowledge of Duration Conditions – Males**

Condition		HR (bpm)	%HR <sub>peak</sub>
ACC-20	M	161	88.2
	SD	12	4.2
LONG-30	M	155	86.7
	SD	17	6.6
SHORT-10	M	154	86.8
	SD	15	4.6

Data are Mean (M)  $\pm$  Standard Deviation (SD)

#### 4.1.3 Leg muscle pain ratings (RMP-Legs)

The *predicted* pain rating was provided by the subject immediately prior to undertaking the isotime trial. The *actual* pain rating was a momentary measure of the pain intensity that the

subject reported every two minutes during the isotime trial. Each subject reported a total of 10 actual pain ratings. The *session* pain rating was a global assessment of the pain intensity that the subject experienced throughout the entire isotime trial. The *session* pain rating was measured 10 minutes after completion of the isotime trial. The means for the *predicted*, *actual* and *session* RMP-Legs for each isotime trial are presented separately for females and males in Table 16 and Table 17, respectively.

**Table 16. Predicted, Actual, and Session RMP-Legs for the Female Sample**

Condition		Predicted RMP-Legs	Actual RMP-Legs										Session RMP-Legs
			Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20	
ACC-20	M	5.3	1.5	2.9	3.4	3.9	3.8	3.8	4.2	4.7	4.8	5.3	4.2
	SD	2.1	0.6	1.2	2	2.3	2.4	2.3	2.1	2.2	2.3	2.3	2.3
LONG-30	M	4.5	0.9	1.6	2.2	2.7	2.9	3.1	3.4	3.5	3.7	3.6	2.8
	SD	2.2	0.2	0.8	0.9	0.9	1.1	1.2	1.5	1.5	1.6	1.7	1.1
SHORT-10	M	4.7	2.1	3.0	3.9	4.3	3.3	2.7	2.4	2.5	2.6	2.9	3.0
	SD	2.4	1.8	1.9	2.1	2.4	1.8	1.4	1.3	1.6	1.8	1.9	1.1

Data are Mean (M)  $\pm$  Standard Deviation (SD)

**RMP-Legs:** rating of leg muscle pain

**Table 17. Predicted, Actual, and Session RMP-Legs for the Male Sample**

Condition		Predicted RMP-Legs	Actual RMP-Legs										Session RMP-Legs
			Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20	
ACC-20	M	4.9	2.0	3.4	3.4	3.9	3.5	3.7	4.3	4.8	4.8	5.3	4.0
	SD	2.3	1.3	2.1	2.1	2.1	1.8	1.6	1.6	1.9	2.0	2.1	1.6
LONG-30	M	4.5	2.3	3.7	4.3	5.2	5.3	5.4	5.5	5.0	5.2	5.3	4.1
	SD	2.3	1.4	2.0	2.1	2.1	1.8	1.7	1.9	2.4	2.5	2.6	1.3
SHORT-10	M	4.3	2.6	4.1	4.5	4.6	4.0	3.5	4.0	4.3	4.2	4.5	3.6
	SD	1.7	1.3	1.8	2.0	1.9	2.0	2.4	2.5	2.8	2.7	2.8	1.7

Data are Mean (M)  $\pm$  Standard Deviation (SD)



## 4.2 PREDICTED AND ACTUAL RMP-LEGS FOR FEMALES

The effect of knowledge of exercise duration on leg muscle pain (*predicted* and *actual*) was examined for the female subjects using a two-factor (knowledge (3) x measurement time (11)) mixed model ANOVA with repeated measures on the second factor. One *predicted* rating and 10 *actual* ratings for each subject constituted the 11 measurement time points in the analyses. The results of the ANOVA for the female sample are presented in Table 18. There was a significant ( $p < 0.001$ ) main effect of time on RMP-Legs. The significant time main effect indicated that when averaged over conditions, RMP-Legs differed between measurement time points. There was not a significant main effect of knowledge of duration on RMP-Legs ( $p = 0.160$ ). There was a significant ( $p < 0.001$ ) interaction effect between knowledge of duration and time on RMP-Legs. The significant interaction effect indicated that RMP-Legs differed between knowledge of exercise duration conditions, and differed between selected measurement time points within each knowledge of duration condition.

**Table 18. Results of the ANOVA for the Effect of Knowledge of Duration on Predicted and Actual RMP-Legs for Females**

<b>Main Effects</b>	<b>df</b>	<b>F</b>	<b><i>p</i></b>	<b><math>\eta^2</math></b>
Time (Within)	10	17.923	< 0.001*	0.352
Error	330			
Knowledge (Between)	2	1.938	0.160	0.111
Error	33			
<b>Interaction Effects</b>				
Time x Knowledge	20	3.864	< 0.001*	0.190
Error	330			

\*Statistically significant (2-tailed)

#### 4.2.1 Interaction effect: Between conditions – Predicted RMP-Legs

The significant interaction effect in the ANOVA was first decomposed for the *predicted* RMP-Legs responses for the female group. No differences were found in *predicted* RMP-Legs between knowledge of duration conditions ( $p = 0.693$ ). The marginal mean for *predicted* RMP-Legs was  $4.8 \pm 2.2$ . For purpose of comparison, the *predicted* RMP-Legs data are presented by knowledge of duration condition in Figure 5.

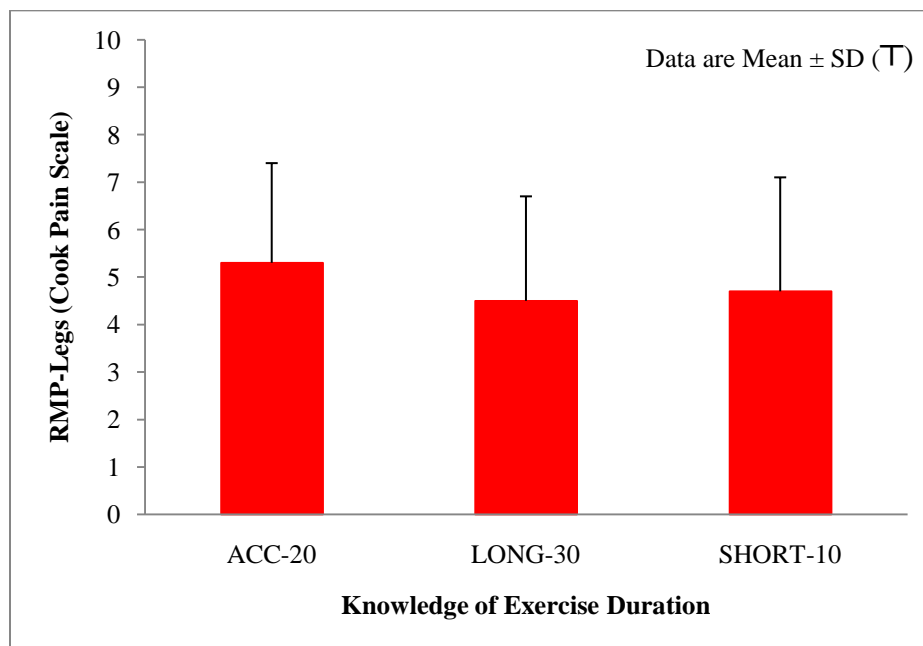


Figure 5. Predicted RMP-Legs for the Three Knowledge of Duration Conditions – Females

#### 4.2.2 Interaction effect: Between conditions – Actual RMP-Legs

The significant interaction effect in the ANOVA was also decomposed for the *actual* RMP-Legs responses for the female group. The significant interaction indicated differences in *actual* RMP-Legs at specific measurement time points between the three isotime trial ( $p < 0.001$ ). For the purpose of comparison, the actual RMP-Legs data are listed at each measurement time point

within the three knowledge of duration conditions in Table 19. *Post hoc* analysis of the interaction effect indicated *actual* RMP-Legs were greater in the SHORT-10 condition than the LONG-30 condition at minute 2 ( $p = 0.012$ ), minute 4 ( $p = 0.020$ ) and minute 6 ( $p = 0.020$ ). *Actual* RMP-Legs were lower in the SHORT-10 condition than ACC-20 condition at minute 14 ( $p = 0.018$ ), minute 16 ( $p = 0.005$ ), minute 18 ( $p = 0.006$ ), and minute 20 ( $p = 0.005$ ). *Actual* RMP-Legs were lower in the LONG-30 condition than the ACC-20 condition at minute 4 ( $p = 0.028$ ) and minute 20 ( $p = 0.042$ ). *Post hoc* analysis indicated no other significant differences in *actual* RMP-Legs between knowledge of duration conditions at any other measurement time points.

**Table 19. Between Condition Comparison of Actual RMP-Legs – Females**

Condition		Actual RMP-Legs at every 2 minute measurement time point									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
ACC-20	M	1.5	2.9	3.4	3.9	3.8	3.8	4.2	4.7	4.8	5.3
	SD	0.6	1.2	2	2.3	2.4	2.3	2.1	2.2	2.3	2.3
LONG-30	M	0.9	1.6*	2.2	2.7	2.9	3.1	3.4	3.5	3.7	3.6*
	SD	0.2	0.8	0.9	0.9	1.1	1.2	1.5	1.5	1.6	1.7
SHORT-10	M	2.1**	3.0**	3.9**	4.3	3.3	2.7	2.4*	2.5*	2.6*	2.9*
	SD	1.8	1.9	2.1	2.4	1.8	1.4	1.3	1.6	1.8	1.9

\*Different from ACC-20 ( $p < 0.05$ )

\*\*Different from LONG-30 ( $p < 0.05$ )

Data are Mean (M)  $\pm$  Standard Deviation (SD)

#### 4.2.3 Interaction effect: Within conditions – Predicted vs. Actual RMP-Legs

The significant interaction effect in the ANOVA was decomposed for *predicted* versus *actual* RMP-Legs responses within each knowledge of duration condition for the female group. The significant interaction indicated differences between *predicted* and *actual* RMP-Legs within each of the three isotime trials ( $p < 0.001$ ). For purpose of comparison, the *predicted* and *actual* RMP-Legs responses are displayed in Figures 6, 7, and 8 for ACC-20, LONG-30, and SHORT-

10, respectively. *Post hoc* analysis of the interaction effect indicated *actual* RMP-Legs for the ACC-20 condition were lower at minute 2 ( $p < 0.001$ ), minute 4 ( $p = 0.004$ ), and minute 6 ( $p = 0.021$ ) compared to the *predicted* rating (Figure 6). *Actual* RMP-Legs for the LONG-30 condition were lower at minute 2 ( $p < 0.001$ ), minute 4 ( $p = 0.002$ ), minute 6 ( $p = 0.009$ ), minute 8 ( $p = 0.018$ ), minute 10 ( $p = 0.035$ ), and minute 12 ( $p = 0.039$ ) compared to the *predicted* rating (Figure 7). *Actual* RMP-Legs for the SHORT-10 condition were lower at minute 2 ( $p = 0.018$ ), minute 12 ( $p = 0.014$ ), minute 14 ( $p = 0.005$ ), minute 16 ( $p = 0.010$ ), minute 18 ( $p = 0.005$ ), and minute 20 ( $p = 0.011$ ) compared to the *predicted* rating (Figure 8).

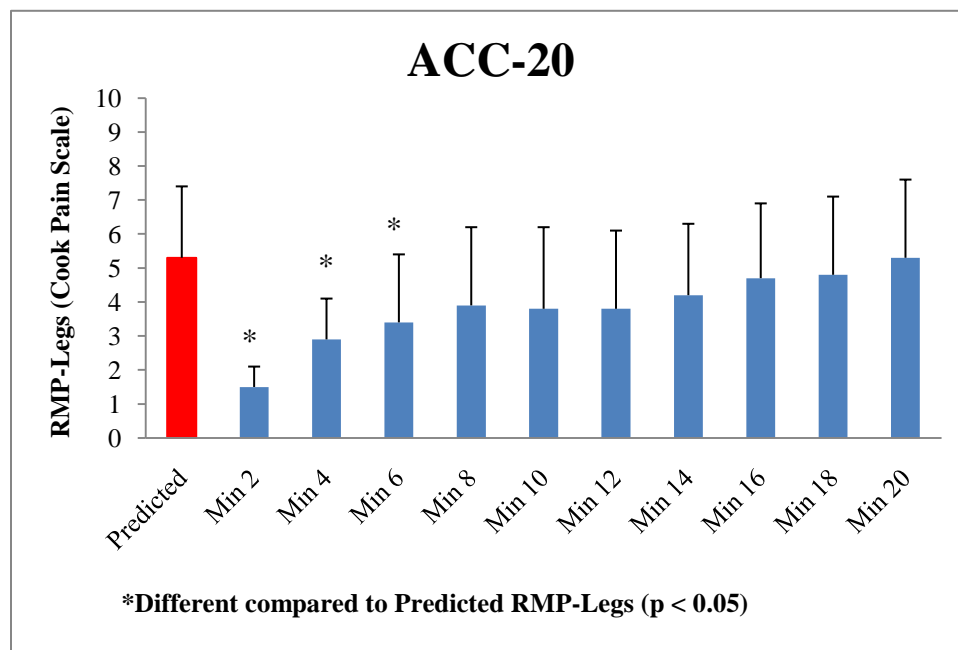
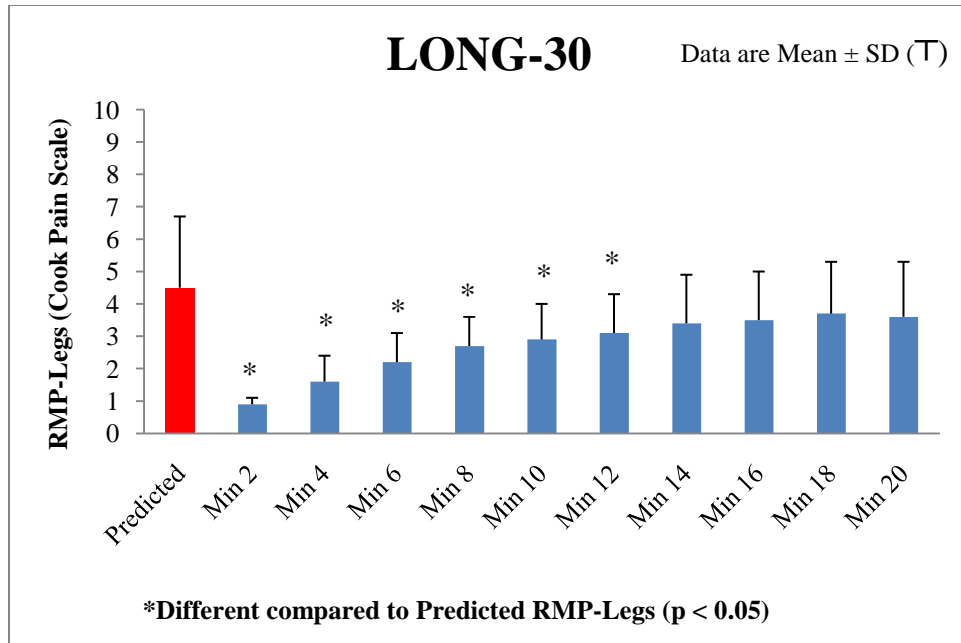
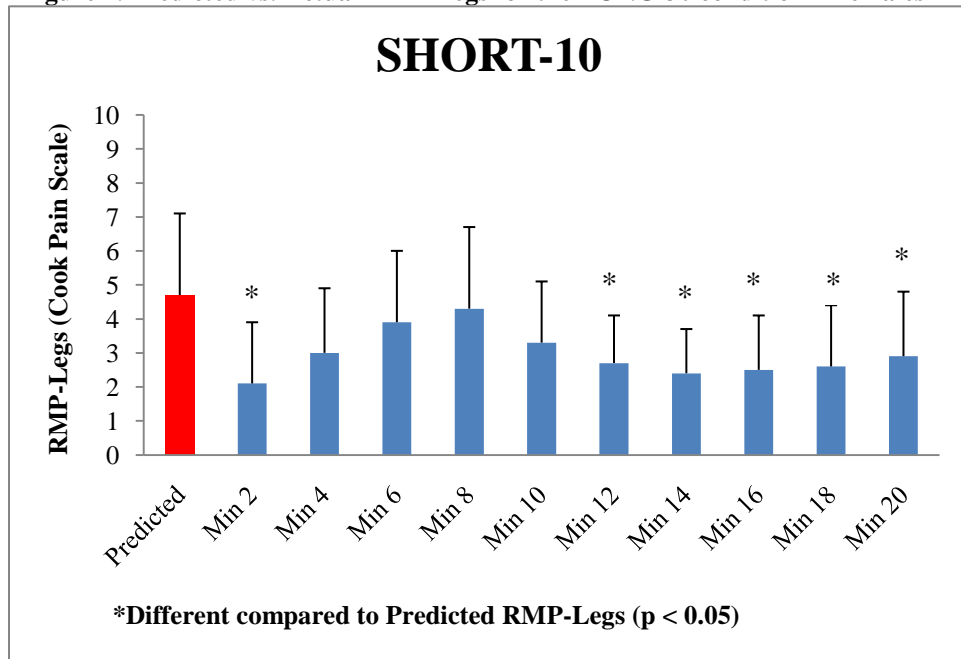


Figure 6. Predicted vs. Actual RMP-Legs for the ACC-20 condition – Females



**Figure 7. Predicted vs. Actual RMP-Legs for the LONG-30 condition – Females**



**Figure 8. Predicted vs. Actual RMP-Legs for the SHORT-10 condition – Females**

*Post hoc* analysis of the interaction effect also indicated *actual* RMP-Legs at minute 2 was lower ( $p < 0.001$ ) compared to minute 20 for both the ACC-20 condition (Min 2:  $1.5 \pm 0.6$ ; Min 20:  $5.3 \pm 2.3$ ) and LONG-30 (Min 2:  $0.9 \pm 0.2$ ; Min 20:  $3.6 \pm 1.7$ ). No increase was found

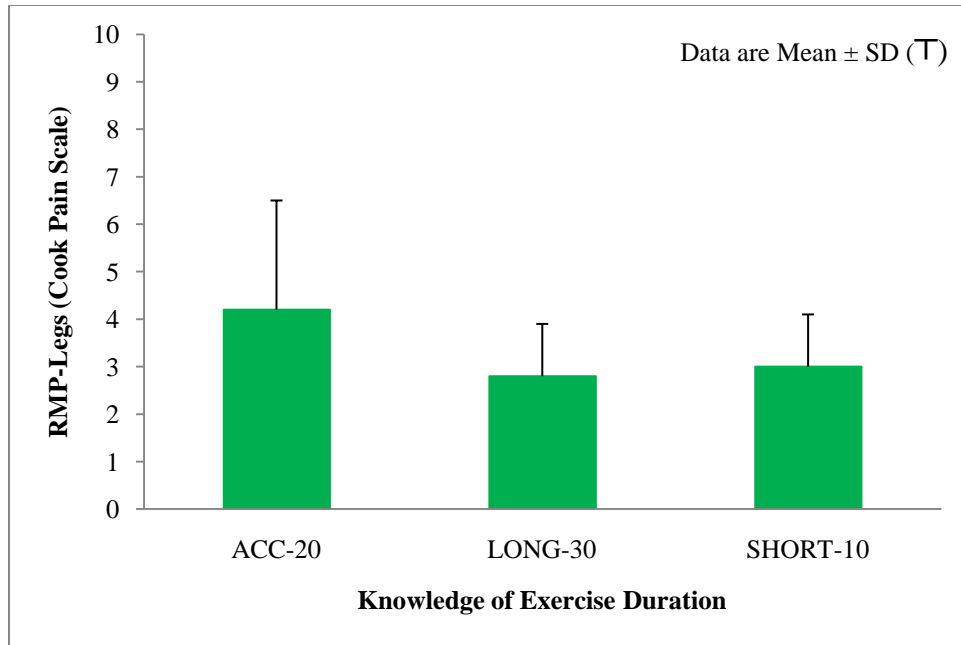
for the SHORT-10 condition between *actual* RMP-Legs at minute 2 and 20. The trend seen in the ACC-20 and LONG-30 conditions indicates an increase of RMP-Legs over time during the exercise trial, therefore serving as a manipulation check on the effects of knowledge of duration.

### 4.3 SESSION RMP-LEGS FOR FEMALES

The effect of knowledge of exercise duration on *session* RMP-Legs was determined using a one-factor (knowledge) between-subjects ANOVA for the female group. The results of the ANOVA are presented in Table 20. The condition main effect for *session* RMP-Legs was not significant ( $p = 0.084$ ). These findings indicate that knowledge of exercise duration did not have an independent effect on the *session* RMP-Legs. The marginal mean for *session* RMP-Legs was  $3.3 \pm 1.7$ . For the purpose of description only, the *session* RMP-Legs data are presented by knowledge of duration condition in Figure 9.

**Table 20. Results of the ANOVA for the Effect of Knowledge of Duration on Session RMP-Legs for Females**

Main Effects	df	F	<i>p</i>	$\eta^2$
Knowledge (Between)	2	2.666	0.084	0.139
Error	33			



**Figure 9. Session RMP-Legs for the Three Knowledge of Duration Conditions – Females**

#### **4.4 PREDICTED AND ACTUAL RMP-LEGS FOR MALES**

The effect of knowledge of exercise duration on leg muscle pain (*predicted* and *actual*) was examined for the male subjects using a two-factor (knowledge (3) x measurement time (11)) mixed model ANOVA with repeated measures on the second factor. One *predicted* rating and 10 *actual* ratings for each subject constituted the 11 measurement time points in the analyses. The results of the ANOVA for the male sample are presented in Table 21. There was a significant ( $p < 0.001$ ) main effect of time on RMP-Legs. There was no significant main effect of knowledge of duration on RMP-Legs ( $p = 0.480$ ). In addition, there was no interaction effect between time and knowledge of exercise duration ( $p = 0.094$ ).

**Table 21. Results of the ANOVA for the Effect of Knowledge of Duration on Predicted and Actual RMP-Legs for Males**

<b>Main Effects</b>	<b>df</b>	<b>F</b>	<b>p</b>	<b><math>\eta^2</math></b>
Time (Within)	10	9.354	< 0.001*	0.221
Error	330			
Knowledge (Between)	2	0.751	0.480	0.044
Error	33			
<b>Interaction Effects</b>				
Time x Knowledge	20	1.458	0.094	0.081
Error	330			

\*Statistically significant (2-tailed)

#### **4.4.1 Between conditions – Predicted RMP-Legs**

The ANOVA indicated that there was not an independent effect of knowledge of duration on the *predicted* RMP-Legs ( $p = 0.480$ ) for the male group. The marginal mean for predicted RMP-Legs was  $4.6 \pm 2.1$ . For purpose of description only, the *predicted* RMP-Legs data are presented by knowledge of duration condition in Figure 10.



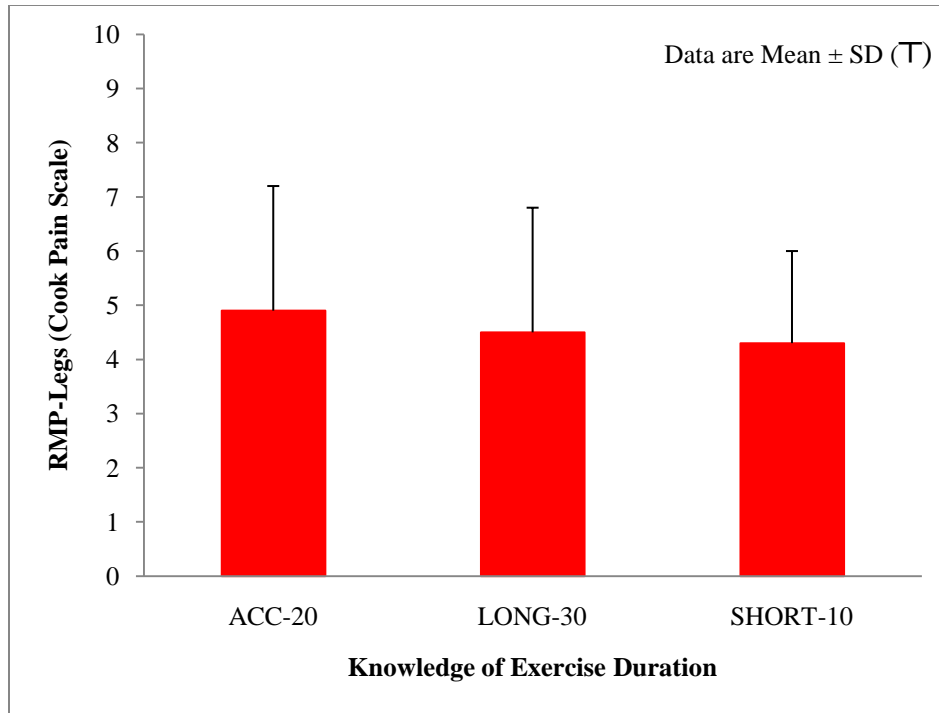


Figure 10. Predicted RMP-Legs for the Three Knowledge of Duration Conditions – Males

#### 4.4.2 Between conditions – Actual RMP-Legs

The ANOVA indicated that there was not an independent effect of knowledge of duration on the *actual* RMP-Legs ( $p = 0.480$ ) for the male group. For purpose of description only, the marginal means for *actual* RMP-Legs are presented in Table 22.

Table 22. Actual RMP-Legs during the Isotime Trial for Males

		Actual RMP-Legs at every 2 minute measurement time point									
		Min 2	Min 4	Min 6	Min 8	Min 10	Min 12	Min 14	Min 16	Min 18	Min 20
Male Sample	M	2.3	3.7	4.1	4.6	4.2	4.2	4.6	4.7	4.7	5.0
	SD	1.3	2.0	2.1	2.1	2.0	2.1	2.1	2.4	2.4	2.5

Data are Marginal Means (**M**)  $\pm$  Standard Deviation (**SD**)

#### 4.4.3 Within conditions – Predicted vs. Actual RMP-Legs

The significant time main effect in the ANOVA was decomposed to identify differences between *predicted* and *actual* RMP-Legs responses. As there was no interaction effect, the comparison between *predicted* and *actual* RMP-Legs employed the marginal means at each measurement time point. Therefore, the *post hoc* analysis compares responses averaged over conditions at each of the 11 measurement time points. The significant time main effect identified differences between *predicted* and *actual* RMP-Legs within the three isotime trials ( $p < 0.001$ ). *Post hoc* analysis of the time main effect indicated *actual* RMP-Legs were lower at minute 2 ( $p < 0.001$ ), and minute 4 ( $p = 0.047$ ) compared to the *predicted* rating. For purpose of comparison, the *predicted* and *actual* RMP-Legs responses are displayed in Figure 11.

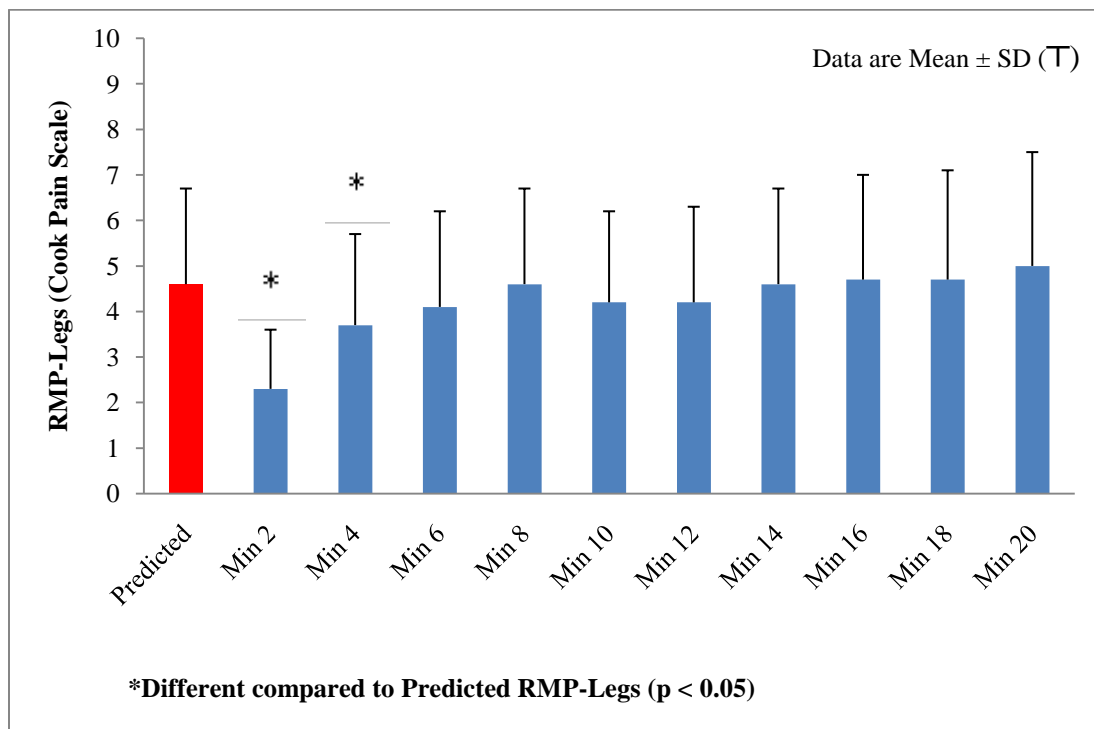


Figure 11. Predicted vs. Actual RMP-Legs (marginal means) for the Isotime Cycle Trial – Males

*Post hoc* analysis of the time main effect also indicated *actual* RMP-Legs at minute 2 was lower ( $p < 0.001$ ) compared to minute 20 for all three isotime trials (Min 2:  $2.3 \pm 1.3$ ; Min 20:  $5.0 \pm 2.5$ ). This trend indicates an increase of RMP-Legs over time during the exercise trial, therefore serving as a manipulation check of the effects of knowledge of exercise duration.

#### 4.5 SESSION RMP-LEGS FOR MALES

The effect of knowledge of exercise duration on *session* RMP-Legs was determined using a one-factor (knowledge) between-subjects ANOVA. The results of the ANOVA are presented in Table 23. The ANOVA did not indicate a significant condition main effect for *session* RMP-Legs ( $p = 0.697$ ). As such, an independent effect of knowledge of duration on the *session* RMP-Legs was not observed. The marginal mean for session RMP-Legs was  $3.9 \pm 1.5$ . For the purpose of description only, the *session* RMP-Legs data are displayed by knowledge of duration condition in Figure 12.

**Table 23. Results of the ANOVA for the Effect Knowledge of Duration on Session RMP-Legs for Males**

Main Effects	df	F	<i>p</i>	$\eta^2$
Knowledge (Between)	2	0.365	0.697	0.022
Error	33			

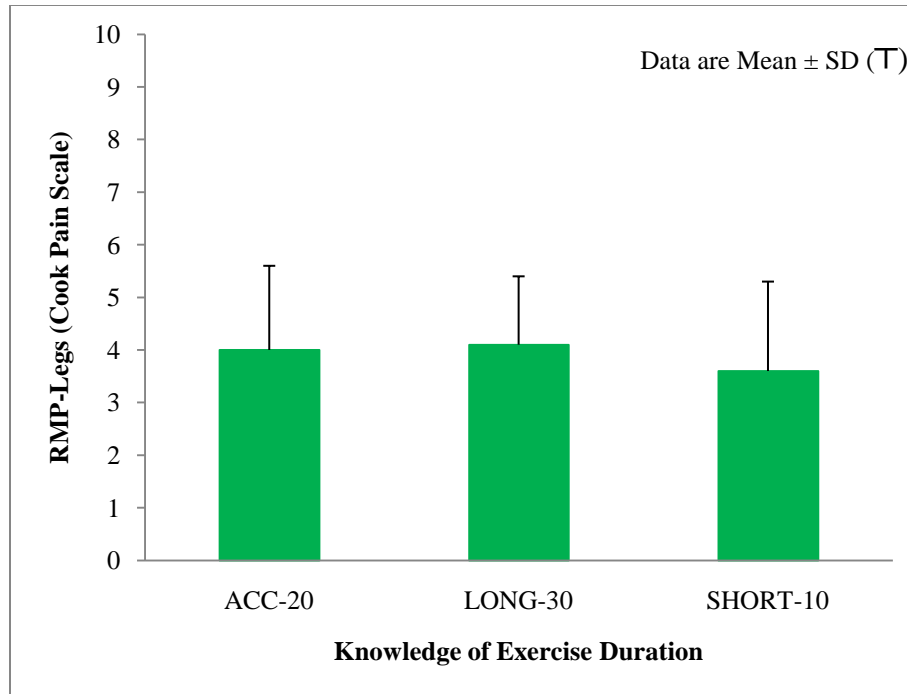


Figure 12. Session RMP-Legs for the Three Knowledge of Duration Conditions – Males

## 4.6 SUMMARY

### 4.6.1 Females

- The ANOVA indicated a significant interaction effect ( $p < 0.001$ ) between knowledge of exercise duration and time for the female subjects.
  - Between conditions
    - No significant differences were found for *predicted* RMP-Legs between the three exercise duration conditions.
    - *Actual* RMP-Legs in the SHORT-10 condition were greater at minutes 2, 4, and 6 compared to *actual* RMP-Legs in the LONG-30 condition.

- *Actual* RMP-Legs in the SHORT-10 condition were lower at minutes 14, 16, 18, and 20 compared to *actual* RMP-Legs in the ACC-20 condition.
- *Actual* RMP-Legs in the LONG-30 condition were lower at minutes 4 and 20 compared to *actual* RMP-Legs in the ACC-20 condition.
- Within condition
  - *Actual* RMP-Legs in the ACC-20 condition were lower at minutes 2, 4, and 6 compared to *predicted* RMP-Legs.
  - *Actual* RMP-Legs in the LONG-30 condition were lower at minutes 2, 4, 6, 8, 10, and 12 compared to *predicted* RMP-Legs.
  - *Actual* RMP-Legs in the SHORT-10 condition were lower at minutes 2, 12, 14, 16, 18, and 20 compared to *predicted* RMP-Legs.
- The ANOVA indicated that the *session* RMP-Legs ( $p = 0.084$ ) did not differ between knowledge of exercise duration conditions.

#### 4.6.2 Males

- A significant time main effect ( $p < 0.001$ ) was found between *predicted* and *actual* RMP-Legs.
  - *Actual* RMP-Legs were lower at minutes 2 and 4 compared to *predicted* RMP-Legs for all conditions.
- The ANOVA indicated that knowledge of exercise duration did not affect either *predicted* or *actual* RMP-Legs ( $p = 0.480$ ).
- ANOVA did not indicate a significant interaction effect between time and knowledge of duration conditions ( $p = 0.094$ ).

- The ANOVA indicated that the *session* RMP-Legs ( $p = 0.697$ ) did not differ between knowledge of exercise duration conditions.

## 5.0 DISCUSSION

It is important to understand barriers to physical activity adoption and maintenance. One such barrier may be the individuals' anticipation that the activity will be too difficult or painful. Moderately intense exercise can be accompanied by some level of naturally occurring muscle pain (41). The anticipation of muscular pain may be a barrier to an individual's decision to participate in an exercise task. Such psycho-physiological barriers are often in place well before the individual even begins to perform a given exercise. Once provided with information regarding the exercise, it is theorized that individuals develop a pacing strategy to complete the exercise without depleting energy for muscular contraction or causing harm to the body (i.e. injury, pain, muscle soreness) (62). Therefore, in anticipation of an exercise task, individuals may establish a cognitive strategy that sets the upper limits of tolerance for the noxious sensory elements of that exercise. The cognitive strategy employs information regarding the exercise task, such as past experience or pre-performance knowledge of exercise duration (33, 58, 62).

The goal of the present investigation was to use a teleoanticipatory model to examine the effect of providing knowledge of exercise duration prior to performance on *predicted* and *actual* leg muscle pain responses reported by recreationally active females and males during prolonged cycle exercise at 70%  $\text{VO}_{2\text{peak}}$ . The present investigation also examined whether knowledge of exercise duration prior to performance effects *session* pain responses reported by recreationally active females and males following prolonged cycle exercise at 70%  $\text{VO}_{2\text{peak}}$ . This appears to be

the first investigation to examine the effects of knowledge of exercise duration on leg muscle pain response during prolonged exercise at sub-maximal intensity. It was important to ensure muscle pain responses were a result of the isotime exercise trial and not influenced by recent pain experiences (i.e. delayed onset muscle soreness). As such, subjects completed a pre-exercise questionnaire to identify any pre-existing levels of muscle pain. All subjects reported no muscle pain prior to the isotime trial. Therefore, descriptive responses indicated that the intensity and duration of the exercise trial were sufficient to induce *moderate* to *somewhat strong* leg muscle pain in female and male subjects. This reported level of muscle pain established an internal check on the ability of the experimental design to produce moderate sensations of leg pain over the full time course of the 20 minute exercise trial. Such responsiveness in turn facilitated use of a deception paradigm to determine the effect of knowledge of exercise duration on leg muscle pain during prolonged sub-maximal cycle exercise.

## **5.1 PRIMARY FINDINGS: PREDICTED AND ACTUAL RMP-LEGS**

### **5.1.1 Predicted RMP-Legs – Females and Males**

For both females and males, it was hypothesized that in comparison to the leg muscle pain that was *predicted* to occur during a 20 minute sub-maximal cycle ergometer trial where subjects were given accurate information regarding exercise duration: 1) leg muscle pain would be greater when subjects were told the exercise duration would be 30 minutes, and 2) leg muscle pain would be less when subjects were told the exercise duration would be 10 minutes. The



*predicted* RMP-Legs was taken as an anticipatory response that reflected an individual's expected pain experience during an upcoming exercise trial.

The *predicted* RMP-Legs did not differ between knowledge of duration conditions for either sex. Responses indicated that in comparison to a 20 minute reference condition, the *predicted* RMP-Legs was not greater for those who were told they would be exercising for a longer duration, nor was it less for those who were told they would be exercising for a shorter duration. These findings did not support the hypotheses. When averaged over knowledge of duration conditions, the mean *predicted* RMP-Legs for the female sample and the male sample, respectively, was  $4.8 \pm 2.2$  and  $4.6 \pm 2.1$ . The mean *predicted* RMP-Legs for each knowledge of duration condition for females and males was presented previously in Figure 5 and Figure 10 of the Results section. Regardless of the knowledge that the exercise duration would be either 10, 20 or 30 minutes, both females and males anticipated experiencing *moderate* to *somewhat strong* pain during all three exercise trials. In addition, the experimental paradigm assumed that recreationally active individuals would be capable of maintaining an intensity equivalent to 70%  $\text{VO}_{2\text{peak}}$  while experiencing moderate leg muscle pain for a period of time equivalent to a typical exercise conditioning session (i.e. 20 minutes).

The primary question in the present investigation was to determine whether knowledge of exercise duration provided a cognitive reference upon which leg muscle pain response were based, i.e. a teleoanticipation sensory set-point. For that purpose, subjects performed a single (i.e. fixed load) exercise intensity during all three knowledge of duration conditions. All subjects maintained an intensity equivalent to 70-74%  $\text{VO}_{2\text{peak}}$ . It was expected that the *predicted* RMP-Legs would differ where various knowledge of exercise duration conditions were presented.

However, the present investigation found no difference in the *predicted* RMP-Leg based on such pre-exercise knowledge.

### 5.1.2 Actual RMP-Legs – Females and Males

For both females and males, it was hypothesized that in comparison to the *actual* leg muscle pain experienced during a 20 minute sub-maximal cycle ergometer trial where subjects were given accurate information regarding exercise duration: 1) leg muscle pain would be greater when subjects were told the exercise duration would be 30 minutes, and 2) leg muscle pain would be less when subjects were told the exercise duration would be 10 minutes. The *actual* RMP-Legs was a momentary response provided by the subject at the end of each two minute interval during the isotime cycle trial.

For the female sample, a portion of the findings supported and a portion of the findings rejected the experimental hypothesis. The hypothesis stated that the *actual* RMP-Legs would be greater when subjects were informed that the exercise would be longer than the 20 minute reference condition and less when they were informed the exercise duration would be shorter than 20 minutes. The mean of the *actual* RMP-Legs was calculated by averaging all measurement time points within each isotime trial separately for the three conditions (Table 24). For the entire female sample, the *actual* RMP-legs was  $3.2 \pm 1.5$  when averaged across all measurement time points and experimental conditions. This indicated that the female subjects regardless of their knowledge of exercise duration reported *moderate* to *somewhat strong* leg pain during an isotime cycle exercise trial equivalent to 70%  $\text{VO}_{2\text{peak}}$ . The mean leg muscle pain experienced by females in the present investigation is similar to a previous investigation that

reported moderate intensity leg pain during a 20 minute sub-maximal (69-74%  $\text{VO}_{2\text{peak}}$ ) cycle exercise trial (41).

**Table 24. Mean of the Actual RMP-Legs across Time Points for the Three Experimental Conditions for Females**

Condition		Actual*
ACC-20	M	3.8
	SD	1.8
LONG-30	M	2.8
	SD	1.0
SHORT-10	M	3.0
	SD	1.3

Data are Mean (**M**)  $\pm$  Standard Deviation (*SD*)

\*Cook Pain Scale (0 – 10)

A significant interaction effect between knowledge of duration and exercise time was found for the *actual* RMP-Legs responses in the female sample. This allowed the examination of differences in the *actual* RMP-Legs between knowledge of duration conditions at each measurement time point throughout the isotime exercise trial. The *actual* RMP-Legs was significantly different between knowledge of duration conditions at several but not all measurement time points. The following is a summary of the between condition differences noted by the interaction effects:

**SHORT-10 vs. ACC-20:** The *actual* RMP-Legs for the SHORT-10 condition did not differ from those reported during the ACC-20 condition from 2 to 12 minutes of the isotime trial. However, from minutes 14 through 20 of exercise, RMP-Legs for the SHORT-10 condition were lower than the ACC-20 condition. These findings show partial support of the hypothesis that knowledge of shorter duration will provide for less RMP-Legs.

**LONG-30 vs. ACC-20:** The *actual* RMP-Legs did not differ between the LONG-30 condition and the ACC-20 condition, with the exception of minute 4 and minute 20 where RMP-

Legs was lower in the LONG-30 condition than in the ACC-20 condition. These findings do not support the hypothesis that knowledge of lower duration will provide for greater RMP-Legs.

**SHORT-10 vs. LONG-30:** At minutes 2, 4, and 6 of exercise, subjects in the SHORT-10 condition reported significantly greater RMP-Legs compared to the LONG-30 condition. However, as the exercise trial progressed the *actual* RMP-Legs for the SHORT-10 condition decreased, becoming similar to those reported for the LONG-30 condition. These findings again do not support hypotheses that knowledge of comparatively longer duration will yield greater RMP-Legs than comparatively shorter duration.

There were no significant differences in the *actual* RMP-Legs between knowledge of duration conditions in the male sample. These findings were not consistent with the hypothesis. Pre-performance knowledge of exercise duration did not affect the *actual* RMP-Legs in the male sample. For the entire male sample, the *actual* RMP-legs was  $4.2 \pm 1.7$  when averaged across all measurement time points and experimental conditions. For descriptive purposes, the mean of all the *actual* RMP-Legs for each isotime trial are listed in Table 25. Therefore, male subjects regardless of their knowledge of exercise duration reported *somewhat strong* pain sensations during an isotime cycle exercise trial requiring approximately 70%  $\text{VO}_{2\text{peak}}$ .

**Table 25. Mean of the Actual RMP-Legs across Time Points for the Three Experimental Conditions for Males**

Condition		Actual*
ACC-20	M	3.9
	SD	1.4
LONG-30	M	4.7
	SD	1.7
SHORT-10	M	4.0
	SD	1.9

Data are Mean (M)  $\pm$  Standard Deviation (SD)

\*Cook Pain Scale (0 – 10)

### 5.1.3 Explanatory Mechanisms

#### 5.1.3.1 Anticipatory Intensity

Pain is a frequently reported barrier to exercise (2). The hypotheses of the present investigation paralleled previous literature examining pain responsiveness during exercise. Results of such previous research provided evidence that duration of exposure to a painful stimulus contributes to an individual's ability to predict pain intensity and accept pain during exercise (64). Assuming normal body functioning, the longer an individual is exposed to a pain stimulus, the more intense will be the reported pain. By providing individuals with the knowledge of duration of the painful stimulus, it was assumed such cognitive information would affect the individual's preparation and acceptance responses of the muscle pain that would actually be experienced during the exercise task. This teleoanticipation mechanism was not apparent for the *predicted* RMP-Legs responses for the male subjects and only partially apparent for the female subjects.

During an isotime trial, total exercise load is determined by the reciprocal forcing functions of duration and intensity. The present investigation focused on only one of these two factors, i.e. exercise duration. Exercise intensity was held constant with its relative metabolic level not known to the subjects. That is, subjects were not provided with information regarding the intensity of the exercise trial to be performed. All subjects were provided with the same pre-exercise instructions and then asked to rate how much leg muscle pain they anticipated experiencing. While most subjects examined the scale and gave their pain rating, a number paused to ask how intense the exercise would be. Consistent with the experimental protocol, that information was not provided. Instead, a scripted response that instructed the subject to focus on the exercise duration rather than the intensity when choosing their rating was related to the subject. This anecdotal observation suggests that exercise intensity is an important and perhaps

primary factor that is used to establish a cognitive anticipatory set-point when estimating pain sensation. As such, pre-performance knowledge of exercise intensity may be considered an interactive complement to knowledge of exercise duration when establishing expectations of the noxious sensations to be experienced during prolonged sub-maximal exercise. Providing knowledge of exercise intensity prior to participation may influence, independently or interactively, the *predicted* muscle pain responses.

The influence of stimulus intensity has been shown to be crucial in setting the response level of a number of psycho-physiological variables. Previous research has examined the *predicted* RPE where exercise intensity was expected to vary. These studies demonstrated that the *predicted* RPE was lower when subjects were informed that the exercise intensity to be performed would be light. Conversely, when informed that exercise would be performed at vigorous intensity, the *predicted* RPE was higher. These responses occurred during both imposed and self-selected exercise (32). In a conceptually analogous manner, research in chronic pain management has shown that estimates of pain intensity can be manipulated by suggesting variations in exposure to environmental temperature. Individual's rated the experience as more painful when told that the stimulus was hot, as compared to when they were told it was cold (4). These responses suggest that pain responsiveness can be manipulated by and may be dependent on cognitive suggestion of stimulus intensity.

As seen with the *predicted* rating response, knowledge of exercise duration may not effect cognitive processes that mediate the *actual* RMP-Legs. Subjects were not provided with an indication of elapsed performance time at any point during the exercise trial. Therefore, they may have been unable to use teloanticipatory set-points based on exercise duration to adjust muscle pain responses as exercise progressed. As such, knowledge of exercise intensity may

provide a stronger influence in setting muscle pain level than simply knowing the duration of the exercise that is being performed. During the final portion (i.e. last 8 minutes) of the exercise trial, differences in the *actual* RMP-Legs between conditions demonstrated partial support for the experimental hypotheses. That is, when information was given that the impending exercise would be shorter than 20 minutes, the reported pain sensation in the exercising muscle was lower than when the expected duration was comparatively longer than 20 minutes.

#### **5.1.3.2 Sex Effect**

The present experimental design was not intended to examine sex specific effects of knowledge of exercise duration on muscle pain responses. However, differences between knowledge of duration conditions were observed at selected time points for the female sample. In contrast, no differences in the *actual* RMP-Legs were seen between conditions at any measurement time point for the male sample. In both a clinical and research context, it has been noted that females and males perceive pain intensity differently. Females typically rate pain sensations higher than males when performing similar physical activities and when exposed to similar noxious forcing functions (27). It follows that when evaluating expected pain responses to exercise performance, pre-participation knowledge of either the exercise duration or intensity may undergo sex specific neuro-sensory coding. Therefore, the possibility of a sex effect on the influence of knowledge of exercise duration and exercise intensity should be explored in future research that assesses pain responses during prolonged sub-maximal exercise.

### 5.1.3.3 Exercise Modality

A number of previous investigations have examined the effect of knowledge of exercise duration on RPE. This research determined that in a cohort of elite male cyclists, the *actual* RPE did not differ between experimental conditions when subjects were provided incorrect distance feedback during a series of 20-km self-paced time trials (1). The previously reported findings are consistent with the present findings for *actual* RMP-Legs in males. That is, in the present investigation, providing inaccurate information regarding exercise duration did not affect RMP-Legs. Such responses are conceptually similar to that reported by Albertus et al. for perceived exertion (1). Interestingly, these results do not agree with those involving treadmill exercise (10, 52). Both investigations by Baden et al. (10) and Rejeski and Ribisl (52) found that RPE changed when knowledge of exercise duration was experimentally manipulated. This suggests the possible nociceptive influence of muscle recruitment and muscle force required for a given task, i.e. primarily leg muscle recruitment versus upper and lower body muscle recruitment, and also weight bearing versus non-weight bearing exercise. Future research that focuses on neuromuscular factors may help to answer the question of how mode of exercise affects both muscle pain and the role of teleoanticipation in establishing the cognitive set-point for the nociceptive response.

## 5.2 SECONDARY FINDINGS: PREDICTED VS. ACTUAL RMP-LEGS

Secondary hypotheses focused on within group comparisons of *predicted* versus *actual* RMP-Legs. It was hypothesized that the *predicted* RMP-Legs: a) would be more intense than the *actual* RMP-Legs when subjects were told they would exercise for 30 minutes, b) would be less



intense than the *actual* RMP-Legs when subjects were told they would exercise for 10 minutes, and c) would be equally intense as the *actual* RMP-Legs when subjects were provided with accurate knowledge of exercise duration, i.e. 20 minutes.

## **5.2.1 Predicted vs. Actual RMP-Legs – Females**

### **5.2.1.1 ACC-20 Condition**

Subjects who were randomly assigned to the ACC-20 condition were provided with accurate knowledge of the duration of exercise they were about to perform. In the female sample, the *predicted* RMP-Legs was greater than the *actual* ratings at minutes 2, 4, and 6 of the isotime trial. The *predicted* rating matched the *actual* ratings throughout the remainder of the exercise trial. The difference in the *predicted* rating compared to the *actual* ratings observed in the first part of the exercise trial may represent an adjustment period during which the female subject adapted to the intensity of the exercise. With the exception of the ratings corresponding to the first 6 minutes of exercise, the pain responses of the female subjects during the ACC-20 condition agreed with the hypothesis. That is, the *predicted* RMP-Legs was equal to the *actual* RMP-Legs when subjects were provided with accurate knowledge of sub-maximal cycle exercise duration.

### **5.2.1.2 LONG-30 Condition**

Subjects assigned to the LONG-30 condition were provided with false information regarding the duration of the cycle exercise trial they were to perform. The subjects in this condition were told they would be exercising for 30 minutes, when in reality they only performed 20 minutes of cycle exercise. It was hypothesized that the *predicted* pain rating would be greater than the

*actual* ratings given the anticipation of a comparatively long exercise trial. This anticipatory response was observed in the female sample during the first half of the exercise trial. The *predicted* RMP-Legs was greater than the *actual* RMP-Legs at minutes 2, 4, 6, 8, 10, and 12 of exercise. Beginning at the 14<sup>th</sup> minute, the *predicted* and *actual* pain ratings were similar for the remainder of the exercise trial. As such, the greater pain responsiveness reported by the females during the early phase of exercise partially supported the hypothesis. However, the match between the *predicted* and *actual* muscle pain ratings observed for the female subjects during the last portion of the exercise trial was not consistent with the hypothesis. The time-points where the *predicted* RMP-Legs was greater than the *actual* ratings may be due to the subjects adjustment to the exercise intensity. As time progressed, they adapted to the pre-established metabolic demand of exercise resulting in a match between the *predicted* and *actual* muscle pain.

#### **5.2.1.3 SHORT-10 Condition**

Subjects assigned to the SHORT-10 condition were provided with false information regarding the duration of the cycle exercise trial they were to perform. They were told they would be exercising for 10 minutes, when in reality they performed 20 minutes of cycle exercise. It was hypothesized that *predicted* pain responses would be lower than *actual* responses when subjects were told the exercise duration would be comparatively short. In contrast to the hypothesis, *predicted* RMP-Legs was greater than *actual* ratings reported at minutes 2, 12, 14, 16, 18, and 20 of the exercise trial in the female sample. An early phase adjustment may have accounted for the higher pain rating measured at the two minute time point. This initial early phase overshoot in pain response of the female subjects was also noted in the other two conditions. A match between the *actual* ratings and *predicted* rating was observed at minutes 4 through 10 of exercise. However, a mismatch was again observed over the final phase of the exercise trial

where *actual* leg muscle pain ratings were again less than predicted for the female subjects. In general, these findings were not consistent with the hypothesis that when subjects were told the exercise trial would be comparatively short, the anticipated leg muscle pain would be less than the *actual* response.

### **5.2.2 Predicted vs. Actual RMP-Legs – Males**

For the male sample, there were no differences between the *predicted* and *actual* RMP-Legs responses within each of the three knowledge of duration conditions. However, when data were averaged over the three isotime cycle trials to examine the time main effect, the *predicted* leg muscle pain was greater than the *actual* leg muscle pain for the 2 minute and 4 minute measurement time-points. At all other measurement time points, the *actual* RMP-Legs did not differ from the *predicted* RMP-Legs. This early and somewhat isolated elevation of the *predicted* response could be due to the fact that exercise had just begun. In this early exercise period, intensity and/or duration factors had not been cognitively processed and therefore, did not contribute to the leg pain rating. Again, these findings are generally not consistent with the hypothesis. Similar to the findings in the female cohort, it can be speculated that the leg muscle pain responses were are not necessarily influenced by the manipulation of pre-performance knowledge of exercise duration. Rather, they reflect early adjustments to the exercise intensity.

### **5.2.3 Explanatory Mechanism – Overshoot Strategy**

The present hypothesis proposed that either a match or mismatch between an individual's anticipated level of muscle pain and the level of pain that is actually experienced during

prolonged sub-maximal cycle ergometry would be influenced by cognitive awareness of the duration of the exercise to be performed. The nociceptive sensory pathways by which this teleoanticipation mechanism was thought to function were based on theory arising from findings that examined *predicted* and *actual* ratings of both exertional perceptions and muscle pain during constant and variable load exercise paradigms. Previous studies have observed overprediction of RPE and RMP-Legs in both male and female subjects during load incremented exercise (12, 28, 30). However, less is known about *predicted* versus *actual* leg muscle pain responses during a continuous sub-maximal exercise trial. In the present investigation, females in each knowledge of duration condition overpredicted the *actual* leg muscle pain that they experienced during the early phase of the exercise trial. However, the female subjects appeared to attain a sensory match between *predicted* and *actual* responses for the remainder of the exercise trial. This pattern of responsiveness was consistent across conditions. The females in the SHORT-10 condition overpredicted their actual RMP-Legs at the 2 minute measurement time point, achieved a sensory match in RMP-Legs through the 10 minute measurement time point, then again evidenced an overprediction compared to their *actual* RMP-Legs at the 12<sup>th</sup> through 20<sup>th</sup> minute measurement time points. The early phase overprediction observed in the female subjects in all three knowledge of duration conditions may in part be explained by a variant of the perceptual overshoot strategy proposed by Weiser et al. (66). While evaluating responses to a cardiac exercise rehabilitation circuit program, Weiser et al. (66) observed a consistent overshoot in heart rate at the onset (within the first 2 minutes of exercise) when patients were instructed to self-regulate intensity to produce a target RPE of 13 (Borg 6-20 Scale). It was also found that when patients were provided with the opportunity to “ramp up”, or gradually self-regulate up to the RPE of 13 over the initial several minutes of exercise (RPE of

11 for the first 2 minutes, increasing to RPE 13 for minutes 2 through 6), there was a reduced tendency of overshooting target intensity.

The findings of O'Connor and Cook (41) are consistent with Weiser's overshoot strategy. O'Connor and Cook examined the ability of females to maintain an exercise intensity that produced a moderately intense level of muscle pain (41). It was noted that the female and male subjects required approximately the first 4 minutes of the self-regulated exercise trial to achieve a moderately intense level of leg muscle pain. Subsequently, they were able to continue at the prescribed pain intensity for the duration of the exercise trial. The current investigation also employed a moderate exercise intensity, with findings adding support for a sensory overshoot strategy involving pain responsiveness during the first several minutes of an exercise trial. The overshoot strategy may have accounted for the mismatch between the *predicted* and *actual* leg muscle pain experienced by the female subjects during the early phase of prolonged sub-maximal cycle exercise. Depending on knowledge of duration condition however, the predicted vs. actual mismatch was evident for up to 6 minutes into the exercise (i.e. ACC-20), up to 12 minutes into exercise (i.e. LONG-30) and even observed again towards the end of exercise (i.e. SHORT-10). The male sample however, confirmed more closely to Weiser's strategy in that the overpredicted pain response was only evident during the first 4 minutes of exercise. In a somewhat analogous manner, previous research has indicated that females may be more likely to overpredict RPE while males may have a tendency to underpredict RPE (35). As stated previously, although there was no underprediction by the males as observed by Matthews et al. (35), this may indicate sex differences in cognitive anticipation of pain experience when *predicted* leg muscle pain is compared to momentary (*actual*) responses during prolonged sub-maximal exercise.

### 5.3 FINDINGS FOR SESSION RMP-LEGS

#### 5.3.1 Session RMP-Legs – Females and Males

For both females and males, it was hypothesized that in comparison to the *session* leg muscle pain responses for a 20 minute sub-maximal cycle ergometer trial where subjects were given accurate information regarding exercise duration: 1) the *session* leg muscle pain would be greater where subjects were told the exercise duration would be 30 minutes when actually performing for 20 minutes, and 2) the *session* leg muscle pain would be less where subjects were told the exercise duration would be 10 minutes when actually performing for 20 minutes. The *session* rating served as the global measure of leg muscle pain that the individuals experienced during the entire exercise trial. The *session* RMP-Legs was recorded 10 minutes post-exercise. The post-exercise period included 2 minutes of active cool-down followed by 8 minutes of seated rest. The *session* RMP-Legs did not differ between knowledge of duration conditions for either sex. Therefore, in comparison to the 20 minute reference condition, the *session* RMP-Legs were not greater for those subjects who were told they would be exercising for a longer duration, nor were they less for those who were told they would be exercising for a shorter duration. These findings did not support the hypotheses. The mean *session* RMP-Legs for females and males was, respectively,  $3.3 \pm 1.7$  and  $3.9 \pm 1.5$ . The mean *session* RMP-Legs for each knowledge of duration condition were reported previously in the results section (Figure 9 and Figure 12). Regardless of the knowledge of exercise duration, both females and males rated global pain for the entire exercise session as being *moderate* to *somewhat strong*. The findings suggest that the *session* leg muscle pain responses may not be affected by pre-performance knowledge of the duration of exercise to be performed.

### 5.3.2 Explanatory Mechanism – Rebound Effect

The post-exercise measurement of the *session* RMP-Legs may provide valuable prescriptive information regarding the appropriateness of the exercise dosage. It may also allow for more precise cognitive preparation prior to subsequent exercise where intensities are self-regulated to be comfortable for the duration of a prescribed exercise task. These applications can be demonstrated using a match, mismatch paradigm where the *predicted*, *actual*, and *session* pain responses are measured. In a preliminary investigation by Hunt et al. (30) involving recreationally active young adult females, ratings of leg muscle pain were measured during a graded cycle protocol. The *predicted* rating of leg muscle pain was higher compared to the *actual* ratings (30). Interestingly, the *session* RMP-Legs was also higher than the *actual* ratings, but did not differ from the *predicted* rating. Hunt and colleagues described these responses as a “sensory rebound effect” involving exercise-induced pain. The mechanism underlying this sensory rebound is unclear. However, it is speculated that a mismatch between *predicted* and *actual* muscle pain may carry over to the *session* rating. Such a response may be a psychological barrier to adoption of and adherence to physical activity. That is, the *session* response is the last sensory signal to be processed following cessation of the exercise task. If it has “rebounded” to a comparatively elevated level, it is possible that the cognitive set-point for pain expectation during the next exercise session will also be artificially elevated. This in turn, reduces the likelihood of continued participation in subsequent exercise sessions. Such a mechanism provides a theoretical framework for cognitive management of pain expectation that can be included in physical activity intervention strategies that involve personal training and counseling. Individuals may be able to use their *session* pain rating to establish a sensory set-point upon which to match *predicted* and *actual* muscle pain during subsequent exercise sessions. This may

decrease the role of muscle pain as a psychological barrier to exercise participation as well as improve adherence to exercise.

In the present investigation, a rebound effect was not evident for females in any of the knowledge of duration conditions. Summarys of the two-factor mixed model ANOVAs for comparison of *predicted*, mean *actual*, and *session* RMP-Legs for females and males are reported in Appendix H. All conditions evidenced a pre-participation overprediction of pain compared to the *actual* leg muscle pain ratings. However, *actual* ratings were generally similar to *session* ratings, i.e. a *session* rebound was not evident (Figures 13, 14, and 15). The previous research that found a rebound effect of leg muscle pain responses employed a load incremented protocol. No evidence is available regarding a rebound effect of muscle pain as measured by *session* responses to prolonged sub-maximal cycle exercise. However, a perceived exertion analogy is available. Recently, Kilpatrick et al. (32) examined *predicted*, *actual*, and *session* RPE during three, 30 minutes treadmill exercise trials of light, moderate, and vigorous intensity. Results indicated a rebound effect of the *session* RPE for all three sub-maximal intensities. Results also noted that *session* RPE reflected the final exertion rating given during exercise rather than an average of the exertion ratings given throughout the exercise trial. It was concluded that duration of exercise may be setting the level of the *session* RPE during self-regulated, prolonged exercise. Further investigation into the relation of *actual* and *session* muscle pain responses could be helpful in determining the mechanism underlying the absence of rebound effect in the present investigation. The absence of a rebound effect in the females may be a positive finding, indicating that the subjects may be able to accurately report a *session* RMP-Legs in relation to their *actual* responses. This may assist in adjusting *predicted* leg muscle pain responses to match *actual* responses for subsequent exercise. This strategy uses the



teleoanticipation set-point established in the *session* response from the most recently completed exercise task to eliminate the tendency of overprediction in future exercise tasks.

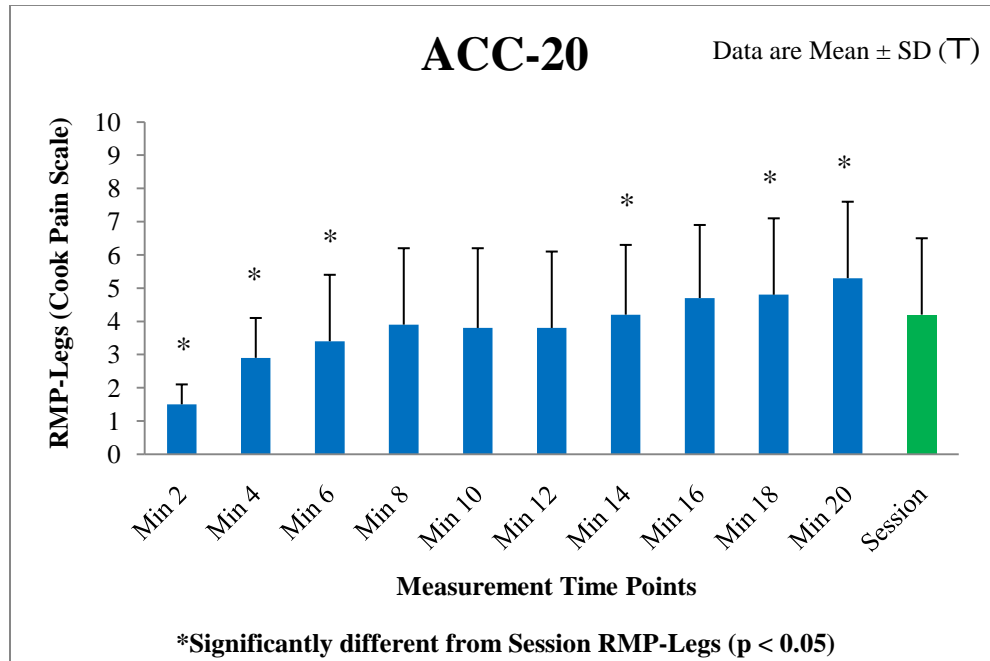


Figure 13. Session vs. Actual RMP-Legs for the ACC-20 Condition – Females

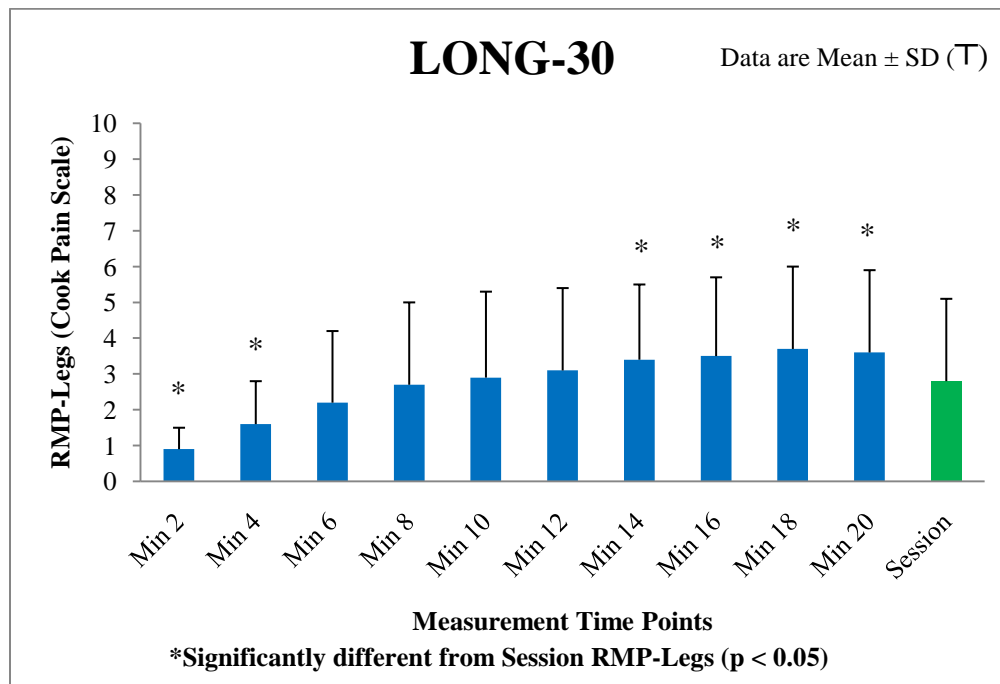
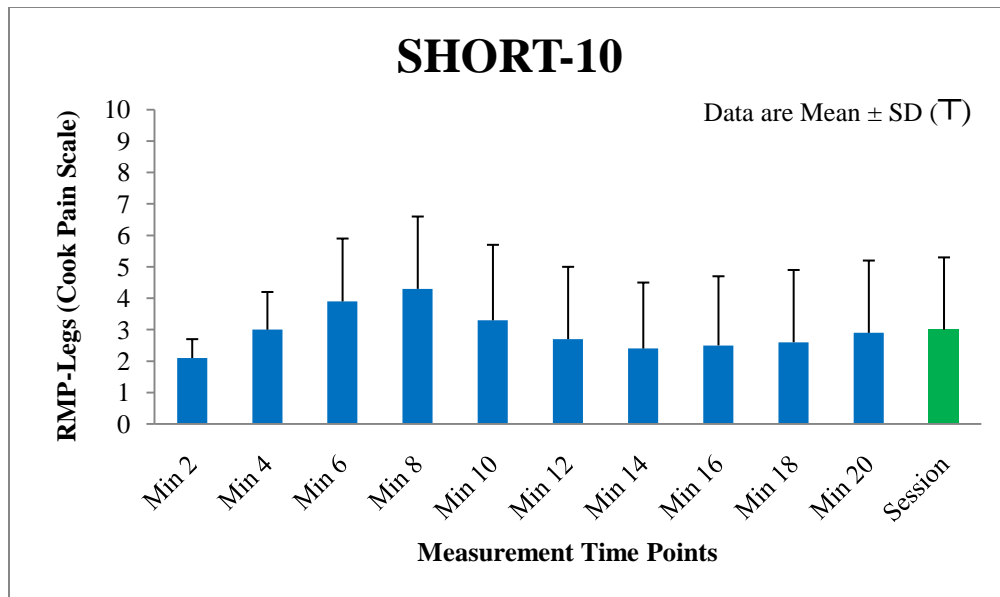


Figure 14. Session vs. Actual RMP-Legs for the LONG-30 Condition – Females



**Figure 15. Session vs. Actual RMP-Legs for the SHORT-10 Condition – Females**

Preliminary research has also examined the *session* pain responses to load incremented exercise in recreationally active males (28). These preliminary findings demonstrated a rebound effect of pain responses in males, similar to the response of females reported by Hunt et al. (30). *Predicted* and *session* pain responses did not differ. However, both measures were greater than the mean *actual* leg pain rating. In a follow-on investigation by Haile et al. (28) involving a load incremented cycle protocol, male subjects overpredicted leg muscle pain in comparison to mean *actual* responses. The *session* responses were also higher than *actual* responses. For the male subjects in the present investigation, the *predicted*, *actual*, and *session* ratings of leg muscle pain did not differ within each of the knowledge of duration conditions. Therefore, no rebound effect was evident for RMP-Legs during prolonged cycle exercise in the male subjects. This suggests that using the *actual* pain rating as a reference, the male subjects were able to accurately rate the global *session* RMP-Legs as shown in Figures 16. Again, this may be a positive finding indicating that the male subjects were able to accurately predict, report, and give a global rating

of leg muscle pain responses. This match allows more favorable expectation and acceptance of the muscle pain to be experienced during subsequent exercise.

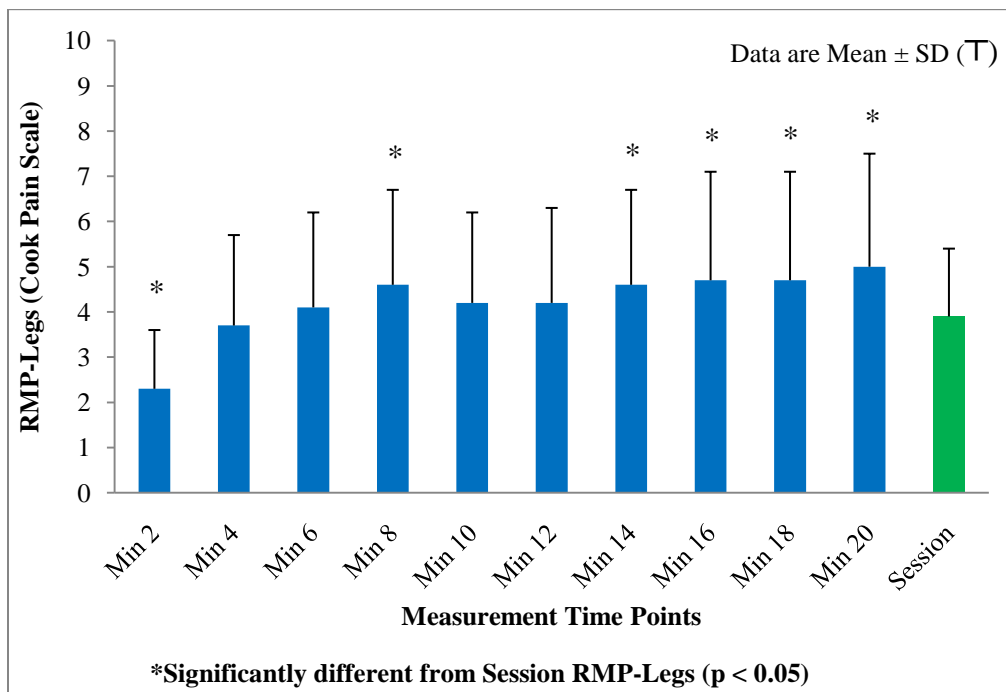


Figure 16. Session vs. Actual RMP-Legs (marginal means) for the Isotime Cycle Trial – Males

## 5.4 CONCLUSIONS

### 5.4.1 Predicted and Actual RMP-Legs – Females

Pre-participation knowledge of exercise duration did not affect *predicted* rating of leg muscle pain reported by recreationally active females. Findings showed partial support for the hypothesis that knowledge of shorter duration (i.e. the SHORT-10 condition) would yield lower *actual* pain ratings compared to knowledge of accurate duration (i.e. the ACC-20 condition). Knowledge of longer duration (i.e. LONG-30) however, did not result in higher *actual* pain

ratings compared to knowledge of accurate duration as suggested by the hypothesis. The overprediction of leg muscle pain ratings observed during the first half of exercise trial for the ACC-20 and LONG-30 conditions was not evident in the second half of the exercise trial. Conversely, with the exception of the first 2 minutes, the overprediction of leg muscle pain ratings was only evident in the final 10 minutes of the exercise trial for the SHORT-10 condition. This suggests that pre-participation knowledge of the duration of the exercise did not evidence a consistent influence on the intensity of pain sensation arising from active muscle during prolonged cycle ergometer exercise at 70%  $\text{VO}_{2\text{peak}}$ . As such the findings provide only limited support of the hypotheses.

#### **5.4.2 Predicted and Actual RMP-Legs – Males**

Knowledge of exercise duration did not affect the *predicted* rating of leg muscle pain reported by recreationally active males. In addition, knowledge of exercise duration did not affect *actual* ratings of leg muscle pain reported by the male subjects. Male subjects reported similar leg muscle pain ratings during exercise regardless of the pre-participation information they were provided regarding the duration of the sub-maximal exercise they were to perform. The *predicted* rating of leg muscle pain was greater than the *actual* pain rating during the first 4 minutes of the exercise trial, and was similar to the *actual* pain rating for the remainder of the exercise trial. These findings for the male subjects suggest that pre-participation knowledge of the duration of the exercise to be performed is not a contributing factor in setting the intensity of pain sensation arising from active muscle during prolonged cycle ergometer exercise at 70%  $\text{VO}_{2\text{peak}}$ . As such, the findings did not support the hypotheses.

### **5.4.3 Session RMP-Legs – Females and Males**

Knowledge of exercise duration did not affect the session rating of leg muscle pain reported by recreationally active males and females. The session leg muscle pain rating was similar regardless of the pre-participation information that was provided regarding the duration of the sub-maximal exercise to be performed. These findings did not support the hypothesis. For both males and females, session and actual ratings of muscle pain were generally similar, possibly indicating a favorable post-exercise anticipatory set-point that promotes future exercise participation.

### **5.4.4 Summary**

The experimental hypotheses for the current investigation proposed that pain responsiveness would be influenced by pre-participation knowledge of exercise duration. However, the findings provided mixed conclusions regarding these hypotheses. Individuals were exposed to a 20 minute sub-maximal cycle exercise trial at a metabolic rate equivalent to 70%  $\text{VO}_{2\text{peak}}$ . This duration and intensity effectively simulated a typical fitness conditioning session and all participants were able to complete the exercise task. The investigation was highly controlled with only knowledge of exercise duration differing between groups. Nevertheless, expectation for variations in leg pain when the exercise was projected to 10 minutes or 30 minutes compared to the group receiving accurate knowledge was not met. The effect of pre-performance knowledge of exercise duration did not appear to be a key factor in setting leg muscle pain responses in recreationally active males and females. It was speculated that knowledge of

exercise intensity may be the comparatively more important factor that drives individuals' leg muscle pain responses during prolonged sub-maximal cycle exercise.

## **5.5 RECOMMENDATIONS**

In light of current findings, future research should focus on the following research areas:

- 1) The time increment between expected exercise durations of 10, 20, and 30 minutes may have been insufficient. A broader range of expected durations (i.e. 20, 40, 60 minutes) may provide a more effective teleoanticipation forcing function to study the effect of knowledge of exercise duration on pain responses.
- 2) The present investigation employed a constant sub-maximal cycle exercise intensity equivalent to 70%  $\text{VO}_{2\text{peak}}$ . This metabolic rate is typically sufficient to produce cardiorespiratory fitness improvements when employed in a conditioning program. Future investigation should examine the effect of knowledge of exercise duration on leg muscle pain during exercise trials of intensity lower and higher than the ventilatory breakpoint (i.e. 50-80%). Such an experimental paradigm will focus on lactacidemia as a nociceptive mediator and identify exercise intensity as a teleoanticipation factor in setting leg muscle pain.
- 3) An a priori determined exercise intensity was used in the current investigation. Knowledge of exercise duration's effects on leg muscle pain may differ when subjects are able to self-select exercise intensity.
- 4) The present investigation examined the effect of knowledge of exercise duration on leg muscle pain responses during prolonged cycle exercise. Other modes of exercise

should be considered for future research to determine influence of muscle recruitment and muscle force required for a given type of exercise, i.e. primarily leg muscle recruitment vs. upper and lower body muscle recruitment, and also weight bearing vs. non-weight bearing exercise. Mode of exercise may impact both muscle pain and the role of teleoanticipation in establishing the cognitive set-point for the nociceptive response.

- 5) Examining leg muscle pain responses over repeated trials involving manipulation of both knowledge of duration and intensity may be necessary to identify factors that individuals use to interpret muscle pain responses when sensory adaptation is a factor.
- 6) Recreationally active females and males participated in the present investigation. Other population subsets should also be studied to investigate the effect of knowledge of exercise duration on muscle pain responses, i.e. individuals with varying levels of cycle exercise experience, sedentary overweight individuals, athletes participating in high intensity exercise, and individuals with chronic pain (i.e. peripheral vascular disease).
- 7) The present investigation focused on between condition differences of *session* RMP-Legs. Further investigations involving the effect of pre-participation knowledge of exercise duration on the relation of *session* and *actual* RMP-Legs should also be considered.
- 8) The possible mitigating effects of sex in studying the role of pre-participation knowledge of exercise duration on muscle pain should be considered in future research designs.

- 9) Examine mood, affect, and enjoyment as interactive factors that influence the effect of knowledge of exercise duration on muscle pain responses.



## **APPENDIX A**

### **RECRUITMENT FLYER**



# University of Pittsburgh

## RESEARCH STUDY

DEPARTMENT OF HEALTH AND PHYSICAL ACTIVITY  
CENTER FOR EXERCISE AND HEALTH-FITNESS RESEARCH

- Now recruiting study participants for 2 separate exercise sessions investigating individuals leg muscle pain responses during cycle exercise.
  - Each session will be no longer than 45 minutes.
  - You will be provided a personal report of your body fat analysis and your aerobic fitness level.
  - Both sessions to be completed within a 5 day period.
  - You will receive \$20.00 upon completion of the study.
- If you are a between the ages of *18 to 30 years* and you participate in recreational activity\*, you may qualify for this study.
- Call 412-648-8251, *Department of Health & Physical Activity*, University of Pittsburgh, or email [CML35@pitt.edu](mailto:CML35@pitt.edu) for more details.

\*Recreational activity: aerobic activity for at least 20 minutes two times per week, for a weekly total of no more than 150 minutes per week. However, no more than 30 minutes of cycle exercise per week.

## **APPENDIX B**

### **SUBJECT RECRUITMENT PACKET**

## B.1 INFORMED CONSENT



University of Pittsburgh

*School of Education  
Health, Physical and Recreation Education  
Center for Exercise and Health-Fitness Research*

A149B Trees Hall  
Pittsburgh, Pennsylvania 15261  
412-648-8251  
Fax: 412-648-7092

## INFORMED CONSENT

**TITLE: EFFECT OF KNOWLEDGE OF EXERCISE DURATION ON PREDICTED, ACTUAL, AND SESSION LEG MUSCLE PAIN DURING CYCLE ERGOMETRY**

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School of Education

**CO-INVESTIGATORS:** Robert J. Robertson, Ph.D.  
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107 Trees Hall  
Pittsburgh, PA 15216  
Phone: (412) 648-8251 Fax: (412) 648-7092  
Email: rrobert@pitt.edu  
Department of Health and Physical Activity  
School of Education

**SOURCE OF SUPPORT:** School of Education Research Grant

### ***Why is this research being done?***

Leg muscle pain is a common sensation felt during moderate intensity exercise. Leg muscle pain is defined as the intensity of pain felt in the upper front leg (quadriceps) muscles of both legs during exercise. Leg muscle pain ratings (RMP-Legs) vary among individuals. It is unknown what impact knowledge of exercise duration (i.e. total exercise time) has on these ratings of leg muscle pain. Therefore, the purpose of this investigation is to examine leg muscle pain responses during different durations (i.e. 10 – 30 minutes) of cycle exercise.

### ***Who is being asked to take part in this research study?***

Thirty-six male and thirty-six female adults (18-30 yrs old) will be recruited as subjects in this research. The research study will last approximately one week. You are being invited to take part in this research study because you are healthy, have normal body weight, and undertake at least 20 minutes of recreational aerobic activity two times per week with a total of less than 150 minutes per week with no more than 30 minutes per week doing cycle/spinning exercise. To minimize risks associated with maximal aerobic exercise testing, you will be asked to complete the Medical History Form and a Physical Activity Readiness Questionnaire (PAR-Q) that contains questions about your current health status. If you have an orthopedic (muscle or bone), cardiovascular (heart), and/or metabolic disease (i.e. coronary artery disease/heart disease), prior myocardial infarction (heart attack), peripheral vascular disease (blockages in legs), chronic obstructive pulmonary disease (lung disease), and diabetes mellitus (high/low blood sugar) and/or if you are knowingly pregnant or you are a current smoker, you will not be eligible to participate in this research study.

### ***What procedures will be performed for research purposes?***

If you decide to take part in this research study, you will be required to complete two separate visits, separated by a 3-4 day period. Each visit will involve a stationary cycle ergometer exercise. The first visit will be a Baseline Graded Exercise Test (GXT) and the second visit will be the Cycle Exercise Trial.

If an abnormal response occurs during exercise, such as chest pain, the test will be immediately stopped and you will be given proper medical attention. Emergency equipment will be available on site for all testing procedures and research staff are certified in CPR and First Aid by the American Red Cross. If you have an abnormal response to the cycle test, you will be told of the findings and will be encouraged to contact your primary care physician.

All procedures will take place in the Human Energy Research Laboratory at the Center for Exercise and Health-Fitness Research (CEHFR) located in Trees Hall at the University of Pittsburgh. All testing sessions will be administered by trained staff members from the CEHFR.

### **Pre-Exercise Procedures:**

1. Before starting the study protocol, you will complete the Medical History Form and a Physical Activity Readiness Questionnaire (PAR-Q). Both forms will take less than five minutes to complete.

2. Prior to the GXT and the exercise trial, a heart rate monitor will be positioned around your chest and secured in place with an elastic strap. Immediately prior to exercise, a rubber mouthpiece, connected to a headset, will be placed in your mouth to determine the amount of oxygen that you use during exercise. A rubber padded clip will be attached to your nose to insure that all the air that you breathe goes in and out through your mouth. Some individuals become anxious when fitted with the nose clip and mouthpiece. If this occurs to you, please inform the individual performing the test and the test will be stopped. Your heart rate and the amount of oxygen that your body uses will be measured during cycle exercise.
3. Prior to the GXT and the exercise trials, you will receive standard instructions on rating your leg muscle pain (RMP-Legs). The investigator will first read to you the following definition of leg muscle pain: "*Leg muscle pain is defined as the intensity of pain you feel in your upper front leg (quadriceps) muscles of both legs during cycle exercise*". A set of instructions on how to use the Cook Pain Intensity Scale during exercise will then be read to you.

### **Trial 1: Fitness Assessment and Baseline GXT**

4. Your body height and weight will be measured using a standard physicians' scale.
5. Body composition will be assessed using a Tanita bioelectrical impedance analyzer (BIA). The BIA is a non-invasive pain-free procedure for measuring your body fat and muscle that transmits a low-grade electrical impulse through the body. You will remove your shoes and socks and stand on the Tanita scale for approximately 10 seconds to obtain body fat assessment. During the body composition measurement there may be a potential for the hair on your arms and legs to stand up.
6. Based on the information you provide on the Medical History Form and PAR-Q, if you do not have any conditions that would limit your ability to exercise, you will complete the first testing session in order to determine your fitness level. You will perform the GXT on a stationary cycle while maintaining a pedal rate of 50 revolutions per minute. The exercise protocol will begin at a low resistance and the resistance will increase every 2 minutes. You will be encouraged to continue until fatigued. However, you may stop the test at any time for any reason.

### **Trial 2: Cycle Exercise Trial**

7. Three to four days after you have completed the baseline GXT, you will return to the laboratory to perform the cycle exercise trial on a stationary cycle.
8. Following a 2-minute warm-up, the exercise trial will consist of between 10 and 30 minutes of continuous cycle exercise. The duration of the exercise trial will be told to you immediately prior to beginning exercise.

***What are the possible risks, side effects, and discomforts of this research study?***

### **Risks of the Graded Exercise Test**

Abnormal responses, such as excessive rises in blood pressure, mental confusion, shortness of breath, chest pain, heart attack, and death, to maximal aerobic exercise tests in young healthy adults are rare, occurring in less than 1% of people (less than 1 out of 100 people tested). However, some common risks, occurring in 1% to 25% of people (1 to 25 out of 100 people tested), of maximal exercise testing include: heavy breathing, dizziness, muscle fatigue, headache, and overall fatigue.

### **Risks of the Study Monitors**

Risk associated with study monitors (e.g. heart rate monitor and mouthpiece) include skin redness, irritation, and chafing.

#### ***What are possible benefits from taking part in this study?***

You will likely receive no direct benefit from taking part in this research study. However, you will receive information regarding your aerobic fitness level, percent body fat, and the importance of promoting your cardiovascular health.

#### ***If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?***

You will be promptly notified if, during the conduct of this research study, any new information develops which may cause you to change your mind about continuing to participate.

#### ***Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?***

Neither you, nor your insurance provider, will be charged for the costs of any procedures performed for the purpose of this research study.

#### ***Will I be paid if I take part in this research study?***

You will be paid \$20 upon completion of both the GXT and the cycle exercise trial. There will be no partial compensation for completion of only the GXT.

#### ***Who will pay if I am injured as a result of taking part in this study?***

University of Pittsburgh researchers and their associates who provide services at UPMC recognize the importance of your voluntary participation in their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research. If you believe that you are injured as a result of the research procedures being performed, please contact immediately the Principal Investigator or one of the Co-Investigators listed on the first page of this form.

Emergency medical treatment for injuries solely and directly related to your participation in this research study will be provided to you by the hospitals of the UMPC.

It is possible that the UPMC may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your research-related injury requires medical care beyond this emergency treatment, you will be responsible for the cost of this follow-up unless otherwise specifically stated below. There is no plan for monetary compensation. You do not, however, waive any legal rights by signing this form.

***Who will know about my participation in this research study?***

Any information about you obtained from this research will be kept as confidential (private) as possible. All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results unless you sign a separate consent form giving your permission (release).

***Will this research study involve the use or disclosure of my identifiable medical information?***

This research study will not involve the use or disclosure of any identifiable medical information.

***Who will have access to identifiable information related to my participation in this research study?***

In addition to the investigators listed on the first page of this authorization (consent) form and their research staff, the following individuals will or may have access to identifiable information related to your participation in this research study:

- Authorized representatives of the University of Pittsburgh Research Conduct and Compliance Office may review your identifiable research information for the purpose of monitoring the appropriate conduct of this research study.
- In unusual cases, the investigators may be required to release identifiable information related to your participation in this research study in response to an order from a court of law. If the investigators learn that you or someone with whom you are involved is in serious danger or potential harm, they will need to inform, as required by Pennsylvania law, the appropriate agencies.
- Authorized people sponsoring this research study, because they need to make sure that the information collected is correct, accurate, and complete, and to determine the results of this research study.



***For how long will the investigators be permitted to use and disclose identifiable information related to my participation in this research study?***

The investigators may continue to use and disclose, for the purposes described above, identifiable information related to your participation in this research study for a minimum of six years after final reporting or publication of a project.

***Is my participation in this research study voluntary?***

Your participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above, is completely voluntary. (Note, however, that if you do not provide your consent for the use and disclosure of your identifiable information for the purposes described above, you will not be allowed, in general, to participate in this research study.) Whether or not you provide your consent for participation in this research study will have no effect on your current or future relationship with the University of Pittsburgh. Whether or not you provide your consent for participation in this research study will have no effect on your current or future medical care at a UPMC hospital or affiliated health care provider or your current or future relationship with a health care insurance provider. If you are a student, the decision to participate or not participate in this study will have no influence on class standing or grades.

***May I withdraw, at a future date, my consent for participation in this research study?***

You may withdraw, at any time, your consent for participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above. Any identifiable research information recorded for, or resulting from, your participation in this research study prior to the date that you formally withdrew your consent may continue to be used and disclosed by the investigators for the purposes described above.

To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form.

Your decision to withdraw your consent for participation in this research study will have no effect on your current or future relationship with the University of Pittsburgh. Your decision to withdraw your consent for participation in this research study will have no effect on your current or future medical care at a UPMC hospital or affiliated health care provider or your current or your future relationship with a health care insurance provider.

***If I agree to take part in this research study, can I be removed from the study without my consent?***

It is possible that you may be removed from the research study by the researchers to protect your safety or if you are unable or unwilling to complete the research protocol.

## **VOLUNTARY CONSENT**

---

All of the above has been explained to me and all of my questions have been answered. I understand that any future questions I have about this research study during the course of this study, and that such future questions will be answered by the investigators listed on the first page of this consent document at the telephone numbers given. Any questions I have about my rights as a research subject will be answered by the Human Subject Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668). By signing this form, I agree to participate in this research study.

\_\_\_\_\_  
Participant's Name (Print)

\_\_\_\_\_  
Participant's Signature

\_\_\_\_\_  
Date

-----

## **CERTIFICATION OF INFORMED CONSENT**

I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits, and possible risks associated with participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise. I further certify that no research component of this protocol was begun until after this consent form was signed.

\_\_\_\_\_  
Printed Name of Person Obtaining Consent

\_\_\_\_\_  
Role in Research Study

\_\_\_\_\_  
Signature of Person Obtaining Consent

\_\_\_\_\_  
Date

## B.2 MEDICAL HISTORY

ID # \_\_\_\_\_

### University of Pittsburgh

### Center for Exercise and Health-Fitness Research

#### MEDICAL HISTORY

	YES	NO
1. History of heart problems, chest pain, or stroke?	_____	_____
2. Increased blood pressure?	_____	_____
3. Any chronic illness or condition?	_____	_____
4. Difficulty with physical exercise?	_____	_____
5. Advice from a physician not to exercise?	_____	_____
6. Recent surgery? (Last 12 months)	_____	_____
7. Pregnancy? (Now or within the last 3 months)	_____	_____
8. History of breathing or lung problems?	_____	_____
9. Muscle, joint, back disorder, or any previous injury still affecting you?	_____	_____
10. Diabetes or thyroid conditions?	_____	_____
11. Cigarette smoking habit?	_____	_____
12. Increased blood cholesterol?	_____	_____
13. History of heart problems in your immediate family?	_____	_____
14. Hernia or any condition that may be aggravated by lifting weights?	_____	_____
15. Do you have any condition limiting your movement?	_____	_____
16. Are you aware of being allergic to any drugs or insect bites?	_____	_____
17. Do you have asthma?	_____	_____
18. Do you have epilepsy, convulsions, or seizures of any kind?	_____	_____
19. Do you follow any specific diet?	_____	_____

Please explain in detail any “YES” answers:

Family History

Has any member of you family had any of those listed above?

### B.3 PAR-Q

ID # \_\_\_\_\_

## University of Pittsburgh Center for Exercise and Health-Fitness Research

### Physical Activity Readiness Questionnaire (PAR-Q)

Now I am going to ask you a few questions to determine if you are eligible to complete the stationary cycle exercise ...

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

2. Do you feel pain in your chest when you do physical activity?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

3. In the past month, have you had chest pain when you were not doing physical activity?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

6. Is your doctor currently prescribing drugs (for example, water pills) for a blood pressure or heart condition?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

7. Do you know of any other reason why you should not do physical activity?

No \_\_\_\_ Yes \_\_\_\_ If yes, specify: \_\_\_\_\_

## APPENDIX C

### RESEARCH DESIGN

<b>TRIAL 1: Baseline Graded Exercise Test (GXT)</b> <ul style="list-style-type: none"> <li>-Informed Consent</li> <li>-PAR-Q</li> <li>-Medical History Form</li> <li>-HT, WT, BMI, Body Fat</li> <li>-Pain scale instructions and low/high anchoring procedures</li> <li>-VO<sub>2</sub> &amp; HR</li> <li>-Predicted, Actual, and Session RMP-Legs</li> </ul>		
<b>TRIAL 2: Subjects randomly assigned into one of the following isotime cycle trials</b>		
<b>1</b> ACC-20* -Instructions: Knowledge of exercise duration (ACC-20)* -VO <sub>2</sub> & HR -Predicted, Actual, and Session RMP-Legs	<b>2</b> LONG-30* -Instructions: Knowledge of exercise duration (LONG-30)* -VO <sub>2</sub> & HR -Predicted, Actual and Session RMP-Legs	<b>3</b> SHORT-10* -Instructions: Knowledge of exercise duration (SHORT-10)* -VO <sub>2</sub> & HR -Predicted, Actual, and Session RMP-Legs
Time: 0 → 7 days	Time: 0 → 7 days	Time: 0 → 7 days
* Counterbalanced; Each experimental trial is 20 minutes in duration. Knowledge of exercise duration is manipulated (accurate (ACC-20), longer (LONG-30), shorter (SHORT-10))		

## **APPENDIX D**

### **INSTRUCTIONS, PROCEDURES, AND DATA SHEETS FOR EXERCISE TRIALS**

## **D.1 LEG MUSCLE PAIN SCALE DEFINITION AND SCALE ORIENTATION**

### **Definition of RMP-Legs:**

Leg muscle pain is defined as the intensity of the pain you feel in your upper front leg (quadriceps) muscles of both legs during cycle exercise.

### **Instructions:**

The scale before you contains the numbers 0 to 10. You will use this scale to assess the intensity of pain in the upper front leg (quadriceps) muscles of both legs during the exercise test. For this task, you are asked to rate the intensity of pain that you feel in your leg (quadriceps) muscles only. Don't underestimate or overestimate the degree of pain you feel, just try to estimate it as honestly and objectively as possible. The numbers on the scale represent a range of pain intensity from very faint pain (number 0.5) to extremely intense pain-almost unbearable (number 10). When you feel no pain in your leg (quadriceps) muscles, you should respond with the number zero. When the pain in your legs (quadriceps) becomes just noticeable, you should respond with the number 0.5. If your leg (quadriceps) muscle pain feels extremely strong such that it is almost unbearable, you should respond with the number 10. You can also respond with numbers greater than 10. If the pain is greater than 10, respond with the number that represents the pain intensity you feel in relation to 10. In other words, if the pain is twice as great then respond with the number 20. Repeatedly during the test, you will be asked to rate the feelings of pain in your leg (quadriceps) muscles. When rating these pain sensations, be sure to attend only to the specific sensations in your leg (quadriceps) muscles and not report other pain you may be feeling (e.g., seat discomfort). It is very important that your ratings of pain intensity reflect only the degree of pain you are feeling in the quadriceps muscles of both legs. Do not use your ratings as an expression of fatigue (i.e. inability of the muscle to produce force) or exertion (i.e. how much effort you are putting into performing the exercise).

Do you have any questions on how to use the scale?

## **D.2 BASELINE GRADED EXERCISE TRIAL (GXT) INSTRUCTIONS**

1. **“Today we ask you to rate the intensity of any leg muscle pain that you feel in both legs during a maximal cycle exercise test. Please rate only the pain intensity that you feel in your upper front leg (quadriceps) muscles of both legs.”**

2. With the Cook Pain Scale in clear view of the subject, read the following instructions:

**“You will ride on the cycle for as long as you can. Every two minutes the resistance on the cycle will increase. Please maintain a pedal rate of 50 rev•min<sup>-1</sup> throughout the test. Use the signal of the metronome and the speedometer display to help keep the proper rate. At the end of each minute we will ask you to rate your feelings of leg muscle pain in both legs. Please point to the number on the scale that represents the intensity of pain in your upper front leg (quadriceps) muscles of both legs. Please give a maximal effort at the end of the test. When you cannot continue or cannot maintain the proper pedal rate for 10 consecutive seconds, the test will be ended.**

**Do you have any questions?”**

3. Once GXT instructions are read to the subject and all questions are answered, while subject is still seated read the following to the subject and record response:

**“How much leg (quadriceps) muscle pain in both legs do you anticipate experiencing during the entire maximal cycle exercise test?”**

In response to the prediction question, if a subject asks about the intensity of the exercise to be performed, the investigator will respond with the following:

**“Rather than be concerned with the test intensity, we would like you to concentrate on test duration only.”**

4. Set cycle seat appropriately for subject and have subject sit on the cycle, attached metabolic headgear and prepare to initiate exercise test. Instruct the subject to begin pedaling at 50 rpm. Begin test. Record RMP-Legs at :45 and 1:45 of each stage by asking the subjects the following:

**“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

After recording RMP-Legs, record HR at :55 and 1:55 of each stage, VO<sub>2</sub> will be recorded at 1:00 and 2:00 of each stage. Also at 1:00 and 2:00 of each stage, give verbal encouragement to the subject by saying:

**“Good Job, Keep it up!”**

\*At 85% max HR give verbal encouragement ad libitum.



REMEMBER: Subject should be unaware of the power output throughout the test.

5. Immediately following test termination, subject should complete a 2 minute cool-down free-wheeling at 0 W. Following a two minute active cool-down at a PO of 0W, have the subject sit for eight minutes then asked them to provide a session pain rating (a total of 10 minutes post-exercise) by reading the following:

**“How much leg (quadriceps) muscle pain in both legs did you actually experience during the entire maximal cycle exercise test?”**

### D.3 BASELINE GRADED EXERCISE TEST (GXT) – FEMALE DATA SHEET

#### Baseline GXT

Date: \_\_\_\_\_

ID: \_\_\_\_\_

CB Code: \_\_\_\_\_

Room Temp: \_\_\_\_\_ °C      Relative Humidity: \_\_\_\_\_ %

Age: \_\_\_\_\_ Height (cm): \_\_\_\_\_ Weight (kg): \_\_\_\_\_ % Fat (BIA): \_\_\_\_\_

Resting Heart Rate (bpm): \_\_\_\_\_ APMHR (bpm): \_\_\_\_\_ 85% APMHR (bpm): \_\_\_\_\_

Pedal Rate = 50 rpm

RMP-Legs Prediction: \_\_\_\_\_

#### Females:

Stage	Time	R	PO		HR	RMP-Legs	VO <sub>2</sub>
	(min)	(kg)	(kgm/min)	(Watts)	(bpm)		(l/min)
I	1	1.0	300	50			
	2						
II	1	1.5	450	75			
	2						
III	1	2.0	600	100			
	2						
IV	1	2.5	750	125			
	2						
V	1	3.0	900	150			
	2						
VI	1	3.5	1050	175			
	2						
VII	1	4.0	1200	200			
	2						
VIII	1	4.5	1350	225			
	2						

Cool-down: 2 min free-wheeling at 0W

Following 8 minutes seated rest: RMP-Legs Session: \_\_\_\_\_

Staff Initials \_\_\_\_\_

#### Ventilatory Breakpoint (from computer)

VO<sub>2</sub>: \_\_\_\_\_ L/min      %VO<sub>2peak</sub>: \_\_\_\_\_      Time: \_\_\_\_\_      PO: \_\_\_\_\_

#### Reminders:

APMHR = 226 – Age  
Pain Measurement @ :45  
HR Measurement @ :55

#### Regression Analysis: @ 70% VO<sub>2peak</sub>

VO<sub>2</sub>: \_\_\_\_\_ L/min      PO: \_\_\_\_\_ W      RMP-Legs: \_\_\_\_\_

## D.4 BASELINE GRADED EXERCISE TEST (GXT) – MALE DATA SHEET

### Baseline GXT

Date: \_\_\_\_\_

ID: \_\_\_\_\_

CB Code: \_\_\_\_\_

Room Temp: \_\_\_\_\_ °C      Relative Humidity: \_\_\_\_\_ %

Age: \_\_\_\_\_ Height (cm): \_\_\_\_\_ Weight (kg): \_\_\_\_\_ % Fat (BIA): \_\_\_\_\_

Resting Heart Rate (bpm): \_\_\_\_\_ APMHR (bpm): \_\_\_\_\_ 85% APMHR (bpm): \_\_\_\_\_

Pedal Rate = 50 rpm

RMP-Legs Prediction: \_\_\_\_\_

#### Males:

Stage	Time	R	PO		HR	RMP-Legs	VO <sub>2</sub>
	(min)	(kg)	(kgm/min)	(Watts)	(bpm)		(l/min)
I	1	1.5	450	75			
	2						
II	1	2.5	750	125			
	2						
III	1	3.5	1050	175			
	2						
IV	1	4.5	1350	225			
	2						
V	1	5.5	1650	275			
	2						
VI	1	6.5	1950	325			
	2						
VII	1	7.5	2250	375			
	2						
VIII	1	8.5	2550	425			
	2						

Cool-down: 2 min free-wheeling at 0W

Following 8 minutes seated rest: RMP-Legs Session: \_\_\_\_\_

Staff Initials

Ventilatory Breakpoint (from computer)

VO<sub>2</sub>: \_\_\_\_\_ L/min      %VO<sub>2peak</sub>: \_\_\_\_\_      Time: \_\_\_\_\_      PO: \_\_\_\_\_

#### Reminders:

APMHR = 220 – Age  
Pain Measurement @ :45  
HR Measurement @ :55

Regression Analysis: @ 70% VO<sub>2peak</sub>

VO<sub>2</sub>: \_\_\_\_\_ L/min      PO: \_\_\_\_\_ W      RMP-Legs: \_\_\_\_\_

## **D.5 PRE-CYCLE TRIAL RMP-LEGS QUESTIONNAIRE**

**1. Are you currently experiencing any leg muscle pain?      Yes    or    No**

(If you answered no, go directly to question #2; if you answered yes, please answer the following before proceeding to question #2.)

**If yes, is the muscle pain due to the previous exercise test?    Yes    or    No**

**If no, please specify what is the cause of your current leg muscle pain:**

**2. Using the scale below, please rate the intensity of any leg muscle pain you are experiencing: \_\_\_\_\_**

0	No pain at all
0.5	Very faint pain (just noticeable)
1	Weak pain
2	Mild pain
3	Moderate pain
4	Somewhat strong pain
5	Strong pain
6	
7	Very strong pain
8	
9	
10	Extremely intense pain (almost unbearable)
•	Unbearable pain

## **D.6 ISOTIME CYCLE TRIAL INSTRUCTIONS**

Prior to the isotime cycle trial, the subject will be asked to rate their current leg muscle pain. If the subject rates any amount of leg muscle pain, the test will be postponed until leg muscle pain is no longer evident. This is to ensure that leg muscle pain ratings provided on the day of testing are solely based on the effects of the experimental trial and not due to other factors (i.e. delayed muscle soreness, injury, accident). If the subject's rating indicates that no leg muscle pain is present in either leg, the exercise trial will be administered according to the experimental protocol.

**“Today we ask you to rate your feelings of leg muscle pain during a 10/20/30\* minute cycle exercise trial. Remember, leg muscle pain is defined as the intensity of pain you feel in your upper front leg (quadriceps) muscles in both legs during cycle exercise. Please rate only the intensity of pain that you feel in the upper front leg (quadriceps) muscles of both your legs.**

**You will ride on the cycle ergometer for 10/20/30\* minutes. Please maintain a pedal rate of 50 rev•min<sup>-1</sup> throughout the exercise trial. Use the beat of the metronome and the speedometer display to help keep the proper pedal rate. You will be asked repeatedly to rate the pain you feel in your upper front leg (quadriceps) muscles of both legs. You will be given a brief warm-up before beginning your exercise trial.**

**Do you have any questions?”**

Once isotime cycle trial instructions are read to the subject and all questions are answered, while subject is still seated read the following to the subject and record response:

**“How much leg (quadriceps) muscle pain in both legs do you anticipate experiencing during the entire 10/20/30\* minute cycle exercise trial?”**

In response to the prediction question, if a subject asks about the intensity of the exercise to be performed, the investigator will respond with the following:

**“Rather than be concerned with the test intensity, we would like you to concentrate on test duration only.”**

Set cycle seat appropriately for subject and have subject sit on the cycle, attached metabolic headgear and prepare to initiate exercise test. Instruct the subject to begin pedaling at 50 rpm. Slowly set the pre-selected power output (50W for females, 75W for males) for the 2 minute warm-up. After the two minute warm-up, cycle break resistance will be set at the subjects initial PO determined from the baseline GXT. Begin the 20 minute exercise trial.

**At 1:45: “Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

**At 1:55: Record HR**

At 2:00: Record  $\text{VO}_2$ .

At 3:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 3:55: Record HR

At 4:00: Record  $\text{VO}_2$ . If the subject exhibits a positive or negative drift in  $\text{VO}_2$  greater than  $150 \text{ ml} \cdot \text{min}^{-1}$ , adjust PO in the appropriate direction (i.e. decreased or increased, respectively), by 25W for males and 13W for females.

At 5:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 5:55: Record HR

At 6:00: Record  $\text{VO}_2$ .

At 7:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 7:55: Record HR

At 8:00: Record  $\text{VO}_2$ . If the subject exhibits a positive or negative drift in  $\text{VO}_2$  greater than  $150 \text{ ml} \cdot \text{min}^{-1}$ , adjust PO in the appropriate direction (i.e. decreased or increased, respectively), by 25W for males and 13W for females.

At 9:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 9:55: Record HR

At 10:00: Record  $\text{VO}_2$ .

At 11:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 11:55: Record HR

At 12:00: Record  $\text{VO}_2$ . If the subject exhibits a positive or negative drift in  $\text{VO}_2$  greater than  $150 \text{ ml} \cdot \text{min}^{-1}$ , adjust PO in the appropriate direction (i.e. decreased or increased, respectively), by 25W for males and 13W for females.

At 13:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 13:55: Record HR

At 14:00: Record  $\text{VO}_2$ .

At 15:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 15:55: Record HR

At 16:00: Record  $\text{VO}_2$ . If the subject exhibits a positive or negative drift in  $\text{VO}_2$  greater than  $150 \text{ ml} \cdot \text{min}^{-1}$ , adjust PO in the appropriate direction (i.e. decreased or increased, respectively), by 25W for males and 13W for females.

At 17:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 17:55: Record HR

At 18:00: Record  $\text{VO}_2$ .

At 19:45: **“Please point to a number on the scale that tells the intensity of pain you are experiencing in your leg (quadriceps) muscles of both legs.”**

At 19:55: Record HR

At 20:00: Record  $\text{VO}_2$ . End of test.

**\*\*REMEMBER: Subject should be unaware of the power output. Be sure not to give any encouragement, reinforcement or direction other than what is as directed on these instructions!!\*\***

Immediately following test termination, subject should complete a 2 minute cool-down free-wheeling at 0 W. Following a two minute active cool-down at a PO of 0W, have the subject sit for eight minutes then asked them to provide a session pain rating (a total of 10 minutes post-exercise) by reading the following:

**“How much leg (quadriceps) muscle pain in both legs did you actually experience during the entire 10/20/30\* minute cycle exercise trial?”**

\* A specific pre-performance knowledge of duration condition has been assigned to that subject will be used in the question, i.e. “10, 20, or 30 minute cycle exercise trial”.

## D.7 ISOTIME CYCLE TRIAL DATA SHEET

### Production Cycle Ergometer Test

Date: \_\_\_\_\_

ID: \_\_\_\_\_  
CB Code: \_\_\_\_\_  
Trial:   A     B     C  

Room Temp: \_\_\_\_\_ °C      Relative Humidity: \_\_\_\_\_ %

Sex: \_\_\_\_\_ Age: \_\_\_\_\_ Resting Heart Rate (bpm): \_\_\_\_\_

#### Estimation

VO<sub>2</sub>: \_\_\_\_\_ +   150   ml/min =

VO<sub>2</sub>: \_\_\_\_\_ -   150   ml/min =

Target VO<sub>2</sub> Range (l/min)

\_\_\_\_\_

\_\_\_\_\_

**RMP-Legs Prediction:** \_\_\_\_\_

Initial 2 minute warm-up: Females = 50W    Males = 75W      Pedal Rate = 50 rpm

**Initial PO:** \_\_\_\_\_      **Adjustment W: 25W for males; 13W for females**

Interval	Time (min)	PO (W)	RMP-Legs	HR (bpm)	VO <sub>2</sub> (L/min)
I	1				
	2				
	3				
	4				
II	5				
	6				
	7				
	8				
III	9				
	10				
	11				
	12				
IV	13				
	14				
	15				
	16				
V	17				
	18				
	19				
	20				

**Cool-down: 2 minutes free-wheeling at 0W**

Following 8 min seated rest:

**RMP-Legs Session:** \_\_\_\_\_

\_\_\_\_\_  
Staff Initials



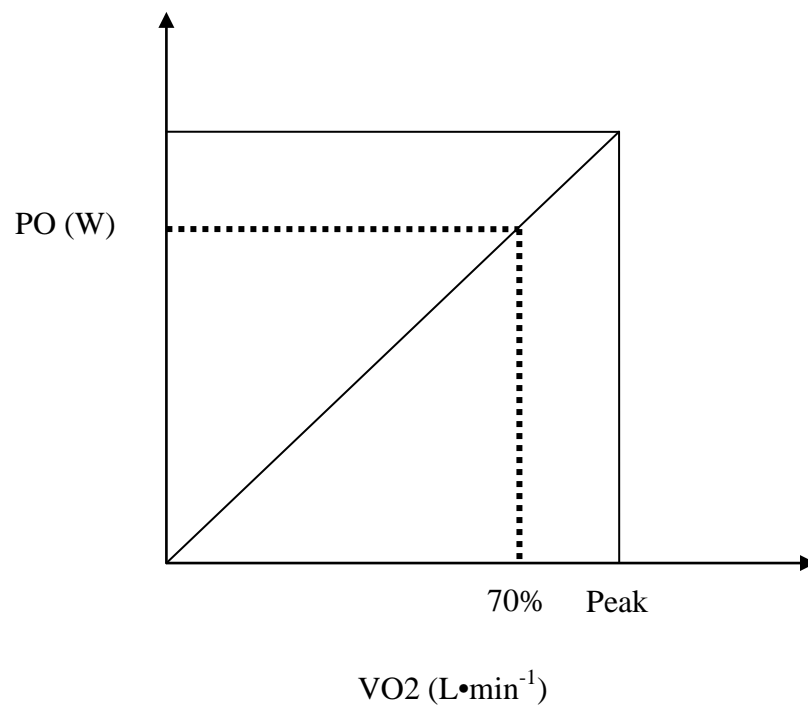
## APPENDIX E

### COOK PAIN INTENSITY SCALE

0	No pain at all
0.5	Very faint pain (just noticeable)
1	Weak pain
2	Mild pain
3	Moderate pain
4	Somewhat strong pain
5	Strong pain
6	
7	Very strong pain
8	
9	
10	Extremely intense pain (almost unbearable)
•	Unbearable pain

## APPENDIX F

### INDIVIDUAL REGRESSION PLOT



## **APPENDIX G**

### **LETTER FROM PRIMARY INVESTIGATOR FOLLOWING STUDY COMPLETION**



# University of Pittsburgh

*School of Education*  
*Health, Physical and Recreation Education*  
*Center for Exercise and Health-Fitness Research*

A149B Trees Hall  
Pittsburgh, Pennsylvania 15261  
412-648-8251  
Fax: 412-648-7092

ID: \_\_\_\_\_

Dear Participant,

In the past few months, you participated in a research study at the Center for Exercise and Health-Fitness Research at the University of Pittsburgh. You visited the laboratory on two separate occasions where you performed one baseline graded exercise test and one cycle exercise trial. Upon completion of your participation, you were compensated with \$20.00.

When you consented to participate in this investigation, you were informed that the purpose of the study was to examine leg muscle pain responses during different durations (i.e. 10 to 30 minutes) of cycle exercise. The *actual* purpose of the investigation was to examine the effect of knowledge of exercise duration on predicted, actual, and session leg muscle pain during cycle ergometry. Due to the true nature of this investigation, deception was used throughout the study in order to determine findings based on specific research questions. In order to produce relevant findings, it was necessary to blind our subjects from the true duration of each exercise trial. You were told that the cycle exercise trial you performed was either 10, 20, or 30 minutes in duration. In fact, all cycle exercise trials performed in this investigation were 20 minutes in duration. It was necessary to use deception in order to determine how knowledge of exercise duration effects an individual's predicted, actual, and session leg muscle pain responses during cycle exercise.

For your additional information, here are the results of your health-fitness status:

Maximal Oxygen Uptake ( $VO_{2max}$ ): \_\_\_\_\_ ml/kg/min

Aerobic Fitness Classification according to sex/age criteria (based on  $VO_{2max}$ ): \_\_\_\_\_

Percent Body Fat (%BF): \_\_\_\_\_ Ideal Range: \_\_\_\_\_

Body Mass Index (BMI;  $kg/m^2$ ): \_\_\_\_\_ Ideal BMI: < 25 is considered normal weight

The findings of this investigation will be analyzed and conclusions will be developed as my doctoral dissertation. Thank you for your participation in this investigation. If you have any further questions, please feel free to contact me at 610-721-7276 or email CML35@pitt.edu.

Sincerely,

Christina M. Ledezma, MS, HFS  
Doctoral Candidate  
Principal Investigator

## **APPENDIX H**

### **Summary Tables of the ANOVAs**

## G.1 DESCRIPTIVE CHARACTERISTICS

**Table 26. Results of the one-factor ANOVAs for Female Subject Characteristics**

Main Effects	df	F	<i>p</i>	$\eta^2$
Age	2	0.054	0.947	0.003
Height	2	3.879	0.031*	0.190
Weight	2	0.599	0.555	0.035
BMI	2	2.715	0.081	0.141
Body Fat	2	0.583	0.564	0.034
VO <sub>2</sub>	2	1.874	0.169	0.102
VO <sub>2</sub>	2	2.662	0.085	0.139
Error	33			

\*Statistically significant (2-tailed).

**Table 27. Results of the one-factor ANOVAs for Male Subject Characteristics**

Main Effects	df	F	<i>p</i>	$\eta^2$
Age	2	0.861	0.432	0.050
Height	2	1.835	0.176	0.100
Weight	2	0.090	0.914	0.005
BMI	2	0.961	0.393	0.055
Body Fat	2	1.511	0.236	0.084
VO <sub>2</sub>	2	1.950	0.158	0.106
VO <sub>2</sub>	2	3.031	0.062	0.155
Error	33			

## G.2 $\text{VO}_2$ and $\% \text{VO}_{2\text{peak}}$

**Table 28. Results of the one-factor ANOVAs for  $\text{VO}_2$  and  $\% \text{VO}_{2\text{peak}}$ : Females**

Main Effects	df	F	<i>p</i>	$\eta^2$
$\text{VO}_2$	2	0.788	0.463	0.046
$\% \text{VO}_{2\text{peak}}$	2	7.312	0.002*	0.308
Error	33			

\*Statistically significant (2-tailed).

**Table 29. Results of the one-factor ANOVAs for  $\text{VO}_2$  and  $\% \text{VO}_{2\text{peak}}$ : Males**

Main Effects	df	F	<i>p</i>	$\eta^2$
$\text{VO}_2$	2	2.166	0.131	0.116
$\% \text{VO}_{2\text{peak}}$	2	0.276	0.761	0.016
Error	33			

### G.3 HR and %HR<sub>peak</sub>

**Table 30. Results of the one-factor ANOVAs for HR and %HR<sub>peak</sub>: Females**

Main Effects	df	F	<i>p</i>	$\eta^2$
HR	2	0.457	0.637	0.027
%HR <sub>peak</sub>	2	0.146	0.864	0.009
Error	33			

**Table 31. Results of the one-factor ANOVAs for HR and %HR<sub>peak</sub>: Males**

Main Effects	df	F	<i>p</i>	$\eta^2$
HR	2	0.750	0.480	0.044
%HR <sub>peak</sub>	2	0.279	0.759	0.017
Error	33			



#### G.4 Predicted, Mean Actual, and Session RMP-Legs

**Table 32. Results of the ANOVA for the Effect of Knowledge of Duration on Predicted, Mean Actual, and Session RMP-Legs for Females**

Main Effects	df	F	<i>p</i>	$\eta^2$
Time (Within)	2	16.097	< 0.001*	0.328
Error	66			
Knowledge (Between)	2	257.301	0.158	0.106
Error	33			
<b>Interaction Effects</b>				
Time x Knowledge	4	0.218	0.928	0.13
Error	66			

\*Statistically significant (2-tailed)

**Table 33. Results of the ANOVA for the Effect of Knowledge of Duration on Predicted, Mean Actual, and Session RMP-Legs for Males**

Main Effects	df	F	<i>p</i>	$\eta^2$
Time (Within)	2	2.026	0.140	0.058
Error	66			
Knowledge (Between)	2	0.398	0.675	0.024
Error	33			
<b>Interaction Effects</b>				
Time x Knowledge	4	0.562	0.691	0.033
Error	66			

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