Chapter 14
Application of Perceptual Models to the Measurement of Pain and Affective Responses to Exercise

Thus far, this laboratory manual has presented the conceptual models, background information, previous literature, and current methodologies for the measurement of perceived exertion responses to exercise. The application of perceptual responses to exercise assessment, prescription and program monitoring has been discussed. The study and development of the perceived exertion knowledge base, however, has expanded over the years to include other perceptual and psychosocial constructs, i.e., naturally occurring muscle pain, affect, and enjoyment. It has been argued that, in addition to an individual's perception of physical exertion, variables such as pain, affect, and enjoyment may play an important role in determining the level of regular PA participation. Part 4 of this manual is titled Applied Perceptual and Psychosocial Research. This, the first chapter in Part 4, presents a series of *power reviews*, or brief summaries of the literature, concerning the measurement of naturally occurring muscle pain, affect, and enjoyment during exercise. Each section of this chapter can be linked retroactively to specific content presented previously regarding perceived exertion. Then, the remaining chapters of Part 4 present more extensive literature reviews for topics that are of growing interest concerning perceptual and psychosocial responses to exercise. These topics include the effects of caffeine supplementation, acute carbohydrate feeding, and music on perceptual, affective, and physiological responses to exercise.

14.1 Application of Perceived Exertion Scaling Procedures to Pain and Affect

See Chap. 5. Perceived Exertion Scaling Procedures.

L. Haile et al., *Perceived Exertion Laboratory Manual*,
DOI 10.1007/978-1-4939-1917-8_14

14.1.1 Comment on Anchoring for Exercise-Induced Pain

Anchoring procedures are not as extensive for measurement of naturally occurring muscle pain during exercise compared to those required for perceived exertion metrics. The memory anchoring procedures can be quite similar for exercise-induced pain as described above for perceived exertion. Prior to exercise, while presenting a standardized instructional set, the individual is asked to think about the pain experienced in the active muscles during previous exercise or physical activity. Then, the individual is asked to remember times when levels of muscle pain equal to the low and high anchor points on the scale were experienced. During subsequent bouts of exercise, the individual is asked to rate muscle pain levels based on the memory of muscle pain at the low and high anchor points.

However, an exercise anchoring procedure cannot be used in conjunction with a pain scale in the same manner that it is used with a perceived exertion scale. The psychophysical concept underlying perceived exertion scale anchoring is based on the predictions of Borg's Range Model. The basic tenets of this model assume that as individuals undertake exercise intensities across their entire performance range they are able to link physiological responses to corresponding and interdependent RPE values. This assumes that maximal RPE (e.g., ten on the OMNI Scale) is linked to attainment of maximal exercise intensity (e.g., POmax, VO_2max, 1RM). However, the achievement of maximal level of exercise-induced muscle pain as required for exercise anchoring procedures is not always possible. In studies by Cook and colleagues (1997, 1998), individuals did not detect muscle pain during load-incremented exercise until they attained 50–60 % of peak exercise capacity, with the pain threshold of some individuals not occurring until 90 %. Peak muscle pain values averaged ~5.5 in females and 8–8.5 in males using the 0–10 Pain Intensity Scale (Cook et al. 1997, 1998). In addition, although an individual may be able to remember a high level of muscle pain sensation experienced during previous exercise, for both clinical and physiological reasons it may not be possible to elicit such a response in certain individuals. Such limitations render the use of exercise anchoring procedures for category pain scales impractical.

14.1.2 Comment on Anchoring for Affective Responses to Exercise

Ratings of affective responses (AR) and PA enjoyment (PAE) during exercise are recognized as psychosocial correlates of perceived exertion. However, category scales to measure these constructs cannot be anchored at very low and very high exercise intensities as is the accepted procedures when anchoring an RPE scale. Individuals cannot be instructed to link AR or PAE values to any specific exercise intensity because these responses have been uniquely shaped over time in each individual. Previous PA experience, subjective behavioral norms, and values pertaining to

PA adherence can vary greatly between individuals. This can result in interindividual differences between specific psychosocial domains that dominate the affective and enjoyment experience to exercise intensity.

Research results are conflicting regarding the intensities of exercise that result in the most positive AR during exercise. Kirkcaldy and Shephard (1990) proposed an inverted-U paradigm, predicting that moderate intensity exercise produces an optimal AR. Similar findings have been reported by Moses et al. (1989). Low exercise intensities may be insufficient to evoke positive changes in AR and high exercise intensities may produce significant negative shifts in AR. More recent evidence refutes this relation such that both high (Tate and Petruzzello 1995) and low intensity (Ekkekakis et al. 2000) exercise programs have led to positive changes in AR.

Ekkekakis' (2003) "dual-mode" model explains the interindividual variability in AR that occurs across exercise intensities, specifically as it relates to the anaerobic threshold (AT). The AR during low to moderate intensity exercise (i.e., below the AT) is primarily shaped by cognitive processes that are unique to the individual. Above the AT, interoceptive cues driven by the increasing demand for energy supplied by anaerobic pathways dominate the AR. Therefore, AR at exercise intensities at or somewhat below the AT are rather heterogeneous, but AR at exercise intensities above the AT become increasingly less positive/more negative and are relatively homogeneous (Ekkekakis 2003; Ekkekakis et al. 2005; Hall et al. 2002).

Research has confirmed the marked interindividual differences in AR during exercise intensities below the AT, especially involving moderate intensity exercise. In a study by Van Lunduyt and colleagues (2000), participants estimated AR during moderate intensity cycle exercise (60 % VO_2peak). Results indicated that 44.4 % of subjects experienced an increase in AR, 41.3 % experienced a decrease in AR, and 14.3 % experienced no change in AR. Other studies have confirmed the shift from heterogeneity in AR at intensities below the AT to homogeneity in AR above the AT. In response to separate 15-min bouts of treadmill exercise, 47 % of subjects exhibited a decline in AR at intensities below the ventilatory threshold (VT) and 80 % of subjects exhibited a decline in AR at intensities above the VT (Ekkekakis et al. 2005). Similar results were found in response to 20 min of treadmill exercise. AR was more positive and stable below the AT with only 25 % of subjects exhibiting a decline in AR during performance at these intensities. Above the AT, 83 % of subjects exhibited a negative shift in AR (Parfitt et al. 2006).

14.1.3 Scaling Procedures: Practice and Feedback for Perceptual and Affective Variables

When exercise-induced muscle pain or affect are part of a perceptual research paradigm, it may be beneficial to ask the individual to practice rating these variables along with perceived exertion during exercise anchoring procedures or a practice exercise test. This will allow the individual to practice rating all three of these independent constructs within a close time-frame during exercise. In addition, such orientation procedures present an opportunity to provide feedback to an individual prior to fitness testing or experimental exercise procedures regarding psychophysical appropriateness of his/her rating responses. It may be especially beneficial for children, enabling them to more accurately link the exercise intensity range to their own pain and affective experience (Robertson et al. 2009).

14.2 Validation of Scales for Measuring Pain and Affect During Exercise

See Chap. 6. Perceived Exertion Scale Validation.

14.2.1 Validity of Exercise-Induced Pain Scales

The neurophysiological mechanisms for naturally occurring, exercise-induced pain in healthy, uninjured individuals involve stimulation of mechanical and biochemical nociceptive systems in skeletal muscle. Pain threshold is defined as the onset of pain sensation and varies between individuals. Once pain threshold is reached, ratings of exercise-induced muscle pain should increase with physical measures of exercise intensity, such as PO and weight lifted. This measure of pain sensation occurs in conjunction with the accumulation of noxious by-products of metabolism such as blood lactate, hydrogen ions, and bradykinin, all of which increase as a function of increasing exercise intensity. Early exercise-induced muscle pain studies used the Borg (0–10) CR10 Scale to measure “aches and pain in the legs” during load-incremented and constant PO cycle exercise (Borg et al. 1985; Ljunggren et al. 1987). The investigations demonstrated evidence of concurrent validity of the CR10 Scale to measure pain sensations. Pain ratings were moderately correlated to blood lactate concentration at high PO’s during load-incremented exercise, with $r=0.45$ at 200 W and $r=0.39$ at 240 W (Borg et al. 1985), and at the end of constant PO exercise, with $r=0.54$ (Ljunggren et al. 1987).

Later studies confirmed concurrent validity of the Pain Intensity Scale developed by Cook and colleagues (1997). The Pain Intensity Scale employs construct-specific verbal descriptors that are linked to the same numerical categories as appear on the original Borg CR10 Scale. In Cook’s investigation, pain ratings increased as a positively accelerating function of exercise intensity once pain threshold was achieved. It was noted that pain threshold ranged from 9 to 95 % of POpeak, indicating marked interindividual differences during load-incremented cycle ergometry (Cook et al. 1997, 1998). Mean pain threshold was ~50 % POpeak in males (Cook et al. 1997, 1998) and ~60 % POpeak in females (Cook et al. 1998). In males, pain ratings derived from the Pain Intensity Scale increased from a mean of ~2 at 60 % of POpeak to ~8–8.5 at 100 % of POpeak. In females, pain ratings increased from a mean of ~1 at 60 % of POpeak to ~5.5 at 100 % of POpeak

(Cook et al. 1997, 1998). Robertson and colleagues (2009) developed the OMNI-Muscle Hurt Scale to measure exercise-induced muscle pain in children. This investigation found evidence for concurrent scale validity during isotonic resistance exercise performed by young children. High correlations were exhibited between weight lifted and pain ratings for biceps curl resistance exercise and knee extension resistance exercise, with r values across sets ranging from 0.67 to 0.87 (Robertson et al. 2009). In addition, construct validity was evidenced in Cook's original study using the Pain Intensity Scale during load-incremented cycle exercise. High correlations ranging from $r = 0.79–0.94$ were found at intensities from 60 to 100 % POpeak (Cook et al. 1997).

14.2.2 Construct Validity Evidence for the Feeling Scale

Hardy and Rejeski (1989) demonstrated both construct and content validity of the Feeling Scale (FS) in college-aged males and females. The Multiple Affective Adjective Checklist (MAAC) employs a set of 132 adjectives. Subscales of the MAAC were used to compute criterion scores for both positive and negative affect. One group of subjects was instructed to choose adjectives describing a good feeling during exercise, while the other group chose adjectives describing a bad feeling during exercise. The results of the study found that subjects identified different affective states having good and bad feelings during exercise. The AR appropriately represented items at either end of the pleasure–displeasure continuum. The differentiated AR continuum was seen in 97 % of subjects who were asked to identify adjectives matching bad feelings and 94 % of subjects asked to identify adjectives matching good feelings (Hardy and Rejeski 1989). Kenney and colleagues (1987) conducted an investigation that also provided construct validity evidence for the FS in college-aged females. The study involved a cognitive-behavioral distress management training (DMT) program. The DMT program was administered to half of the participants between separate treadmill exercise bouts performed to exhaustion. The subjects who were administered the DMT program rated a more positive AR than subjects who did not receive the DMT when measures were obtained at the end of the treadmill run to exhaustion. However, RPE values were similar between subject groups (Kenney et al. 1987).

14.2.3 Validity of Enjoyment Measures during Exercise

A few investigations have tested the validity of recently developed single-item PA enjoyment (PAE) scales (Haile et al. 2012; Stanley et al. 2009). These investigations correlated PAE ratings with AR measured using the FS. During both a load-incremented cycle ergometer protocol terminating at VO_2peak (Haile et al. 2012) and during a 20-min moderate intensity constant load cycle ergometer protocol

(Stanley et al. 2009), significant positive relations were demonstrated between PAE and FS responses. In the investigation by Haile et al. (2012), PAE was measured using an 11-category scale that used the same format as the FS, with responses ranging from −5 to 5. The observed correlation coefficient between PAE and FS ratings was $r = 0.92$. In the investigation by Stanley et al. (2009), PAE was measured using a seven-point scale that employed a format different than the FS. The observed correlation coefficients between PAE and FS ratings ranged from $r = 0.48$–0.55.

The comparatively higher correlation coefficients reported by Haile et al. (2012) may be due to their use of a scale with similar format for the measurement of both AR and PAE. This argument has been employed to avoid the measurement of independent perceptual constructs using the same scale (Cook et al. 1997). For example, previous investigations measured both perceived exertion and pain during exercise using the CR10 Scale (Borg et al. 1985; Ljunggren et al. 1987). The resultant high correlation coefficients between RPE and pain intensity ratings may have been a "*demand artifact*" resulting from use of the same perceptual scale format to measure the two independent perceptual constructs (Cook et al. 1997). AR and PAE cannot be labeled as independent constructs similar to perceived exertion and pain. Rather, PAE is a specific domain of overall affect that may dominate the AR to exercise in many individuals. In addition, the PAE rating scale, although having a similar format to the FS, has verbal descriptors specific to enjoyment (Haile et al. 2012). Regardless, since acute exercise enjoyment is a novel construct, further research is necessary to study the measurement of AR and PAE simultaneously during exercise. In some populations in which enjoyment is a primary mediator of the overall affective experience during PA, it may be appropriate to measure PAE only.

14.3 Target Pain and Affect Ratings for Exercise Intensity Prescription

See Chap. 7. Target RPE at the Ventilatory Threshold.

14.3.1 Target Pain Ratings for Exercise Prescription

Symptomatic pain has been used routinely to identify tolerable limits of exercise for clinical populations such as those with peripheral artery disease who experience intermittent claudication in active limbs. However, little research has focused on the use of exercise-induced pain as a target for exercise intensity prescription. O'Connor and Cook (2001) had young female adults perform 20 min of cycle ergometer exercise at a target muscle pain intensity rating of 3 on Cook's (1997) 0–10 Pain Intensity Scale. A rating of 3 corresponds to the verbal descriptor "moderate pain." On average, the target level of muscle pain was associated with a relative aerobic metabolic rate of 73.9 % VO_2peak at 6 min of continuous exercise, decreasing to 68.5 % VO_2peak at 20 min (O'Connor and Cook 2001).

The long-term adherence to exercise prescriptions that are based on muscle pain response are unknown. Pain experience of any kind during exercise may be a major factor contributing to sedentary behavior in many individuals. Therefore, prescribing exercise at intensities below the individual's pain threshold may promote adherence to PA programs. However, previous research has found great interindividual variability in the pain threshold, as evoked during exercise. This makes it difficult to identify a group-normalized pain response that corresponds to a target physiological outcome and applies to a variety of activities for a wide range of individuals in a manner such as been shown for the RPE at the VT (Goss et al. 2003). Studies by Cook and colleagues (1997, 1998) determined that the pain threshold during load-incremented exercise occurred at 50–60 % of peak exercise capacity, but values ranged from 9 to 95 % of POpeak. Therefore, exercise intensity prescription based on pain ratings should take an individual approach, recognizing that the procedure may not be appropriate in those with a low pain threshold. Athletes performing high intensity exercise in which exercise-induced muscle pain is expected are a healthy population for which the prescription of exercise intensity using target muscle pain ratings has the most utility.

14.3.2 Target AR for Exercise Intensity Prescription

It has been shown that the amount of time spent during a given situation can depend on the affect experienced during the activity (Emmons and Diener 1986). Therefore, the acute AR to an initial exercise performance may influence future exercise participation. Exercise perceived as feeling pleasant may promote future participation. On the other hand, exercise perceived as feeling unpleasant could decrease future participation or lead to withdrawal from the activity altogether (Parfitt et al. 2006). The goal, then, is to maximize the positive AR that an individual experiences during exercise. This goal recognizes that a positive affective experience is an important link in the chain between exercise adoption and maintenance (Van Lunduyt et al. 2000).

A study by Da Silva and colleagues (2011) determined the AR corresponding to exercise intensities spanning the VT in sedentary normal weight, overweight and obese women. This application of the AR in exercise prescription was similar to methods used for calculation of RPE-VT. FS ratings were assessed throughout a graded treadmill exercise test to measure VO_2max. The FS ratings corresponding to 90 %, 100 % and 110 % of the VT were identified. Group average FS ratings for the entire sample were ~2.7, ~1.6, and ~0 corresponding to exercise intensities at 90 %, 100 % and 110 % of the VT, respectively. The AR were similar between normal weight and overweight groups at each intensity. The FS ratings were approximately 3, 2, and 1 at 90 %, 100 % and 110 % of the VT, respectively. The obese group had similar FS ratings to the normal weight and overweight groups at 90 % of the VT, but their ratings were significantly less positive at 100 % of the VT (mean FS rating = 0.5) and 110 % of the VT (mean FS rating = −1.95). These data indicate a positive affective experience at intensities spanning the VT in sedentary normal weight and overweight women, but obese women may require exercise intensities below the VT to experience positive AR (Da Silva et al. 2011). It must be noted that there was considerable variability in FS responses at each intensity, so even when the average FS rating was positive some subjects rated a negative affective experience. In addition, these data were collected during graded treadmill exercise, unlike normal continuous intensity or interval exercise bouts prescribed for health-fitness benefits.

Performing at exercise intensities that span the VT has resulted in significant changes in FS ratings during exercise. Ekkekakis and colleagues (2008) studied the AR of young adults during 15 min of continuous treadmill exercise at intensities corresponding to the VT, 20 % below the VT, and 10 % above the VT. In the condition where intensity was below the VT, 50 % of subjects experienced no change in AR throughout exercise while 43 % experienced a decrease in AR. At intensities equal to and above the VT, 77 % and 80 % of subjects experienced a decrease in AR throughout exercise, respectively. In every condition, however, a small number of subjects experienced an increase in AR during exercise (Ekkekakis et al. 2008).

The identification of a group-normalized AR at the VT may prove difficult for exercise intensity prescription due to the marked interindividual variability in AR across exercise intensities. This wide response variability is similar to that evidenced for exercise-induced pain ratings. The variability in AR is especially evident during moderate intensity exercise (Van Lunduyt et al. 2000). It is of note that moderate intensity exercise is recommended by professional organizations as the optimal level for PA programs designed to produce health-fitness benefits (ACSM 2013). According to Ekkekakis' "dual-mode model," exercise intensity above the VT results in the lowest interindividual variability in AR. This is due to the comparative dominance of noxious properties of physiological signals over cognitive processes in shaping the affective experience. Unfortunately, the comparatively more homogenous AR to exercise above the VT is typified by progressively more negative feelings (Ekkekakis et al. 2005). A negative AR during exercise indicating a displeasurable experience most likely contributes to poor program adherence.

Various investigations have shown that optimal AR may occur at low, moderate, or even high exercise intensities (Ekkekakis et al. 2000; Moses et al. 1989; Tate and Petruzzello 1995). As such, the development of an exercise prescription using AR measured separately for each individual may be a necessary approach to maximize PA adherence. Exercise prescriptions should identify the appropriate exercise intensity by choosing a target HR or RPE based on the optimal AR, or even by prescribing exercise intensity using a target FS rating. Rose and Parfitt (2008) asked sedentary women to perform separate 30-min treadmill exercise bouts at target FS ratings of 1 and 3. On average, the women chose an exercise intensity similar to the VT for both target FS ratings, indicating that the women felt the treadmill exercise was pleasurable (Rose and Parfitt 2008). The implications for program adherence using prescribed target FS ratings are unknown, but hold promise from a public health perspective. Monitoring and adjusting PA programs to continually optimize AR may be necessary to promote long-term habitual PA participation.

14.4 Estimation–Production Paradigm and Exercise Intensity Self-Regulation Using Pain and Affect

See Chap. 9. The Estimation–Production Paradigm for Exercise Intensity Self-Regulation.

14.4.1 Use of the Estimation–Production Paradigm for Exercise-Induced Pain

An estimation–production prescription paradigm has been used to assess the validity of exercise intensity self-regulation using ratings of exercise-induced muscle pain intensity (O'Connor and Cook 2001). This prescription procedure recognizes that normally occurring muscle pain during exercise may be an appropriate cue upon which to self-regulate exercise intensity for healthy, injury free individuals. The paradigm employed in the investigation by O'Connor and Cook (2001) differed from investigations of prescription congruence using a target RPE in that physiological responses were not compared between estimation and production protocols. Rather, the estimation trial had two purposes: (1) to allow subjects to experience the range of perceptual responses for both quadriceps muscle pain and RPE from very low to very high cycle ergometer exercise intensity, and (2) to measure the PO that corresponded to the subjects' pain threshold, which was used as the initial intensity during the production protocol (O'Connor and Cook 2001).

It has been proposed that mechanisms underlying exercise-induced muscle pain involve noxious chemical by-products of metabolism, such as bradykinin and hydrogen ions. These by-products will accumulate as exercise duration increases, intensifying muscle pain. As such, sustained exercise at an intensity above the pain threshold may result in an increase in ratings of muscle pain intensity. To maintain a specific pain rating, then, would require a gradual decrease in exercise intensity over time. Over prolonged exercise periods at a moderate pain intensity level, it would be expected that physiological variables such as VO_2 and HR would be lower during the production trial than the estimation trial.

O'Connor and Cook (2001) asked college-aged female subjects to produce a moderate muscle pain intensity level equivalent to a category 3 on the Cook (1997) Pain Intensity Scale during 20 min of cycle ergometry. On average, the women achieved the desired pain intensity level by minute 4, then decreased power output almost 16 % throughout the remaining 16 min of the production trial in order to maintain the target pain level. Moderate pain intensity was associated with an average RPE of approximately 14–15 on the Borg Scale and 70–75 % VO_2peak (O'Connor and Cook 2001).

Due to the interindividual variability in pain intensity responses, as well as differing affective components of pain, exercise intensity prescription based on muscle pain may not be appropriate for some. However, athletes accustomed to experiencing naturally occurring muscle pain during high intensity exercise may find it useful to self-regulate exercise intensity according to a pain intensity scale. Others may prefer to exercise at an intensity below the pain threshold. Identifying the highest exercise intensity an individual can perform without experiencing muscle pain may be a method to improve PA participation. However, some individuals may experience their pain threshold at exercise intensities below the physiological threshold required to produce health-fitness benefits. The measurement of exercise-induced muscle pain during a GXT, along with measurements of RPE and AR, can provide the necessary information to prescribe exercise intensity to optimize PA program adherence.

14.4.2 Exercise Intensity Self-Regulation Using AR

An estimation–production prescription paradigm has been used to assess the validity of exercise intensity self-regulation using FS ratings of AR measured during single exercise bouts (Rejeski et al. 1987; Rose and Parfitt 2008). Affect is a psychosocial construct that mediates the perception of physical exertion. As such, it is an appropriate cue for exercise intensity prescription, ultimately promoting optimal adherence to PA programs. Rose and Parfitt (2008) conducted an investigation in which an estimation protocol was used to familiarize sedentary female subjects with use of the FS and Borg Scale prior to the performance of eight 30-min production protocols over the course of 4 weeks. During four consecutive production protocols, subjects were asked to produce a target FS rating of 1 (fairly good). During the other four consecutive production protocols, subjects were asked to produce a target FS rating of 3 (good). The purpose of four consecutive production protocols for each target FS rating was to test the reproducibility of exercise intensity self-regulation using FS ratings of AR (Rose and Parfitt 2008). However, physiological responses were not compared between estimation and production protocols, negating the opportunity to assess prescription congruence. For each target FS rating, subjects consistently self-regulated exercise intensity across trials. A FS rating of 1 was associated with a group average of 68 % HRmax and Borg Scale RPE of 12. A FS rating of 3 was associated with a group average of 64 % HRmax and RPE of 11.4. Interestingly, the difference between feeling “fairly good” and “good” during exercise was represented by 4 HRmax percentage points and less than one Borg Scale RPE numerical category. This indicates that changes in overall AR can be caused by very small changes in exercise intensity (Rose and Parfitt 2008), with some individuals having a more sensitive AR to exercise than others. This highlights the utility of measuring AR, and even possibly enjoyment during exercise, in order to determine appropriate exercise intensity for PA particiption. For example, using a response-normalized perceptual response to prescribe exercise intensity such as an RPE-VT of 13 on the Borg Scale could result in negative FS ratings in some individuals but positive FS ratings in others. Prescribing intensity based on the specific RPE at which positive AR was experienced during an estimation trial, or by using FS ratings directly such as in the study by Rose and Parfitt (2008), may be a practical method to promote exercise adherence. In addition, using VO_2 estimated from

ACSM metabolic equations, subjects produced intensities averaging greater than the VT for FS ratings of both 1 and 3 (Rose and Parfitt 2008). Therefore, this prescription method may be effective for promoting health-fitness benefits as well.

14.5 Interval Exercise Prescription Using Pain and Affect

See Chap. 10. Exercise Intensity Self-regulation for Interval Exercise.

14.5.1 Regulation of Aerobic Interval Exercise Using Target Exercise-Induced Pain Ratings

O'Connor and Cook (2001) conducted an investigation in which the Pain Intensity Scale was used by females to produce a cycle ergometer exercise intensity corresponding to a target pain rating of 3, indicating moderate intensity pain. The target pain rating was achieved after approximately 4 min of exercise, whereupon the women gradually decreased power output to maintain the target pain rating throughout the remainder of the 20-min exercise bout. The self-regulated intensity corresponded to 68–74 % VO_2peak and Borg Scale RPE's of 14–15 (O'Connor and Cook 2001). These responses indicate that exercise intensity self-regulation using target pain ratings can be a model for an effective exercise program.

Prescribing multiple target pain ratings to regulate an interval exercise format should also be explored. Even though popular exercise programs and video programs promote exercise using phrases like "feel the burn" and "no pain no gain" (Cook et al. 1997), some individuals may not be comfortable exercising at a moderate pain intensity for prolonged periods, such as the 20-min exercise bout used by O'Connor and Cook (2001). Therefore, prescribing exercise intensity using an interval format may be more appropriate for these individuals. For health-fitness programming, exercise bouts could be prescribed using comparatively higher intensity intervals corresponding to moderate pain intensity, such as a 3 on the Pain Intensity Scale or a 4 on the Children's OMNI Muscle Hurt Scale. These exercise intervals are interspersed with active recovery phases performed at intensities below the pain threshold, i.e., pain ratings of 0. The duration of higher intensity intervals could be adjusted based on the individual's tolerance to exercise-induced pain.

14.5.2 Aerobic Interval Exercise: Intensity Discrimination Using AR

Rose and Parfitt (2008) used an estimation–production paradigm to assess the validity of exercise intensity self-regulation using target ratings of AR, specifically the target FS ratings 1 (fairly good) and 3 (good). Sedentary women were asked to produce each target FS rating on four separate occasions while performing 30 min of treadmill exercise each session. On average, self-regulated exercise intensity at a target FS rating of 1 was associated with 68 % HRmax and Borg Scale RPE of 12, while the target FS rating of 3 was associated with 64 % HRmax and RPE of 11.4 (Rose and Parfitt 2008). Statistically, these differences in % HRmax and RPE between target FS ratings 1 and 3 were significant, and therefore can be considered evidence for subjective intensity discrimination. From a practical standpoint, a difference of 4 % of HRmax and less than one numerical RPE category, while statistically significant, may not be functionally important. Nevertheless, these results indicate that small changes in exercise intensity can be quite important in altering the affective exercise response. These relatively small changes in HR and perceived exertion represented the difference between feeling "fairly good" and "good" during four 30-min bouts of exercise for each condition. Using ACSM metabolic equations to estimate VO_2, the investigators found the produced intensities to be slightly higher than the group average VT (average of 6 % for FS rating 3, 8 % for FS rating 1) (Rose and Parfitt 2008). At intensities near the VT, substantial changes in the physiological milieu occur that may result in a heightened sensitivity to changes in AR.

The study by Rose and Parfitt (2008) demonstrated that individuals can self-regulate exercise intensity using target FS ratings. In addition, FS ratings of 1 and 3 were both associated with an exercise intensity slightly above the VT. This result is in line with previous research in which subjects were asked to self-select exercise intensity for use during a cardiorespiratory conditioning program. On average, subjects chose intensities near the VT eliciting positive FS ratings between 2 and 4 (Lind et al. 2005; Parfitt et al. 2006; Rose and Parfitt 2007). This indicates that self-regulating exercise intensity based on target AR can yield an effective exercise program from both a physiological and psychological standpoint. Identifying exercise intensities that "feel good" may be an important characteristic to promote long term adherence to an exercise program. Therefore, an aerobic interval exercise program based on target FS ratings could also be effective in promoting health-fitness outcomes. Choosing FS ratings that correspond to target interval intensities may be difficult for some individuals, especially those who exhibit little change in FS ratings during load-incremented exercise. In addition, due to the marked interindividual differences in AR, especially at exercise intensities at or below the VT, an individual approach to determining target FS ratings may be best. Since many individuals provide increasingly negative FS ratings as exercise intensity exceeds the VT, intervals may have to include both positive target FS ratings (for lower intensities) and negative FS ratings (for higher intensities).

14.5.3 Effect of Aerobic Interval Exercise on AR and PAE

A lack of exercise-related enjoyment has been cited as a major barrier to regular PA participation (Trost et al. 2002). The variations in exercise intensity during aerobic interval exercise may be seen as more enjoyable than traditional, continuous, moderate intensity exercise prescriptions, especially for children. Children are more accustomed to spontaneous PA, such as encountered during sports and unstructured games during recess or after school. These activities involve short bouts of high intensity exercise interspersed with longer periods of light to moderate intensity exercise rather than continuous exercise for a prolonged period (Crisp et al. 2012a, 2012b). Interval exercise results in more enjoyment during exercise in both adults and children participating in a wide range of activities.

Bartlett and colleagues (2011) compared enjoyment responses between high intensity interval running with continuous moderate intensity running in recreationally active men. The moderate intensity running was performed at 70 % VO_2max for 50 min. The high intensity interval running included six 3-min intervals at 90 % VO_2max each followed by a 3-min recovery period at 50 % VO_2max. The interval exercise bout included 7 min of warm-up and cool-down at 70 % VO_2max to match overall time and work performed. Interval exercise resulted in a higher Borg Scale RPE versus moderate exercise (group average of 14 versus 13, respectively). Average VO_2, HR and energy expenditure were similar between trials. PA enjoyment (PAE), measured post-exercise using the PA Enjoyment Scale (PACES), was higher following high intensity interval exercise than moderate intensity continuous exercise (Bartlett et al. 2011).

Crisp and colleagues (2012a, 2012b) conducted two investigations that measured the effects of adding sprint intervals to continuous exercise at the intensity that optimizes fat oxidation in young boys performing cycle ergometry. Each exercise bout was performed for 30 min. In the sprint interval bouts, the boys were asked to perform 4-s, maximal intensity sprints every 2 min (Crisp et al. 2012a, 2012b), every 1 min, or every 30 s (Crisp et al. 2012b). This resulted in 1, 2, or 4 min of sprinting within the entire 30-min bout, respectively (Crisp et al. 2012a, 2012b). In the investigation that only included sprints every 2 min (Crisp et al. 2012a), the sprint intervals increased energy expenditure (via carbohydrate oxidation). However, PAE measured post-exercise using PACES was similar between trials. Investigators also asked the boys to indicate which exercise trial they preferred. Only 2 out of 18 preferred the moderate intensity exercise (Crisp et al. 2012a). In the investigation that included three separate exercise bouts with sprint intervals (Crisp et al. 2012b), energy expenditure was greater using the sprint than continuous format, regardless of the length of the active rest phases between sprint intervals. In addition, adding sprints every 30 or 60 s resulted in greater energy expenditure than adding sprints every 2 min, but the two higher frequencies were similar in energy expenditure. PACES scores were similar between exercise bouts with sprints and without except for the 30-s sprint frequency trial, which resulted in lower PAE (Crisp et al. 2012b). Overall, the results of the two studies indicate that adding sprints to a standard exercise intensity protocol at which maximal fat oxidation occurs could improve weight loss or weight maintenance. The sprint intervals added to moderate intensity exercise increased the overall caloric expenditure of acute exercise. PACES scores of PAE measured post-exercise were largely similar between bouts, but sprinting every 30 s was reported as unenjoyable (Crisp et al. 2012b). Since the boys indicated that they preferred the sprint interval exercise over the moderate intensity exercise bout

(Crisp et al. 2012a), perhaps a more simplified rating scale such as the FS or a single-item PAE scale could be used to measure basic AR or PAE during and after aerobic or sprint interval exercise to explore the acute exercise responses of these constructs. Due to the time needed for administration, a questionnaire such as PACES could not be used to measure overall PAE *during* exercise.

14.6 JND Methods for Exercise-Induced Muscle Pain and AR

See Chap. 11. Exercise Intensity Self-regulation using the Perceived Exertion JND.

Methods developed to determine the perceived exertion JND are appropriate for use with exercise-induced muscle pain ratings or FS ratings of AR in most individuals. As noted previously, marked interindividual differences have been found for the relation of these variables with exercise intensity. As such, a pre-participation GXT (i.e., estimation protocol) that includes measurement of pain and affect could help identify whether or not the use of these variables to prescribe exercise intensity is appropriate. For example, an individual may experience his/her pain threshold at or below an exercise intensity that elicits an optimal overload training stimulus. If during exercise, pain intensity ratings gradually increase over time, then a target pain rating could be used for exercise intensity prescription. In this instance, the JND for muscle pain intensity could be measured and used to assess the accuracy of exercise intensity self-regulation error in a subsequent production trial. Likewise, an individual's FS ratings of affect may gradually change (i.e., decrease) across the range of exercise intensities that are used as targets for exercise intensity prescription. When this occurs, a target FS rating could be used for exercise prescription and the JND for the AR during exercise could be measured. It is important that there be a gradual change in pain or affect across a range of exercise intensities so the target rating corresponds to a specific exercise intensity that is to be self-regulated.

However, standard methods to determine the JND may not be appropriate for use with exercise-induced muscle pain ratings or FS ratings of AR for some individuals. In certain cases, the inappropriateness of these variables for use in exercise prescription can be identified during the estimation trial. For example, an individual may not reach the pain threshold until exercise intensity is higher than the VT. A prescribed target intensity equivalent to the pain threshold likely could not be sustained for a sufficient period to achieve health-fitness goals. As such, exercise intensity prescription based on a target pain intensity rating would not be appropriate and JND methods could not be applied to exercise-induced muscle pain. In addition, some individuals may not experience gradual changes in FS ratings across the range of exercise intensities that are part of the prescribed exercise program (i.e., the subject reports each intensity as feeling "very good" or "very bad"). In these instances, a comparatively large range of exercise intensities is linked by a single rating of exercise-induced pain intensity or AR. For such individuals, it would be best to prescribe exercise intensity using RPE, which should gradually increase with exercise intensity regardless of interindividual differences in pain and AR.

14.7 Effect of Self-Selected Versus Imposed Exercise Intensity on Affect

See Chap. 12. Self-Selected versus *Imposed Exercise Intensities.*

Research that has compared FS ratings of AR between self-selected and imposed exercise intensities provides promising results, validating the procedures for use in prescribing exercise programs that are both physiologically effective and also promote long term adherence. It has been shown that many individuals experience a similar AR when performing exercise trials involving self-selected exercise intensity and imposed intensity, even though the intensity is actually higher for the self-selected condition (Ekkekakis and Lind 2006; Lind et al. 2008; Parfitt et al. 2006; Rose and Parfitt 2007). This indicates that subjects may be willing to perform a higher exercise intensity when it is self-selected to achieve a preferred level as compared to a prescription where exercise intensity is imposed. In addition, many individuals will self-select exercise intensities within ACSM guidelines for improvements in cardiorespiratory fitness (Dishman et al. 1994; Lind et al. 2005; Lind et al. 2008; Parfitt et al. 2006; Rose and Parfitt 2007). Therefore, the prescription of self-selected exercise may not only optimize AR and result in improved adherence to exercise programs, but may produce physiological benefit as well.

A number of recent studies have compared FS ratings of AR that were measured during self-selected and imposed exercise intensities. In these investigations, imposed exercise intensities have included those corresponding to levels below AT, above AT (Parfitt et al. 2006; Rose and Parfitt 2007; Sheppard and Parfitt 2008), equal to the AT (Rose and Parfitt 2007), as well as 10 % higher than the self-selected intensity (Ekkekakis and Lind 2006; Lind et al. 2008). Parfitt and colleagues (2006) compared FS ratings between 20 min of self-selected treadmill exercise and imposed exercise at intensities below and above the lactate threshold (LT) in sedentary males. Self-selected intensity was similar to that corresponding to the LT. FS ratings were similar (~3) between self-selected exercise and the imposed intensity below the LT. Self-selected exercise intensity and the imposed exercise intensity below the LT were performed at intensities equivalent to estimated VO_2 levels of 54.1 % and 39.8 % VO_2max, respectively. FS ratings during the imposed exercise condition at an intensity above the LT declined significantly over time, with the mean value eventually becoming negative by the 20-min time point (Parfitt et al. 2006).

Rose and Parfitt (2007) compared FS ratings during 20 min of self-selected treadmill exercise to imposed exercise at intensities below, above, and equal to the LT in sedentary women. Mean blood lactate concentration was similar between the self-selected exercise and the imposed intensities equal to and below the LT. The self-selected intensity resulted in FS ratings (ranging from 2.4 to 2.8) that were similar to those during an imposed exercise intensity which was below the LT. However, significantly more positive FS ratings were observed for self-selected exercise compared to an imposed exercise intensity equal to the LT (FS ratings ranged from 1.0 to 1.3). Imposed exercise at an intensity above the LT resulted mean FS ratings that declined significantly and remained negative throughout exercise with values ranging from −0.3 to −1.9 (Rose and Parfitt 2007).

Sheppard and Parfitt (2008) compared FS ratings between 15 min of self-selected and imposed cycle ergometer exercise intensities in young adolescent boys and girls who self-reported that they were physically active and moderately fit. The imposed intensities were below the VT (80 % of PO corresponding to VT) and above the VT (130 % of PO corresponding to VT). The imposed exercise intensity above the VT resulted in FS ratings that declined significantly over time and were significantly lower compared to those measured for both the imposed intensity that was performed below the VT and to those reported for the self-selected intensity condition. FS ratings were similar and stable over time during both the imposed intensity below the VT and the self-selected intensity condition. The mean FS ratings for the imposed intensities above and below the VT were ~0.4 and 2.5, respectively. Self-selected exercise intensity elicited an average FS rating of ~2.8 (Sheppard and Parfitt 2008).

Lind et al. (2008) compared FS ratings between 20 min of self-selected treadmill exercise to those reported during an imposed intensity that was 10 % higher than the self-selected intensity in sedentary women. At the 20-min time-point, the average exercise intensity was 98 % of VT for self-selected exercise and 115 % of VT for imposed exercise intensity. Subjects maintained a stable, positive AR during the self-selected condition. However, FS ratings of AR declined significantly during the imposed intensity that was only 10 % higher than the self-selected condition. The 10 % increase in intensity for the imposed condition, though comparatively small, was sufficient to prevent attainment of both a physiological and affective steady state (Lind et al. 2008). Ekkekakis and Lind (2006) compared FS ratings measured during 20 min of self-selected treadmill exercise and those measured during imposed exercise at an intensity 10 % higher than self-selected intensity in normal-weight and overweight sedentary women. Average self-selected intensity was below the VT while average imposed intensity was above the VT. However, FS ratings were similar between conditions. In both groups, average FS ratings were between 2 and 3 (Ekkekakis and Lind 2006).

14.8 Predicted and Session Measures of Pain and Affect

See Chap. 13. Predicted, Momentary and Session RPE.

14.8.1 Predicted and Session Exercise-Induced Pain

Hunt et al. (2007) and Haile at al. (2008) compared the predicted and momentary exercise-induced pain responses to load-incremented cycle ergometer exercise in young female and male adults, respectively. In both investigations, pain ratings were measured with Cook's (1997) Pain Intensity Scale. Both female and male subjects overpredicted their overall muscle pain response when compared to the momentary response actually experienced during exercise. The overprediction of pain found in these investigations may be due to the physiological demands of a load-incremented graded exercise test since few individuals perform maximal exercise on a regular basis. In addition, Kane and colleagues (2010) measured predicted exercise-induced muscle pain in middle school children prior to the performance of the PACER shuttle run test. Measures of muscle pain were determined using the Children's OMNI Muscle Hurt Scale. The children significantly over-predicted muscle pain by a value greater than 1 OMNI Scale rating category (Kane et al. 2010). It is common for individuals to overpredict an expected pain experience (Rachman and Arntz 1991). This has been suggested as a protective mechanism to avoid activities having the potential to cause tissue damage (Rachman and Lopatka 1988).

The investigations by Hunt et al. (2007) and Haile et al. (2008) also compared momentary and session pain responses. Subjects' session pain response was greater than the momentary response but was similar to predicted pain intensity. The rebound effect was most likely due to the influence of the most recently performed exercise intensity on the pain response, i.e., the intensity at which VO_2peak was achieved (Haile et al. 2008; Hunt et al. 2007).

14.8.2 Predicted and Session AR

Using the FS, Hardy and Rejeski (1989) asked subjects to predict the AR that would be experienced during running at specific Borg Scale RPEs. However, the question was asked hypothetically, that is, no exercise was performed following the prediction of AR. Average predicted AR was 2.6, 0.6, and −1.0 for Borg RPEs 11, 15, and 19, respectively. As RPE increased, FS ratings decreased. This inverse relation was consistent with predictions of the dual-mode model of Ekkekakis (2003) since the RPE zone encompassing the VT includes a Borg RPE of 11. The predicted FS values were significantly correlated to past and present levels of PA (i.e., past grade school, high school, and college PA, current PA frequency, current miles jogged per week) (Hardy and Rejeski 1989). The results indicate that predicted AR can provide valuable information that may help identify individuals who struggle with the adoption and maintenance of regular PA. Further research using a match–mismatch paradigm to compare the predicted and momentary AR associated with exercise may provide further information that can be useful for PA behavior change interventions.

Haile and colleagues (2013b) conducted an investigation that compared momentary and session FS ratings measured during 20 min of self-selected and imposed cycle ergometer exercise in young adult males. In this study, the self-selected exercise session was undertaken first so that subjects could perform the same intensity in the imposed condition, although they were not aware that the intensity was the same. Session AR was significantly greater than momentary AR for the self-selected exercise, but not the imposed exercise. In either case, however, the difference between momentary and session AR was less than 1 FS unit (Haile et al. 2013b). In another investigation, Haile and colleagues (2013a) compared momentary AR with both session and segmented session AR values for 20 min of self-selected treadmill exercise. In this investigation, both session RPE and segmented session RPE (expressed as the mean of the two segmented session RPE values, one for each half of exercise) were similar to the mean of the momentary RPE's measured during exercise. In addition, each separate segmented session RPE value was similar to the mean of momentary RPE's measured during that respective half of the exercise session (Haile et al. 2013a). Asking individuals to reflect upon specific segments of a previous exercise bout may improve their ability to accurately rate the perceived exertion experienced during previous exercise.

14.8.3 The Exercise Discomfort Index

In a study involving children, Kane et al. (2010) calculated an Exercise Discomfort Index (EDI) as the product of OMNI RPE-O and OMNI Muscle Hurt ratings (EDI = RPE-O × muscle hurt). Comparisons were made between predicted EDI and momentary EDI. The children significantly overpredicted EDI, but this response was primarily driven by the overprediction of muscle hurt ratings (Kane et al. 2010). Session EDI has not been investigated. An index such as EDI may provide a more in-depth explanation of an individual's perceptual expectations of exercise than either perceived exertion or exercise-induced muscle pain alone. A match–mismatch paradigm can be used to compare predicted EDI and momentary EDI. The purpose of this paradigm would be to identify those individuals with a response mismatch who may require cognitive or behavioral intervention to learn appropriate expectations of exertional perceptions during exercise (Kane et al. 2010). Such information may be crucial in helping such individuals to adopt and maintain regular PA. In addition, recall or session EDI can be used in PA questionnaires to describe the perceived exertion and muscle pain response to previous exercise. EDI may provide a more accurate description of an individual's recalled perceptual experience than either perceived exertion or exercise-induced muscle pain alone, whether the exercise was performed minutes ago (session EDI) or over the past few months (recall EDI).

The application of EDI could be expanded to include AR measured using the FS. Positive FS ratings indicate an individual is feeling good during exercise. Such feelings help to minimize exercise discomfort, promote the continuation of an exercise bout, and make it more likely that the individual would perform that exercise bout again. Negative FS ratings indicate an individual is feeling bad during exercise. Such feelings may exacerbate exercise discomfort, lead to premature termination of an exercise bout, and make it less likely that the individual would choose to perform that exercise bout again. Therefore, subtracting the FS rating from the EDI would be appropriate, allowing the formation of a revised EDI (EDI = OMNI RPE × muscle pain/hurt − FS rating). This newly proposed EDI can employ measures of either the undifferentiated or differentiated OMNI RPE, depending on the specific type of exercise evaluated. The modified EDI may also include ratings from the Cook Pain Intensity Scale which can be substituted for ratings obtained from the Children's OMNI Muscle Hurt Scale when adults are evaluated.

References

American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 9th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.

Bartlett JD, Close GL, MacLaren DPM, Gregson W, Drust B, Morton JP. High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: implications for exercise adherence. J Sports Sci. 2011;29:547–53.

Borg G, Ljunggren G, Ceci R. The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. Eur J Appl Physiol. 1985;54: 343–9.

Cook DB, O'Connor PJ, Eubanks SA, Smith JC, Lee M. Naturally occurring muscle pain during exercise: assessment and experimental evidence. Med Sci Sports Exerc. 1997;29:999–1012.

Cook DB, O'Connor PJ, Oliver SE, Lee Y. Sex differences in naturally occurring muscle pain and exertion during maximal cycle ergometry. Int J Neurosci. 1998;95:183–202.

Crisp NA, Fournier PA, Licari MK, Braham R, Guelfi KJ. Adding sprints to continuous exercise at the intensity that maximises fat oxidation: implications for acute energy balance and enjoyment. Metabolism. 2012a;61:1280–8.

Crisp NA, Fournier PA, Licari MK, Braham R, Guelfi KJ. Optimising sprint interval exercise to maximise energy expenditure and enjoyment in overweight boys. Appl Physiol Nutr Metab. 2012b;37:1222–31.

Da Silva SG, Elsangedy HM, Krinski K, De Campos W. Effect of body mass index on affect at intensities spanning the ventilatory threshold. Percept Mot Skills. 2011;113:575–88.

Dishman RK, Farquhar RP, Curetone KG. Responses to preferred intensities of exertion in men differing in activity levels. Med Sci Sports Exerc. 1994;26:783–90.

Ekkekakis P. Pleasure and displeasure from the body: perspectives from exercise. Cogn Emot. 2003;17:213–39.

Ekkekakis P, Hall EE, Van Lunduyt LM, Petruzzello SJ. Walking in (affective) circles. Can short walks enhance affect? J Behav Med. 2000;23:245–75.

Ekkekakis P, Hall EE, Petruzzello SJ. Variations and homogeneity in affective responses to physical activity of varying intensities: an alternative perspective on dose–response based on evolutionary considerations. J Sport Sci. 2005;23:477–500.

Ekkekakis P, Lind E. Exercise does not feel the same when you are overweight: the impact of self-selected and imposed intensity on affect and exertion. Int J Obes. 2006;30:652–60.

Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! Ann Behav Med. 2008;35:136–49.

Emmons RA, Diener E. A goal-affect analysis of everyday situational choices. J Res Pers. 1986;20:309–26.

Goss F, Robertson R, DaSilva S, Suminski R, Kang J, Metz K. Ratings of perceived exertion and energy expenditure during light to moderate activity. Percept Mot Skills. 2003;96:739–47.

Haile L, Ledezma CM, Koch KA, Shouey LB, Aaron DJ, Goss FL, Robertson RJ. Predicted, actual and session muscle pain and perceived exertion during cycle exercise in young men. Med Sci Sports Exerc. 2008;40:S301.

Haile L, Gallagher M, Haile AM, Dixon CB, Goss FL, Robertson RJ. Session, segmented session, and acute RPE and affective responses to self-selected treadmill exercise. Med Sci Sports Exerc. 2013a;45:S167.

Haile L, Goss FL, Robertson RJ, Andreacci JL, Gallagher Jr M, Nagle EF. Session perceived exertion and affective responses to self-selected and imposed cycle exercise of the same intensity ion young men. Eur J Appl Physiol. 2013b;116:1755–65.

Haile AM, Haile L, Taylor M, Shafer A, Wisniewski K, Deldin A, Panzak G, Goss FL, Nagle E, Robertson RJ. Concurrent validity of an exercise enjoyment scale using physiological and psychological criteria. Med Sci Sports Exerc. 2012;44:S645.

Hall EE, Ekkekakis P, Petruzzello SP. The affective beneficence of vigorous exercise revisited. Br J Health Psychol. 2002;7:47–66.

Hardy CJ, Rejeski WJ. Not what but how one feels: the measurement of affect during exercise. J Sport Exerc Psychol. 1989;11:304–17.

Hunt SE, DiAlesandro A, Lambright G, Williams D, Aaron D, Goss F, Robertson R. Predicted and actual leg pain and perceived exertion during cycle exercise in young women. Med Sci Sports Exerc. 2007;39:S485.

Kane I, Robertson RJ, Fertman CI, McConnaha WR, Nagle EF, Rabin BS, Rubinstein EN. Predicted and actual exercise discomfort in middle school children. Med Sci Sports Exerc. 2010;42: 1013–21.

Kenney E, Rejeski WJ, Messier SP. Managing exercise distress: the effect of broad spectrum intervention on affect, RPE, and running efficiency. Can J Sport Sci. 1987;12:97–105.

Kirkcaldy BC, Shephard RJ. Therapeutic implications of exercise. J Sport Psychol. 1990;21: 165–84.

Lind E, Joens-Matre RR, Ekkekakis P. What intensity of physical activity do previously sedentary middle-aged women select? evidence of a coherent pattern from physiological, perceptual, and affective markers. Prev Med. 2005;40:407–19.

Lind E, Ekkekakis P, Vazou S. The affective impact of exercise intensity that slightly exceeds the preferred level: 'pain' for no additional 'gain'. J Health Psychol. 2008;13:464–8.

Ljunggren G, Ceci R, Karlsson J. Prolonged exercise at a constant load on a bicycle ergometer: ratings of perceived exertion and leg aches and pain as well as measurements of blood lactate accumulation and heart rate. Int J Sports Med. 1987;8:109–16.

Moses J, Steptoe A, Mathews A, Edwards S. The effects of exercise training on mental well-being in the normal population: a controlled trial. J Psychosom Res. 1989;33:47–61.

O'Connor PJ, Cook DB. Moderate-intensity muscle pain can be produced and sustained during cycle ergometry. Med Sci Sports Exerc. 2001;33:1046–51.

Parfitt G, Rose EA, Burgess WM. The psychological and physiological responses of sedentary individuals to prescribed and preferred intensity exercise. Br J Health Psychol. 2006;11:39–53.

Rachman S, Lopatka C. Accurate and inaccurate predictions of pain. Behav Res Ther. 1988; 26:291–96.

Rachman S, Arntz A. The overprediction and underprediction of pain. Clin Psychol Rev. 1991; 11:339–55.

Rejeski WJ, Best D, Griffith P, Kenney E. Sex-role orientation and the responses of men to exercise stress. Res Q. 1987;58:260–4.

Robertson RJ, Goss FL, Aaron DJ, Nagle EF, Gallagher Jr M, Kane IR, Tessmer KA, Schafer MA, Hunt SE. Concurrent muscle hurt and perceived exertion of children during resistance exercise. Med Sci Sports Exerc. 2009;41:1146–54.

Rose EA, Parfitt G. A quantitative analysis and qualitative explanation of the individual differences in affective responses to prescribed and self-selected exercise intensities. J Sport Exerc Psychol. 2007;29:281–309.

Rose EA, Parfitt G. Can the feeling scale be used to regulate exercise intensity? Med Sci Sports Exerc. 2008;40:1852–60.

Sheppard KE, Parfitt G. Acute affective responses to prescribed and self-selected exercise intensities in young adolescent boys and girls. Pediatr Exerc Sci. 2008;20:129–41.

Stanley DM, Williams SE, Cumming J. Preliminary validation of a single-item measure of exercise enjoyment: the exercise enjoyment scale. J Sport Exerc Psychol. 2009;31:S138–9.

Tate AK, Petruzzello SJ. Varying the intensity of acute exercise: implications for changes in affect. J Sports Med Phys Fitness. 1995;35:295–302.

Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sports Exerc. 2002;34:1996–2001.

Van Lunduyt LM, Ekkekakis P, Hall EE, Petruzzello SJ. Throwing the mountains into the lakes: on the perils of nomothetic conceptions of the exercise-affect relationship. J Sport Exerc Psychol. 2000;24:151–69.